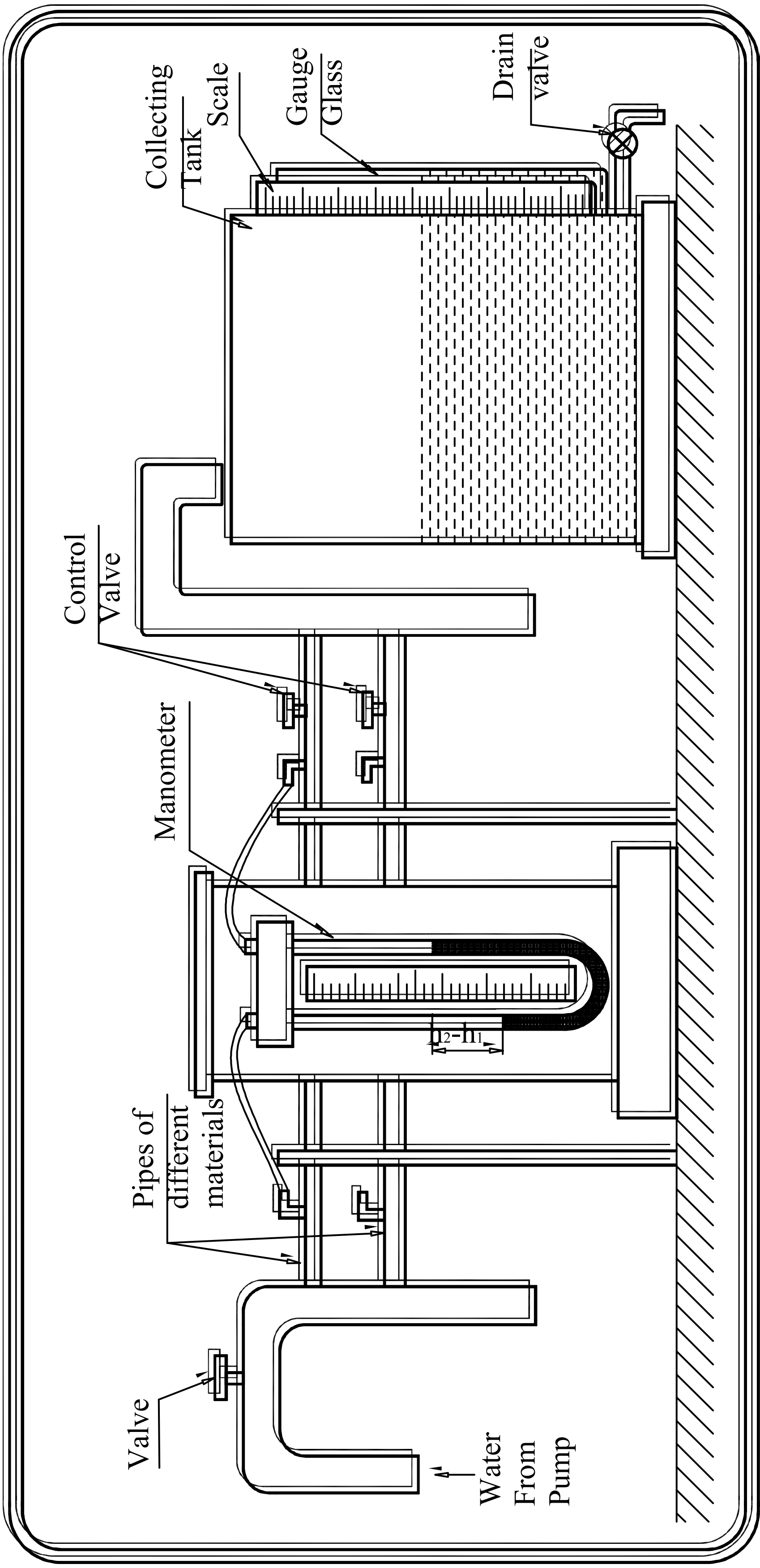
GROUP – A

FLOW THROUGH PIPES

EXPERIMENTAL SET UP



EXPT. NO.: 1 Date : ……………….

FLOW THROUGH PIPES

Object : To determine the following hydraulic constants for the flow of water through pipes of different materials :

(i) Darcy's coefficient
(ii) Chezy's coefficient
(iii) Manning's constant and
(iv) Reynold's number

Theory :

(i) Explain the major and minor losses, and give their equations.
(ii) Define Laminar and Turbulent flow in a pipe.
(iii) Definition and significance of Reynold's number.
(iv) Derive the equations for the following :
(a) Darcy's coefficient (b) Chezy's coefficient (c) Manning's constant
(v) Sketch the hydraulic gradient for the flow of water through a pipe from a tank at a higher level to a tank at a lower level considering both major and minor losses.

Experimental Set Up :

Make a neat sketch of the experimental set up and describe it.

Procedure :

1. Select the pipe on which the experiment is to be conducted and note its diameter and the length of the pipe between the tappings, and also material of the pipe.
2. Connect the two limbs of the manometer to the pressure tappings by the flexible tubes.
3. Open the valves in the selected pipe line and **close** all the other valves.
4. Start the centrifugal pump and allow the water through the selected pipe by opening the main valve to vent the manometer. Make sure that the venting is done properly.
5. Now adjust the gate valve on the selected pipe to get the desired flow.
6. Note down the following readings:
   (a) Mercury level in two limbs of the manometer.
   (b) Time taken for 10 cm rise of water in the collecting tank.
7. Repeat the experiment for different flow rates.
8. Repeat the procedure 1 to 7 for the experiment on pipes of different materials.
9. Tabulate all the readings.

DATA SHEET

Length of pipe, L = 1.25 m
Area of the collecting tank, A_c=(0.4 x 0.4) m^2 = 0.16 m^2
Manometric fluid = Mercury
Specific gravity of Mercury, s_2=13.6
Diameter of the pipe, d =12.5 mm.

TABULATION OF READINGS

Sl. No.	Particulars	Symbol	Units												
1.	Material of the pipe	-	-	Aluminium				Copper				SS			
2	Trial No.	-	-	1	2	3	4	1	2	3	4	1	2	3	
3.	Manometer Reading	h_1 / h_2	mm of Hg												
4.	Time taken for 10cm rise of water in collecting tank	t	s												

SPECIMEN CALUCULATION

Trial No.: **Material:**

1. Area of the pipe, $a = \frac{\pi d^2}{4}$ = ... m^2.
2. Actual discharge through the pipe, $Q_{act} = \frac{A_c \times 10}{100 \times t}$ = ...m^3/s.
3. Velocity of water through the pipe, $V = \frac{Q_{act}}{a}$ = ...m/s.
4. Manometer reading, $h = \frac{h_1 \sim h_2}{1000}$ = ... m of Hg.
5. Head lost due to friction in metres of water

$$h_f = h \times \frac{(s_2 - s_1)}{s_1} =$$ .... m of water

Where s_1 = Specific gravity of water = 1
s_2 = Specific gravity of Hg = 13.6

6. Darcy's Coefficient, $f = \frac{h_f \times 2gd}{4LV^2}$ = ...
7. Equivalent hydraulic mean radius, $R = \frac{d}{4}$ =...........m
8. Hydraulic slope, S = $\frac{h_f}{L}$ = ...m of loss / m of length of pipe

9. Chezy's constant, $C = \frac{V}{\sqrt{RS}}$ =…………

10. Manning's constant, $N = \frac{1}{V} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}}$ =………..

11. Reynold's number, $R_e = \frac{V\,d}{\nu}$ =…………..

where ν = Kinematic viscosity of water = $1 \times 10^{-6}\ m^2/s$

TABULATION OF RESULTS

Sl. No.	Particulars	Symbol	Units											
1.	Material of the pipe	-	-	Aluminium				Copper				SS		
2.	Trial No.	-	-	1	2	3	4	1	2	3	4	1	2	3
3.	Head lost due to friction	h_f	m of water											
4.	Velocity of flow	V	m/s											
5.	Darcy's coefficient	f	-											
6.	Chezy's constant	C	-											
7.	Manning's constant	N	-											
8.	Reynold's number	Re	-											

Graphs: (i) h_f v/s Velocity of flow
(ii) f, C, N v/s Reylond's number

Conclusion:

EXPT. NO.: 2 Date : ……………….

Minor Losses In the Pipe Fittings

Aim: To study the minor losses or to determine the loss coefficient in the pipe fittings such as in Bends, Elbows and for Sudden contraction & sudden expansion.

Theory:

Pipe line systems in general include several auxiliary components in addition to the long pipes such as bends, elbows, sudden contraction pipes, sudden expansion pipes, gate valves, globe valves etc. In addition to energy loss due to friction, these fittings contribute for further energy losses due to eddies formation or turbulence locally. Hence these losses are referred to as local losses or minor losses. Sometimes the energy losses due to these fittings are dominant than the frictional losses. It is therefore necessary to consider the losses due to these fittings in addition to frictional losses in designing the hydraulic systems.

The velocity head through the fittings is $\frac{V^2}{2g}$

Loss coefficient, $K = \frac{Total\ head\ loss}{Velocity\ head} = \frac{h_f}{V^2/2g}$

Experimental set-up:

A pipe fittings such as a bend, elbow, sudden contraction and sudden expansion are fitted to a pipe of internal diameter 12.5 mm. Across each fittings, pressure tappings are provided to measure the pressure or head loss between them. The manometer is used to measure the pressure drop, which is the head loss.

The dimensions of the sudden enlargement and contraction are as follows:

Sudden enlargement:

Inlet pipe diameter = 0.5 times the outlet diameter

Sudden contraction:

Inlet pipe diameter = 2 times the outlet diameter

The complete unit is supported on MS stand. Water flowing out from these pipes is collected in the collecting tank to determine the flow rate and hence the velocity in the pipe.

Experimental Procedure:

1. Select the required pipe fitting
2. Connect the pressure tappings of the required pipe fitting to the manometer by opening the appropriate pressure cocks and closing all other pressure cocks.
3. Open the flow control valve in the pipe line and allow water to pass through the selected fitting.
4. Vent the manometer for driving out the air presented in the system at the lower flow rate.
5. Regulate the flow to a desired value by operating the control valve.
6. Note the pressure difference from the manometer in terms of mercury columns.
7. Note the time taken to collect the water in the collecting tank for a particular rise of level.
8. Repeat the experiments for different flow rates.
9. Repeat the experiments for other fittings.

Tabular Column:

Expt	Manometer reading m of mercury			Head loss H_f m of water	Time for 10 cm rise of water t seconds	Volume flow rate Q in m^3/s	Velocity V in m/s	Loss Coefficient K
	h_1	h_2	$h_g = h_1 - h_2$					
Sudden Expansion								
Sudden Contraction								
Bend								
Elbow								

Calculation:

1. Volume flow rate, $Q = \frac{Ah}{t}$ m³/s = ……………..

   Area of collecting tank, A = 0.4 m x 0.4 m = 0.16 m^2

   Rise of water in collecting tank, h = 10 cm = 0.1 m

   Time taken, t = ……. sec

2. Difference in mercury levels, $h_g = (h_1 - h_2)$= …………. m of Hg

   Equivalent head loss of water, $H_f = (13.6 - 1)\, h_g = 12.6\, h_g$ = ……….. m of water

Loss Coefficient in Bend and Elbow:

3. Velocity in pipe, $V = \frac{Q}{a}$ m/s = ……… m/s

   D = Diameter of pipe = 12.5 mm = 12.5 x 10^{-3} m, a = Area of pipe $= \frac{\pi}{4} D^2$ = …….. m^2

4. Loss coefficient for a bend or elbow

$$K = \frac{h_f}{V^2/2g} = \frac{H_f}{V^2/2g} = \ldots\ldots\ldots$$

Loss Coefficient for Sudden Expansion:

5. Total pressure loss (includes pressure loss + kinetic loss)

   Loss, $h_f = H_f + \frac{V_1^2}{2g}\left[1 - \left(\frac{a_1}{a_2}\right)^2\right]$ = …….. m of water

   D_1= Diameter of inlet pipe = 0.0125 m and $a_1 = \frac{\pi}{4} D_1^2$ = …….. m^2

   D_2= Diameter of outlet pipe = 0.025 m and $a_2 = \frac{\pi}{4} D_2^2$ = …….. m^2

6. Loss coefficient

$$K = \frac{Loss}{V_1^2/2g} = \frac{h_f}{V_1^2/2g} =$$

Loss Coefficient for Sudden Contraction:

7. Total pressure loss (includes pressure loss + kinetic loss)

   Loss, $h_f = H_f + \frac{V_2^2}{2g}\left[\left(\frac{a_2}{a_1}\right)^2 - 1\right]$ = …….. m of water

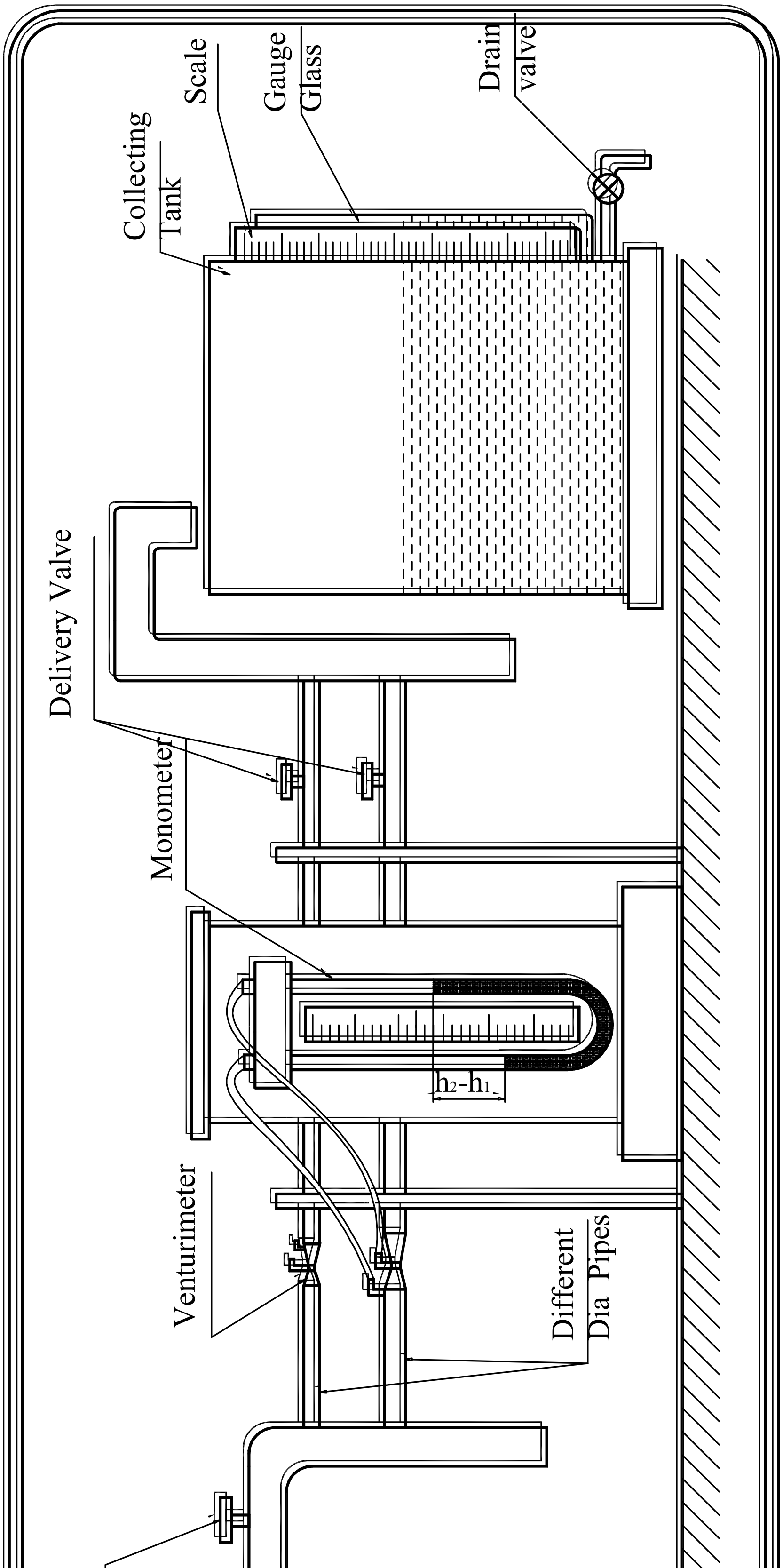
   D_1= Diameter of inlet pipe = 0.025 m and $a_1 = \frac{\pi}{4} D_1^2$ = …….. m^2

   D_2= Diameter of outlet pipe = 0.0125 m and $a_2 = \frac{\pi}{4} D_2^2$ = …….. m^2

8. Loss coefficient $K = \frac{Loss}{V_2^2/2g} = \frac{h_f}{V_2^2/2g}$ =………

VENTURIMETER

EXPERIMENTAL SET UP



EXPT. NO.: 3 Date : ……………….

VENTURIMETER

Object : To determine the coefficient of discharge of the given venturimeter.

Theory : i) State Bernoulli's theorem.
ii) Name the parts of a venturimeter and give its proportions.
iii) Derive the equation

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

iv) State its merits and demerits over other flow measuring devices.

EXPERIMENTAL SET UP :

With a neat diagram describe the experimental set up.

PROCEDURE :

i) Select the pipe to which the venturimeter is fitted.
ii) Close all the valves except the one on the pipe is selected.
iii) Check the manometer connections.
iv) Start the centrifugal pump and open the control valve to allow the required flow rater of water through the venturimeter.
v) Under steady conditions note down the following readings:
   a) the levels of mercury in the two limbs of the manometer.
   b) the time taken for 10 cm rise of water in the collecting tank after closing the drain valve of the collecting tank.
vi) Open the drain valve after noting down the readings.
vii) Repeat the experiment for a minimum of four different flow rates and tabulate the readings.
viii) Repeat the steps (iii) – (viii) for another diameter of the pipe
ix) Draw the graph of
   (i) Q_{th} v/s Q_{act}
   (ii) C_d v/s Q_{act}

DATA SHEET

Specifications of the Venturimeter:

Inlet diameter, d_1 = 20 mm and 25mm.
Throat diameter, $d_2 = 0.6d_1$ = 12 mm and 15 mm
Area of the collecting tank, $A_c = 0.4 \times 0.4\,m^2$
Manometric liquid : Mercury (s = 13.6)

TABULATION OF READINGS

Sl. No.	Particulars	Symbols	Units								
1.	Diameter of the pipe	d_1	mm	← 20 →				← 25 →			
2.	Trial No.	-	-	1	2	3	4	1	2	3	4
3.	Manometer reading	h_1	mm of Hg								
		h_2									
4.	Time taken for 10cm rise of water in collecting tank.	t	s								

SPECIMEN CALCULATION

Trial No.

1. Venturimeter inlet area , $a_1 = \dfrac{\pi\ d_1^2}{4} \times 10^{-6} =$ …………..m².

2. Venturimeter throat area, $a_2 = \dfrac{\pi\, d_2^2}{4} \times 10^{-6} =$ …………m².

3. Head in meters of water causing flow through the venturimeter

$$h = \frac{h_1 \sim h_2}{1000} \times \frac{(s_2 - s_1)}{s_1} = \text{……… m of water}$$

4. Theoretical discharge

$$Q_{th} = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh} = \text{………..}m^3/s$$

5. Actual discharge,

$$Q_{act} = \frac{A_c \times 10}{100 \times t} = \text{…………}m^3/s$$

6. Coefficient of discharge,

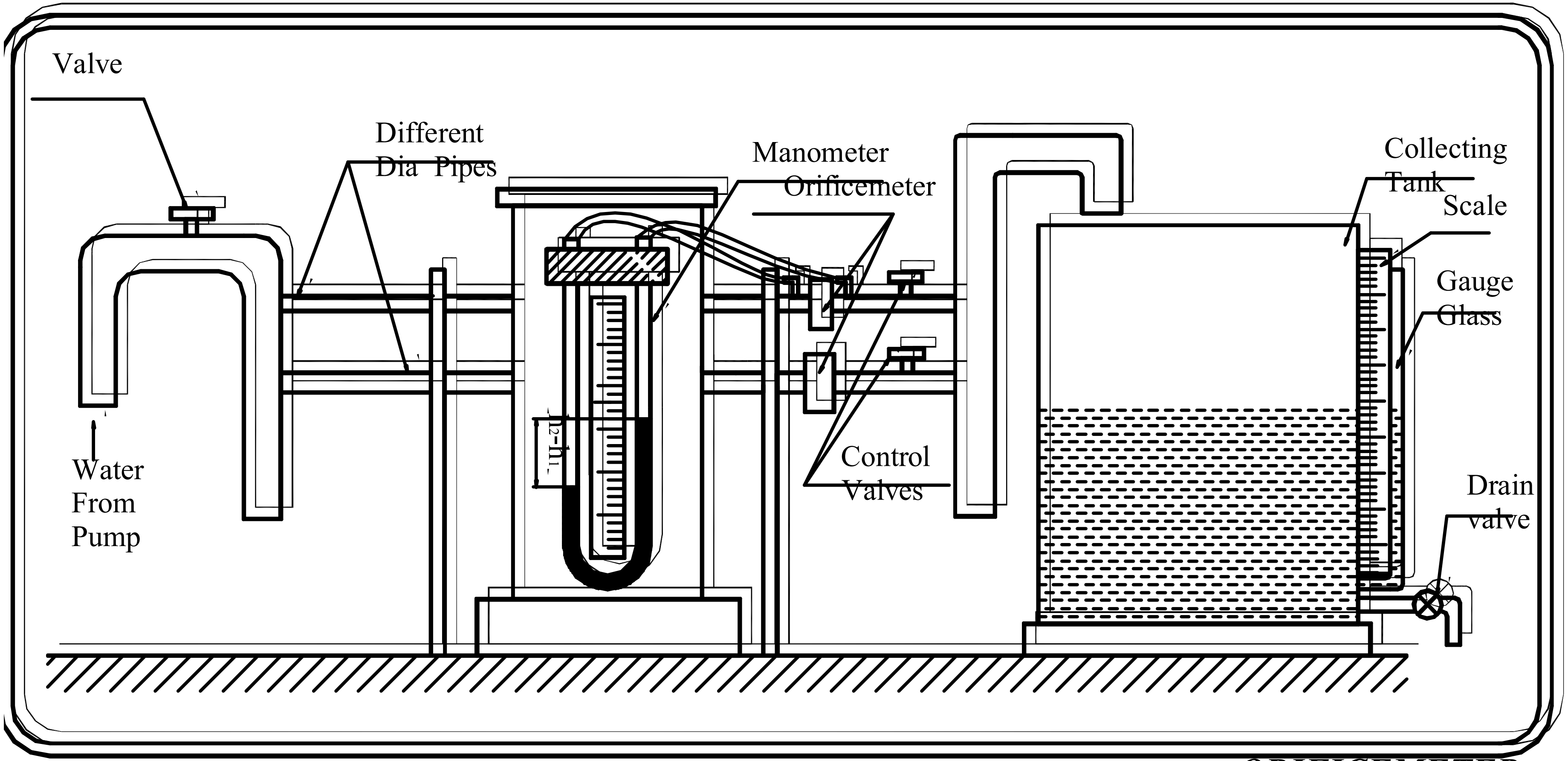
$$C_d = \frac{Q_{act}}{Q_{th}} = \text{…………..}$$

TABULATION OF RESULTS

Sl. No.	**Particulars**	**Symbol**	**Units**								
1.	Diameter of the pipe	d_1	mm	← 20 →				← 25 →			
2.	Trial No.	-	-	1	2	3	4	1	2	3	4
3.	Head of water causing flow through the venturimeter	h	m of water								
4.	Theoretical discharge	Q_{th}	m^3/s								
5.	Actual discharge	Q_{act}	m^3/s								
6.	Coefficient of discharge	C_d	-								

Graphs: (i) Q_{th} v/s Q_{act}
(ii) C_d v/s Q_{th}

EXPERIMENTAL SET UP



ORIFICEMETER

EXPT. NO.: 4 Date : ……………….

ORIFICE METER

Object :To determine the coefficient of discharge of the given orifice.

Theory : i) Derive the equation $Q_{th} = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$

ii) Merits and demerits of orifice meter over other flow measuring device.

Experimental set up:

With a neat diagram describe the experimental set up.

Procedure :

i) Select the pipe to which the orifice meter is fitted and close all other valves except the one on the pipe is selected.
ii) Check the manometer connections and vent the manometer properly.
iii) Start the motor driving the centrifugal pump and open the control valve to the required extent allowing the water to flow through the orifice meter.
iv) Note the following readings:
   (a) Mercury levels in the two limbs of the manometer.
   (b) Time taken for 10 cm rise of water in the collecting tank by closing the drain valve of the collecting tank.
v) Open the drain valve after noting down the time.
vi) Repeat the experiment for a minimum of four different flow rates.
   (i) Q_{th} v/s Q_{act}
   (ii) C_d v/s Q_{act}

DATA SHEET

Inlet diameter, d_1= 20 mm and 25 mm
Orifice diameter, d_2 =0.6d_1= 12 mm and 15 mm
Area of the collecting tank, A_c= 0.4 m x 0.4 m = 0.16 m^2

TABULATION OF READINGS

Sl. No.	Particulars	Symbol	Units								
1.	Diameter of the pipe	d_1	mm	← 20 →				← 25 →			
2.	Trial No.	-	-	1	2	3	4	1	2	3	4
3.	Manometer reading	h_1	mm of Hg								
		h_2									
4.	Time taken for 10cm rise of water in collecting tank	t	s								

SPECIMEN CALCULATION

Trial No.

1. Area of the pipe, $a_1 = \frac{\pi\ d_1^2}{4} \times 10^{-6}$ = ………..m^2

2. Area of the orifice, $a_2 = \frac{\pi\ d_2^2}{4} \times 10^{-6}$ = ………m^2

3. Head causing flow of water through the orifice

$$h = \left(\frac{h_1 - h_2}{1000}\right) \times \frac{s_2 - s_1}{s_1}$$ = ……….. m of water

4. Theoretical discharge, $Q_{th} = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$ = ……….. m^3/s

5. Actual discharge, $Q_{act} = \frac{A_c \times 10}{100 \times t}$ = ……………m^3/s

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

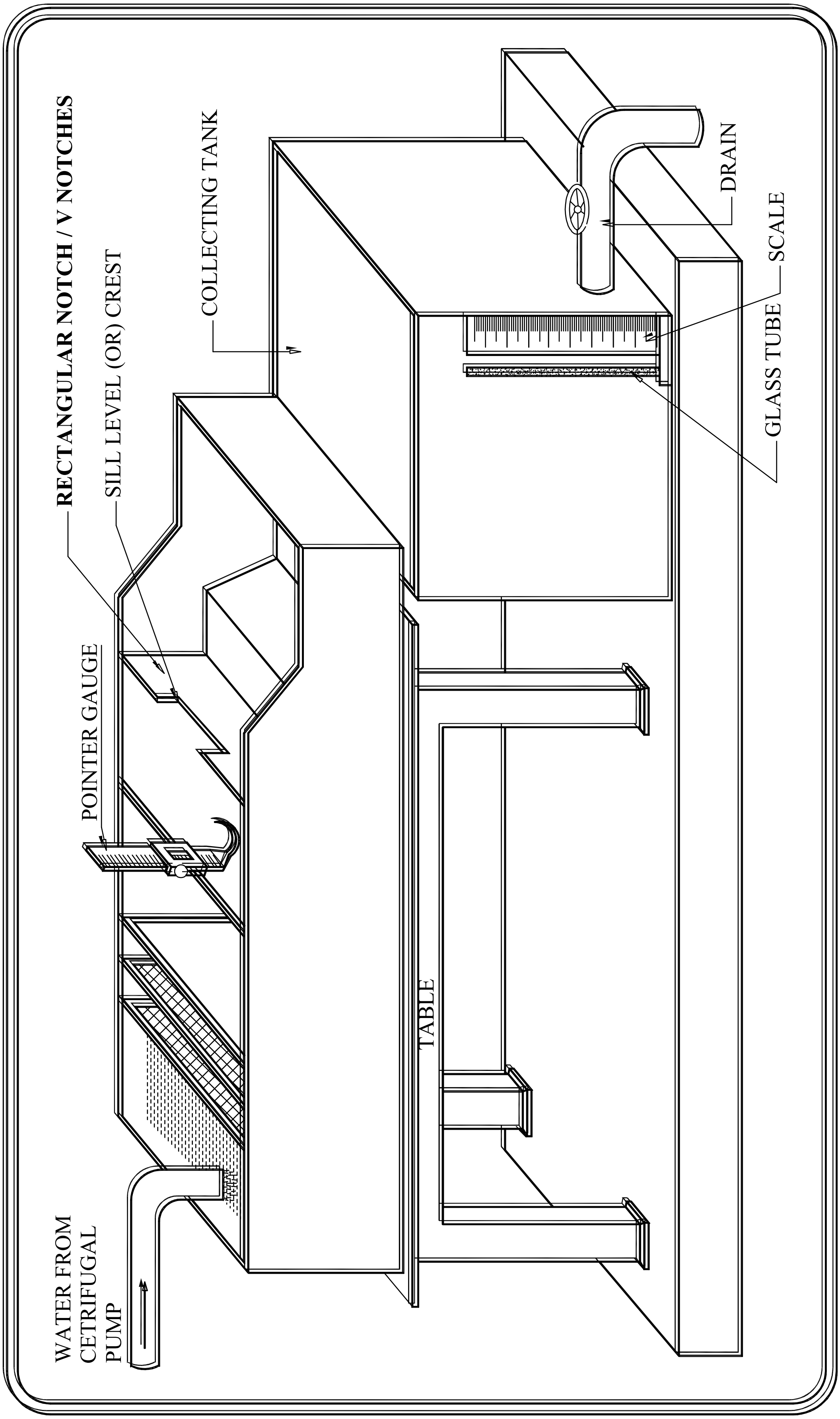
TABULATION OF RESULTS

Sl. No.	Particulars	Symbol	Units								
1.	Diameter of the pipe	d_1	mm	← 20 →				← 25 →			
2.	Trial No.	-	-	1	2	3	4	1	2	3	4
3.	Head causing flow of water through the orifice meter	h	m of water								
4.	Theoretical discharge	Q_{th}	m^3/s								
5.	Actual discharge	Q_{act}	m^3/s								
6.	Coefficient of discharge	C_d	-								

Graphs: (i) Q_{th} v/s Q_{act}
(ii) C_d v/s Q_{act}

FLOW OVER NOTCHES

EXPERIMENTAL SET UP



EXPT. NO.: 5 Date : ……………….

FLOW OVER NOTCHES

Object : To determine the coefficient of discharge of the following types of notches :

i) Rectangular notch
ii) Triangular or v-notch
iii) Trapezoidal notch
iv) Cippoletti notch

Theory : i) Definition of a notch.
ii) Distinction between a notch and a weir.
iii) Classification of notches.
iv) Definitions of terms related to notches: sill or crest of a notch, nappe, velocity of approach.
(v) Derivation of an equation for theoretical discharge through the different types of notches namely, rectangular, triangular, trapezoidal and cippoletti.
(vi) Merits of the different types of notches and their applications.

Experimental Set Up :

With a neat diagram describe the experimental set up.

Procedure :

1. Fix the required notch in the rectangular channel.
2. Start the centrifugal pump and allow the water to flow through the channel until the water just flows over the crest level and then stop the water supply.
3. When the flow of water over the crest ceases, note down the reading of the pointer gauge h_o corresponding to the crest level. This is the initial reading of the pointer gauge.
4. Then open the control valve to the desired extent so as to allow the water flow over the notch.
5. When the head of water over the notch is steady, noted down the following readings:
   i) Final reading of the pointer gauge (h) corresponding to the level of water over the notch.
   ii) Time taken for 10cm rise in level of water in the collecting tank.
6. Repeat the experiment for different flow rates and tabulate all the readings.
7. Repeat the steps 1 to 6 for other notches.

DATA SHEET

Area of the collecting tank $=A_c = 0.8$ m x 0.8 m

Details of the notches :

1.Rectangular notch: Breadth = B =0.2 m

2.Trapezoidal notch : B = 0.8 m , $\frac{\theta}{2} = 45^0$

3.Triangular or V-notch : $\theta = 90^0$

4.Cippoletti notch: B = 0.125 m , $\frac{\theta}{2} = 14^0$

TABULATION OF READINGS

Sl. No.	Particulars	Symbol	Units								
1.	Type of notch	-	-	**Rectangular**				**Triangular**			
2.	Trial No.	-	-	1	2	3	4	1	2	3	4
3.	Initial reading of the pointer gauge	h_o	mm								
4.	Final reading of the pointer gauge	h_1	mm								
5.	Time taken for 10cm rise of water in the collecting tank	t	s								

Sl. No.	Particulars	Symbol	Units								
1.	Type of notch	-	-	**Trapezoidal**				**Cippoletti**			
2.	Trial No.	-	-	1	2	3	4	1	2	3	4
3.	Initial reading of the pointer gauge	h_o	mm								
4.	Final reading of the pointer gauge	h_1	mm								
5.	Time taken for 10cm rise in level of water in the collecting tank	t	s								

SPECIMEN CALCULATION

Rectangular notch : Breadth = B = 0.2

1. Head over the notch, $H = \frac{h_1 \sim h_0}{1000} = \ldots\ldots\ldots\ldots m.$

2. Theoretical discharge, $Q_{th} = \frac{2}{3} \times (B - 0.2H) \times \sqrt{2g} \times H^{\frac{3}{2}} = \ldots\ldots\ldots\ldots m^3/s$

3. Actual discharge, $Q_{act} = \frac{A_c \times 10}{100 \times t} = \ldots\ldots\ldots\ldots m^3/s$

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

Triangular notch: $\theta = 90^0$

1. Head over the notch, $H = \frac{h_1 \sim h_0}{1000} = \ldots\ldots\ldots\ldots m.$

2. Theoretical discharge, $Q_{th} = \frac{8}{15} \times \sqrt{2g} \times \tan\frac{\theta}{2} \times H^{\frac{5}{2}} = \ldots\ldots\ldots\ldots m^3/s$

3. Actual discharge, $Q_{act} = \frac{A_c \times 10}{100 \times t} = \ldots\ldots\ldots\ldots m^3/s$

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

Trapezoidal notch: $\frac{\theta}{2} = 45^0$ and B = 0.08 m

1. Head over the notch, $H = \frac{h_1 \sim h_0}{1000} = \ldots\ldots\ldots\ldots m.$

2. Theoretical discharge, $Q_{th} = \frac{8}{15} \times \sqrt{2g} \times \tan\frac{\theta}{2} \times H^{\frac{5}{2}} + \frac{2}{3} \times \sqrt{2g} \times (B - 0.2H) \times H^{\frac{3}{2}} = \ldots\ldots\ldots\ldots m^3/s$

3. Actual discharge, $Q_{act} = \frac{A_c \times 10}{100 \times t} = \ldots\ldots\ldots\ldots m^3/s$

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

Cippoletti notch : $\frac{\theta}{2} = 14^0$ and B = 0.125 m

1. Head over the notch, $H = \frac{h_1 \sim h_0}{1000} = \ldots\ldots\ldots\ldots m.$

2. Theoretical discharge, $Q_{th} = \frac{2}{3} \times \sqrt{2g} \times BH^{\frac{3}{2}} = \ldots\ldots\ldots\ldots m^3/s$

3. Actual discharge, $Q_{act} = \frac{A_c \times 10}{100 \times t} = \ldots\ldots\ldots\ldots m^3/s$

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

TABULATION OF RESULTS

Sl. No.	Particulars	Symbol	Units								
1.	Type of notch	-	-	Rectangular				Triangular			
2.	Trial No.	-	-	1	2	3	4	1	2	3	4
3.	Head over the notch	H	m								
4.	Actual discharge	Q_{act}	m^3/s								
5.	Theoretical discharge	Q_{th}	m^3/s								
6.	Coefficient of discharge	C_d	-								

Sl. No.	Particulars	Symbol	Units								
1.	Type of notch	-	-	Trapezoidal				Cippoletti			
2.	Trial No.	-	-	1	2	3	4	1	2	3	4
3.	Head over the notch	H	m								
4.	Actual discharge	Q_{act}	m^3/s								
5.	Theoretical discharge	Q_{th}	m^3/s								
6.	Coefficient of discharge	C_d	-								

Calibration procedure for V–Notch

The actual discharge through the notch, $Q = KH^n$ (i)

Or $\text{Log } Q = \text{Log } K + n \text{ Log } H$ (ii)

Trial No.	1	2	3	4
Log Q_{act}				
Log H				

Log K from the graph =

$$n = \frac{\text{Log Q - Log K}}{\text{Log H}} =$$

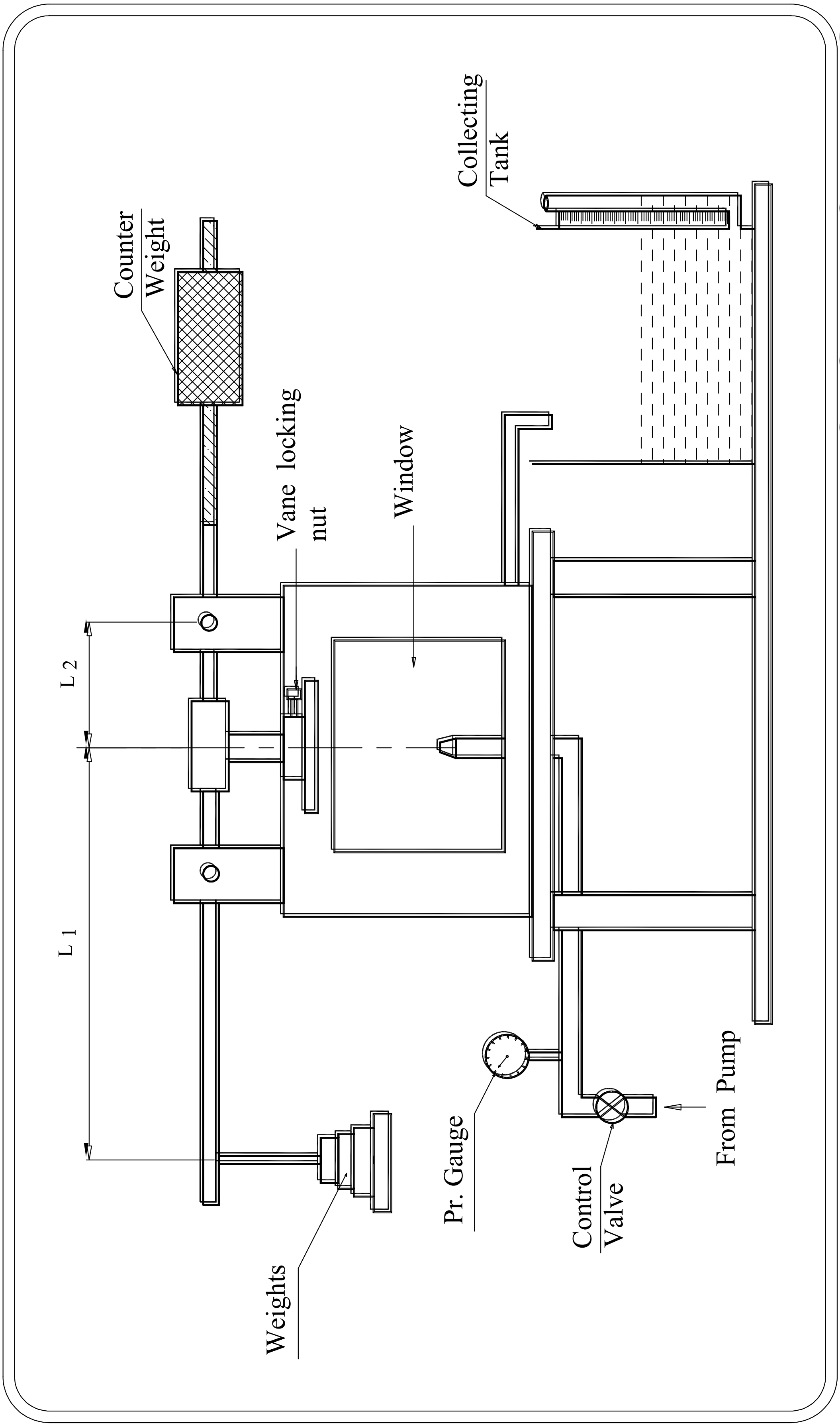
Therefore eqn. (i) or (ii) can be used as the calibration equation.

Alternative Method to C_d:

$$C_d = K \Big/ \left[\frac{8}{15} \times \sqrt{2g} \times \tan\frac{\theta}{2}\right] \quad \text{(iii)}$$

IMPACT OF JET ON VANES

EXPERIMENTAL SETUP



EXPT. NO.: 6 Date : ………………

IMPACT OF JET ON VANES

Object : To determine the coefficient of impact or the vane efficiency of vanes of different shapes.

Theory : (a) Derive the equations for the force exerted by a jet of water on
i)Flat plate ii) Inclined plate and iii) Hemispherical vane.
(b) Expression for the efficiency in each of the above cases

Experimental set up :

The arrangement is as shown in the figure. Vanes are fitted at the center of a horizontal beam or lever. At one end of the lever there is a scale pan or a hanger on which small weights can be placed. At the other end is a counter weight which is used to balance the beam whenever the vane is fitted. The counter weight can be moved to and fro on the lever by the screw arrangement provided. Water is supplied by a centrifugal pump and it issues out through a nozzle in the form of a high velocity jet and strikes the plate. To prevent the water from spilling out, the entire arrangement is enclosed in a box with a glass window. A pressure gauge gives the pressure of water supplied. A collecting tank is provided to collect the water after it strikes the vane.

Procedure :

1. Fit the required vane to the lever or the beam. Fix the hanger at one end and balance the lever balance by moving the counter weight.
2. Place the known weights on the hanger now.
3. Open the control valve now to allow the water through the nozzle which strikes the vane. Adjust the flow of water such that the lever becomes horizontal under equilibrium condition.
4. Note down the following readings:
   (i) Pressure gauge reading at the inlet of the nozzle.
   (ii) The time taken for 5 cm rise in level of water in the collecting tank.
5. Repeat the experiments for different weights placed on the hanger following the steps 3 & 4.
6. Repeat the steps 1 to 5 for different vane shapes fitted to the lever.
7. Tabulate all the readings

DATA SHEET

Area of the collecting tank = $A_c = 0.5 \times 0.5\, m^2$
Length of lever arms : L_1 =0.27 m
L_2 =0.27 m

TABULATION OF READINGS

Sl. No	Particulars	Symbol	Units												
1.	Type of vane	-	-	FLAT VANE				INCLINED VANE				HEMISPHERICAL VANE			
2.	Trial No.	-	-	1	2	3	4	1	2	3	4	1	2	3	4
3.	Weights placed on the hanger	W	kg												
4.	Pressure gauge reading	P	ksc												
5.	Time for 5cm rise in level of water in the collecting tank	t	s												

SPECIMEN CALCULATION

1. Actual discharge of water , $Q = \dfrac{A_c \times 5}{100 \times t} = \ldots\ldots\ldots\, m^3/s$
2. Pressure head at the inlet of the nozzle, h = P x 10 = ………. m of water
3. Velocity of water jet, $V = \sqrt{2gh} = \ldots\ldots\ldots\, m/s$
4. Theoretical force exerted on the vane:
   (a) **Flat Plate**:
   $F_{th} = wQV = \rho g QV = \ldots\ldots\ldots N$
   Where w = specific weight of water = 9810 N/m^3

   (b) **Inclined Plate** :
   $F_{th} = wQV \sin\theta = \ldots\ldots\ldots N$

   (c). **Hemispherical vane** :
   $F_{th} = wQV(1 + \cos\theta)$
   $= wQV \times 2$ $\quad \because \theta = 0$ for hemispherical vane

5. Actual force exerted on the vane,
   $F_{act} = \dfrac{L_1 + L_2}{L_2} \times W \times 9.81 = \ldots\ldots\ldots N$
6. Vane efficiency or coefficient of impact , $\eta = F_{act}/F_{th}\, x100 = \ldots\ldots\ldots\%$

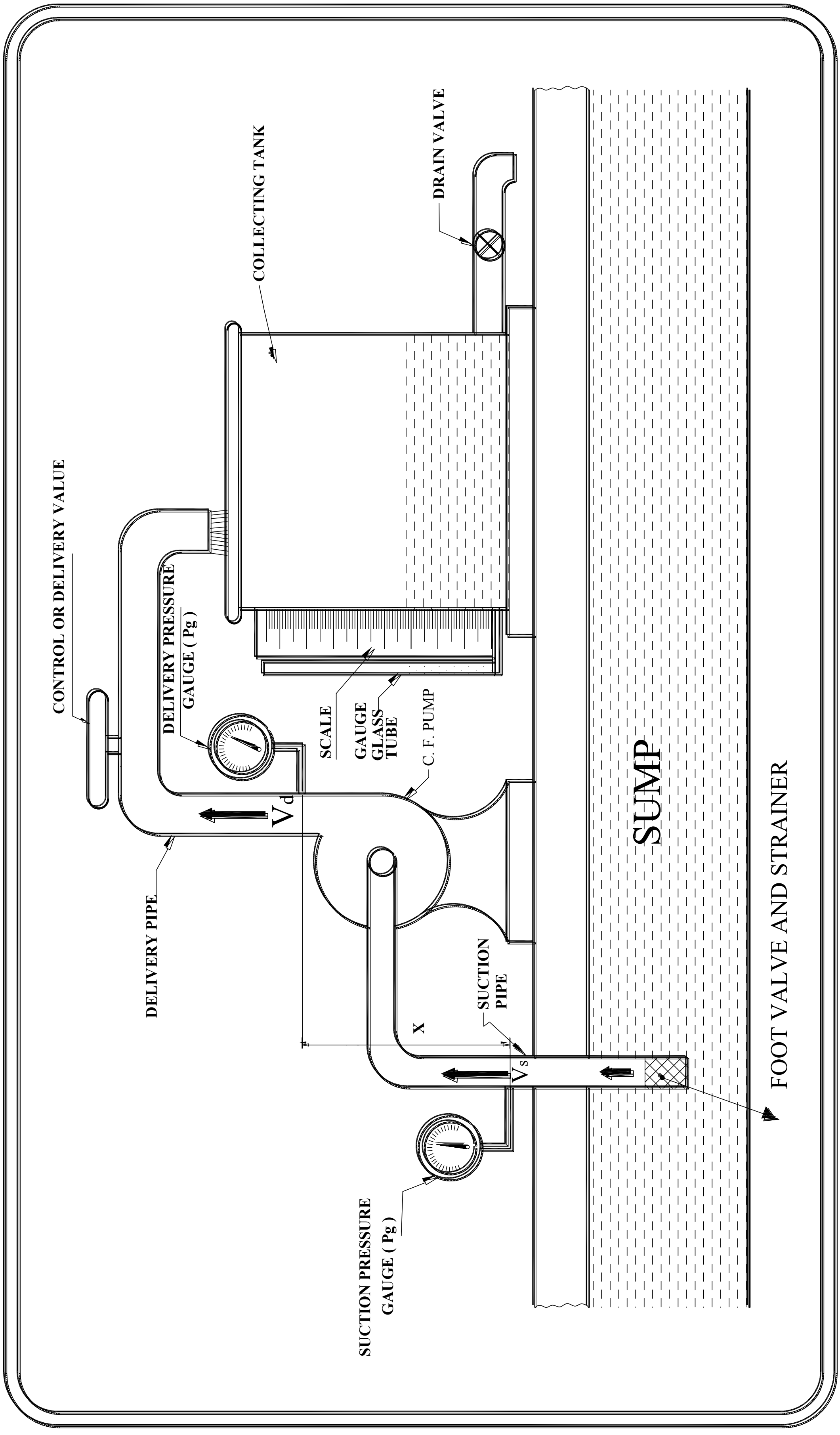
TABULATION OF RESULTS

Sl. No.	Particulars	Symbol	Units	FLAT PLATE				INCLINED PLATE				HEMISPHERICAL VANE			
1.	Trial No.	-	-	1	2	3	4	1	2	3	4	1	2	3	4
2.	Theoretical force	F_{th}	N												
3.	Actual force	F_{act}	N												
4.	Vane η	$\frac{F_{act}}{F_{th}}$	-												

GROUP – B

CENTRIFUGAL PUMP

EXPERIMENTAL SET UP



EXPT. No.1 Date : ……………….

TRIAL ON A CENTERIFUGAL PUMP

Object : To run the centrifugal pump at constant speed and constant head and draw the following characteristic curves.

I. Constant Speed : i) Overall efficiency v/s Discharge
ii) Head v/s Discharge

II. Constant Head : i) Overall efficiency v/s Speed
ii) Speed v/s Discharge

Theory :

i) Classification of pumps.
ii) Working Principle of a centrifugal pump.
iii) What is meant by priming? Its necessity. Methods of priming. What is a self priming pump?.
iv) Types of casing.
v) Distinction between backward curved , radial and forward curved impellers.
vi) Theoretical characteristics of a centrifugal pump.
vii) Advantages of centrifugal pump over reciprocating pump.
viii) What is a multistage centrifugal pump?

Experimental set up :

Describe the experimental set up with a neat sketch.

Procedure :

1. Prime the pump, so as to remove the air present in the suction pipe and the pump casing and fill with water.
2. Close the delivery valve and start the motor coupled to the pump. Open the delivery valve slowly, as soon as the motor starts running.

(a) For Constant Speed and Variable Head

3. Rotate the hand wheel provided at the motor end and vary the belt tension until the required speed is obtained.
4. Measure the speed using a tachometer. Keeping this speed to be a constant and at different openings of the delivery valve, note down the following readings:
   i) Suction pressure or vacuum gauge reading in mm of Hg (P_s).
   ii) Delivery pressure gauge reading in ksc (P_d).
   iii) Time taken for 20cm rise in level of water in the collecting tank.
   iv) Time taken for 5 revolutions of the energy meter disc.
   v) The vertical distance between the suction pressure gauge and delivery pressure gauge tappings in m (X).

(b) Constant Head and Variable Speed

5. By operating the hand wheel provided at the motor end (i.e., by varying the tension in the belt) different speeds are obtained.
6. Maintaining the constant delivery valve opening (i.e., delivery head) the readings mentioned in step 4 are noted down.
7. Steps 5 to 6 are repeated for different speeds, maintaining a constant delivery valve opening.
8. The readings are then finally tabulated.

DATA SHEET

Specifications :

Area of the collecting tank = $A_c = 0.64\,m^2$
Diameter of the suction pipe =D_s = 0.635 m
Diameter of the delivery pipe =D_d=0.0508 m
Vertical distance between the gauge tappings =X = 0.64 m
Energy meter constant = K = 150 revolutions per kWh

TABULATION OF READINGS

Sl. No.	Particulars	Symbol	Units	CONSTANT SPEED				CONSTANT HEAD			
1.	Trial No.	-	-	1	2	3	4	1	2	3	4
2.	Speed of the pump	N	RPM								
3.	Delivery pressure gauge reading	P_g	ksc								
4.	Vacuum gauge reading	P_s	mm of Hg								
5.	Time taken for 20 cm rise in level of water in the collecting tank	t	s								
6.	Time taken for 5 revolutions of energy meter disc.	t_e	s								

SPECIMEN CALCULATION

Trial No.

1.Actual discharge, $Q_{act} = \dfrac{A_c \times 20}{t \times 100} = ...m^3/s$

2.Area of the suction pipe, $a_s = \dfrac{\pi D_s^2}{4} = ...m^2$

3. Velocity of water flow in the suction pipe, $V_s = \dfrac{Q}{a_s} = ...m/s$

4. Area of the delivery pipe, $a_d = \dfrac{\pi D_d^2}{4} = ...m^2$

5. Velocity of water flow in the delivery pipe, $V_d = \dfrac{Q}{a_d} = ...m/s$

6. Delivery head, $H_d = P_d \times 10 = ...m$ of water

7. Suction head, $H_s = P_s \times \dfrac{13.6}{1000} = ...m$ of water

8. Total head against which water is pumped, $H = H_s + H_d + \dfrac{V_d^2 - V_s^2}{2g} + X = ...m$ of water

9. Power output from the pump (Water power), $P_o = \dfrac{\rho\, g\, QH}{1000} = 9.81 \times QH = ...kW$

10. Power input to the pump (P_i) =

$$P_i = \frac{3600 \times n \times \eta_m}{K \times t_e} = \frac{3600 \times 5 \times 0.95}{1200 \times t_e} = ...kW$$

where η_m is the transmission efficiency of the belt and is assumed as 0.95

11. Overall efficiency of the pump, $\eta_o = \dfrac{P_o}{P_i} \times 100 =$

12. Specific speed, $N_s = \dfrac{N\sqrt{Q}}{H^{3/4}} = ...$

13. Unit speed, $N_u = \dfrac{N}{\sqrt{H}} = ...$

14. Unit quantity or unit discharge, $Q_u = \dfrac{Q}{\sqrt{H}} = ...$

15. Unit power, $P_u = \dfrac{P}{H^{3/2}} = ...$

TABULATION OF RESULTS

Sl. No.	Particulars	Symbol	Units	CONSTANT SPEED				CONSTANT HEAD			
1.	Trail No.	-	-	1	2	3	4	1	2	3	4
2.	Speed of the pump	N	RPM								
3.	Actual discharge	Q	m^3/s								
4.	Delivery head	H_d	m of water								
5.	Suction head	H_s	m of water								
6.	Velocity of water in the suction pipe	V_s	m/s								
7.	Velocity of water in the delivery pipe	V_d	m/s								
8.	Total head developed by the pump	H	m of water								
9.	Power output from the pump corresponding to the head developed	P_o	kW								
10.	Power input	P_i	kW								
11.	Overall efficiency of the pump	η_o	%								
12.	Specific speed	N_s	RPM								
13.	Unit speed	N_u	RPM								
14.	Unit discharge	Q_u	m^3/s								
15.	Unit power	P_u	kW								

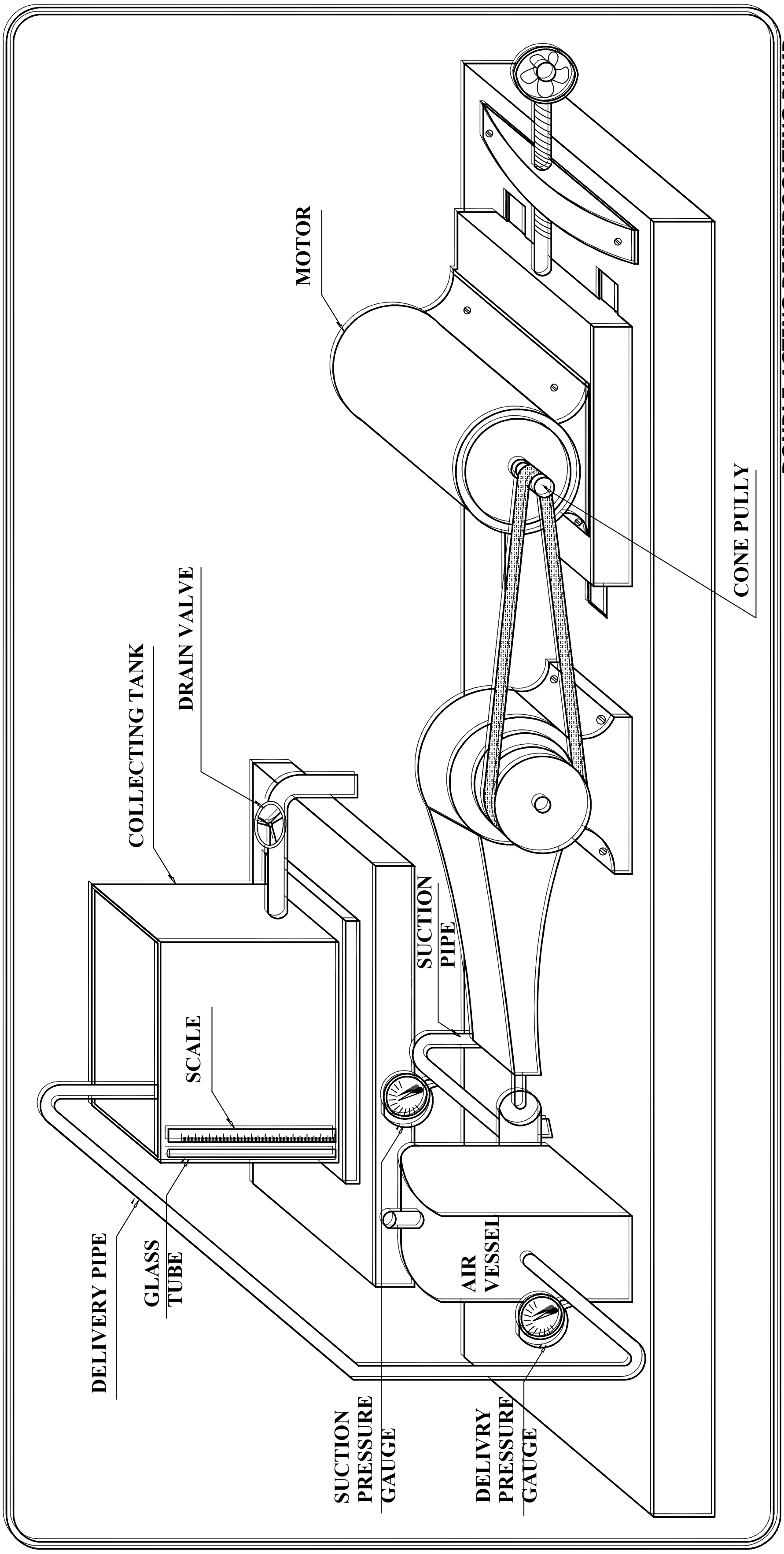
Graphs : I. **Constant Speed**

1. Overall η v/s Discharge
2. Head v/s Discharge
3. Power input v/s Discharge

II. **Constant Head**

1. Overall η v/s Discharge
2. Head v/s Discharge
3. Power input v/s Discharge

DOUBLE ACTING RECIPROCATING PUMP



EXPT. No.2 **Date : …………**

Trial On A Double Acting Reciprocating Pump

Object : To run the double acting reciprocating pump under i) Constant speed & variable head and ii) Constant head and variable speed, and to draw the characteristic curves.

Theory :

i) What is a positive displacement pump?.
ii) How are reciprocating pumps classified?.
iii) Distinguish between single acting and double acting pump.
iv) Explain the principle of working of a double acting reciprocating pump.
v) Explain the function of air vessel.
vi) Define slip in a reciprocating pump.
vii) What is meant by negative slip and when does it occur.
viii) Define coefficient of discharge.

Experimental Set Up :

Describe with a neat diagram.

Procedure:

(a) Constant Speed And Variable Head

1. Select the speed by shifting the belt to the appropriate pulley.
2. Open the gate valve on the delivery side fully and Start the motor.
3. Close the gate valve partially to get the required delivery head.
4. Note down the following readings:
   a) Speed of the pump using a tachometer.
   b) Suction and delivery pressure gauge readings.
   c) Time for 5 revolutions of energy-meter disc.
   d) Time for 10cm rise in level of water in the collecting tank.
   e) Vertical distance between suction and delivery pressure gauge tappings.
5. Repeat step 4 for different delivery heads
6. Repeat the steps 1-5 for other constant speeds.

(b) Constant Head And Variable Speed

Note down the readings mentioned in step (4) for different speeds maintaining a constant head for each speed.

DATA SHEET

Specifications:

Area of the collecting tank, A_c = 0.5x0.5 m^2
Diameter of the suction pipe, D_s = 1" or 2.54 cm.
Diameter of the delivery pipe, D_d = 0.75" or 1.905 cm.
Bore, D = 1.5" or 3.81cm.
Stroke, L = 1.75" or 4.445 cm.
Energy meter constant, K= 1440 rev./kWh.
Distance between suction and delivery pressure gauge tappings, X= 0.08m

TABULATION OF READINGS

Sl. No.	Particulars	Symbol	Units	**CONSTANT SPEED**				**CONSTANT HEAD**			
1.	Trial No.	-	-	1	2	3	4	1	2	3	4
2.	Speed	N	rpm								
3.	Suction gauge reading pressure	P_s	mm of Hg								
4.	Delivery pressure gauge reading	P_g	ksc								
5.	Time for 5cm rise in level of water in the collecting tank	t	s								
6.	Time for 5 Rev. of energy-meter disc.	t_e	s								

SPECIMEN CALCULATION: Trial No.:

1. Actual discharge, $Q_{act} = \dfrac{A_c \times 5}{100 \times t} = \ldots\ldots\ldots\ldots m^3/s$

2. Area of suction pipe, $a_s = \dfrac{\pi D_s^2}{4} = \ldots\ldots\ldots\ldots m^2$

3. Velocity of flow of water in the suction pipe, $V_s = \dfrac{Q_{act}}{a_s} = \ldots\ldots\ldots\ldots m/s$

4. Area of the delivery pipe, $a_d = \dfrac{\pi D_d^2}{4} = \ldots\ldots\ldots\ldots m^2$

5. Velocity of flow of water in the delivery pipe, $V_d = \dfrac{Q_{act}}{a_d} = \ldots\ldots\ldots\ldots m/s$

6. Suction head in meters of water, $H_s = \dfrac{P_s \times 13.6}{1000} = \ldots\ldots\ldots\ldots m \text{ of water}$

7. Delivery head in m. of water, $H_d = P_d \times 10 = \ldots\ldots\ldots\ldots m \text{ of water}$

8. Total head against which water is pumped

$$H = H_s + H_d + \frac{\left(V_d^2 - V_s^2\right)}{2g} + X = \ldots\ldots\ldots\ldots m \text{ of water}$$

9. Theoretical discharge, $Q_{th} = \dfrac{\pi D^2}{4} \times L \times \dfrac{N}{60} \times 2 = \ldots\ldots\ldots\ldots m^3/s$

10.Power output from the pump or water power

$$P_o = \frac{\rho g Q_{act} H}{1000} = 9.81 \times Q_{act} H = \ldots\ldots\ldots\ldots kW$$

11.Power input to the pump, $P_i = \dfrac{3600 \times n_e \times \eta_m}{K \times t_e} = \dfrac{3600 \times 5 \times 0.9}{K \times t_e} = \ldots\ldots\ldots\ldots kW$

Where n_e= number of revolutions of the energy meter disc and η_m = Efficiency of the motor =0.9, K = energy meter constant = 1200 rev / kWh

12. Overall efficiency of the pump, $\eta_o = \dfrac{P_o}{P_i} x 100 =$

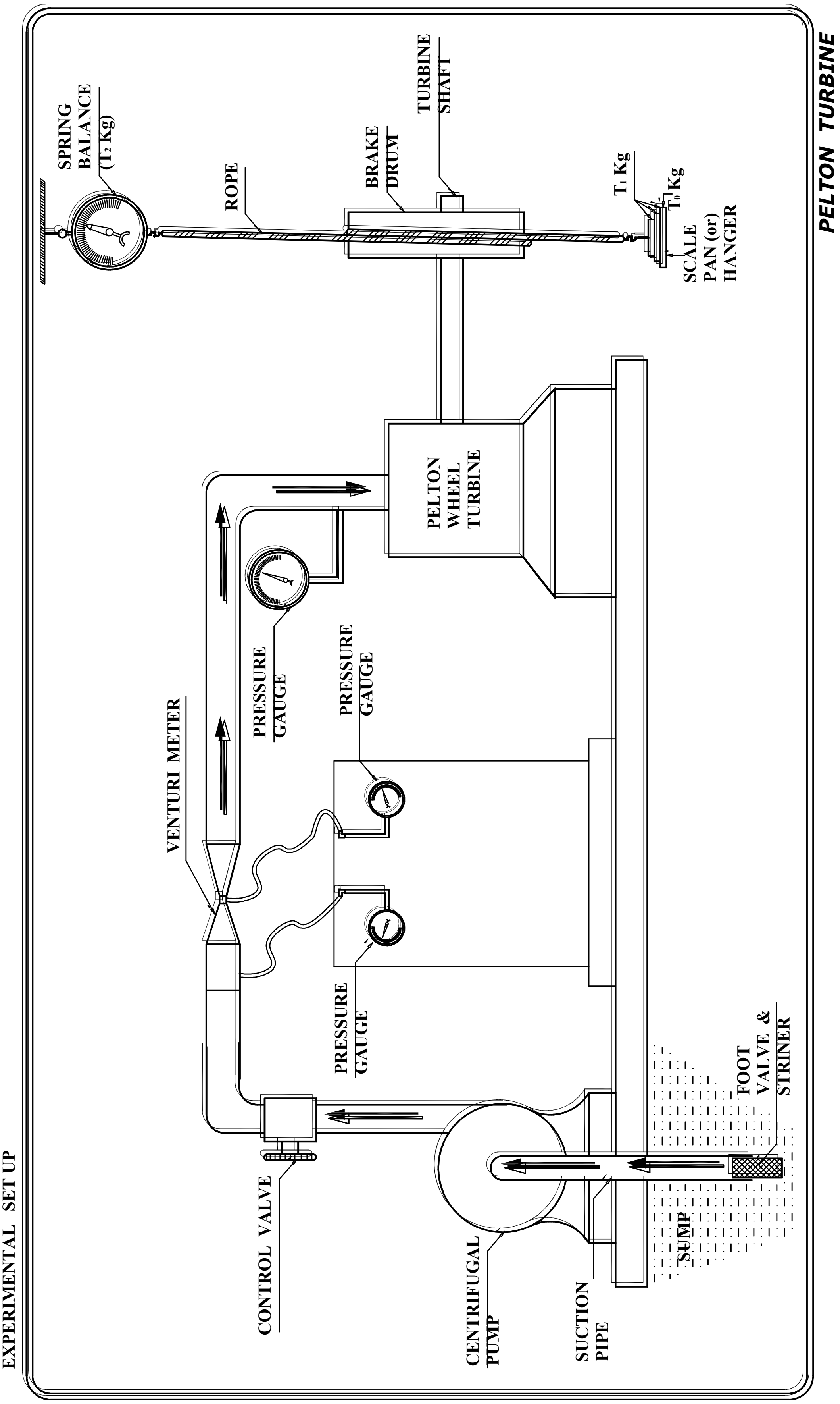
13.Percentage slip, $S = \dfrac{(Q_{th} - Q_{act})}{Q_{th}} \text{ x } 100 =$

TABULATION OF RESULTS

Sl. No.	Particulars	Symbol	Units	CONSTANT SPEED				CONSTANT HEAD			
1	Trial No.	-	-	1	2	3	4	1	2	3	4
2	Suction head	H_s	m of water								
3	Delivery head	H_d	m of water								
4	Velocity of water in the suction pipe	V_s	m/s								
5	Velocity of water in the delivery pipe	V_d	m/s								
6	Total head	H	m of water								
7	Actual discharge	Q_{act}	m^3/s								
8	Theoretical discharge	Q_{th}	m^3/s								
9	Power output from the pump	P_o	kW								
10	Power input to the pump	P_i	kW								
11	Overall efficiency	η_o	%								
12	Percentage slip	S	%								

Graphs:

Constant Speed	**Constant Head**
i) Overall η_0 v/s Discharge	i) Overall η_0 v/s Discharge
ii) Head v/s Discharge	ii) Speed v/s Discharge
iii) % slip v/s Head	iii) % slip v/s Speed


PELTON TURBINE
EXPERIMENTAL SET UP
SPRING BALANCE (T_2 Kg)
ROPE
BRAKE DRUM
TURBINE SHAFT
T_1 Kg
T_0 Kg
SCALE PAN (or) HANGER
PELTON WHEEL TURBINE
PRESSURE GAUGE
PRESSURE GAUGE
VENTURI METER
PRESSURE GAUGE
FOOT VALVE & STRINER
CONTROL VALVE
CENTRIFUGAL PUMP
SUCTION PIPE
SUMP

EXPT No. 3 Date………………….

TRIAL ON A PELTON TURBINE

Object :To run the Pelton Wheel under varying heads and speeds, and to determine its overall η and also to draw the following characteristic curves:

i) Main characteristics
ii) Operating characteristics and
iii) Equal efficiency curves.

Theory:

1. What is a hydraulic turbine?
2. Classification of hydraulic turbines and their uses.
3. Definitions of specific speed, unit speed, unit power, unit discharge and runaway speed.
4. Shapes of theoretical characteristic curves.

Experimental Set-Up :

Sketch and description of experimental set up.

Procedure :

(A) Constant Head And Variable Speed

i) Start the centrifugal pump and open the delivery valve to the required extent to get the desired head, which is to be maintained constant throughout the experiment.
ii) Keep the nozzle (gate) opening at a constant particular value say 25%.
iii) Note down the speed of the turbine at no load condition.
iv) Place the weights on the scale pan of the rope brake arrangement.
v) When the speed is steady, the following readings are to be noted down:
    a) Supply head pressure gauge reading (in ksc)
    b) Speed of the turbine using a tachometer.
    c) Load on the brake drum
    d) Spring balance reading.
    e) Pressure gauge readings across the Venturimeter.
  f) Steps (a) to (e) are repeated for various brake loads.
  g) Steps (iii), (iv) and (v) are repeated for 50%, 75% and 100% nozzle openings.
vi) Readings are then neatly tabulated.

(B) Constant Speed And Variable Head

i) Keep the gate opening at a constant value and speed is measured with no load on the brake drum.
ii) Place the weights on the scale pan, which reduces the speed.
iii) Now alter the supply head by operating the control valve to bring the speed back to the original value.
iv) When steady speed is reached, note down the readings as in steps (a) to (e) of Part -A.
v) Repeat the steps (f) and (g) as in Part-A.
vi) Tabulate all the readings then.

DATA SHEET

Specifications:

Brake drum diameter, D =0.415 m,

Weight of scale pan or hanger, T_o =………kgs.

Rope diameter, d =……..m

Venturimeter constant ,K = 0.0055,

TABULATION OF REDINGS

A. Constant Head

Sl. No.	Particulars	Symbol	Units								
1	Trial No.	-	-	1	2	3	4	1	2	3	4
2	Nozzle opening	-	-	← 25% →				← 50% →			
3	Speed of the turbine	N	rpm								
4	Supply pressure gauge reading	P_s	ksc								
5	Pressure gauge readings across venturimeter	P_1	ksc								
		P_2	ksc								
6	Weights placed on the hanger	T_1	Kgs								
7	Spring balance reading	T_2	Kgs								

Sl. No.	Particulars	Symbol	Units								
1	Trial No.	-	-	9	10	11	12	13	14	15	16
2	Nozzle opening	-	-	← 75% →				← 100% →			
3	Speed of the turbine	N	rpm								
4	Supply pressure gauge reading	P_s	Ksc								
5	Pressure gauge readings across venturimeter	P_1	ksc								
		P_2	ksc								
6	Weights placed on the hanger	T_1	Kgs								
7	Spring balance reading	T_2	Kgs								

B. Constant Speed

Sl. No.	Particulars	Symbol	Units								
1	Trial No.	-	-	1	2	3	4	1	2	3	4
2	Nozzle opening	-	-	← 25% →				← 50% →			
3	Speed of the turbine	N	rpm								
4	Supply pressure gauge reading	P_s	ksc								
5	Pressure gauge readings across venturimeter	P_1	ksc								
		P_2	ksc								
6	Weights placed on the hanger	T_1	Kgs								
7	Spring balance reading	T_2	Kgs								

Sl. No.	Particulars	Symbol	Units								
1	Trial No.	-	-	9	10	11	12	13	14	15	16
2	Nozzle opening	-	-	← 75% →				← 100% →			
3	Speed of the turbine	N	rpm								
4	Supply pressure gauge reading	P_s	Ksc								
5	Pressure gauge readings across venturimeter	P_1	ksc								
		P_2	ksc								
6	Weights placed on the hanger	T_1	Kgs								
7	Spring balance reading	T_2	Kgs								

SPECIMEN CALCULATION

TRIAL No.: Speed = N =…………rpm

1. Supply head, $H = P_s \times 10 = ... \text{m of water}$.
2. Head of water causing flow through the venturimeter, $h_w = (P_1 - P_2) x10 =$ ……… m of water.
3. Actual discharge through the venturimeter

$$Q = K \times \sqrt{h_w} = 0.0055 \times \sqrt{h_w} = ... m^3/s$$

4. Power supplied to the turbine, $P_i = \frac{\rho gQH}{1000} = 9.81QH = ...kW$.
5. Net brake load on the turbine, $W = (T_1 + T_o - T_2) \times 9.81 = ...N$.
6. Brake torque, $T = W \times \frac{(D + d)}{2} = ...Nm$.
7. Power output from the turbine, $P_o = \frac{2\pi NT}{60000} = ...kW$.
8. Overall efficiency of the turbine, $\eta_o = \frac{\text{output}}{\text{input}} = \frac{P_o}{P_i} x100 =$ ………%.
9. Specific speed, $N_s = \frac{N\sqrt{P_o}}{H^{5/4}} =$ ……….
10. Unit speed, $N_u = \frac{N}{\sqrt{H}} =$ …………
11. Unit power, $P_u = \frac{P_o}{\sqrt{H}} =$ ………
12. Unit quantity or unit discharge, $Q_u = \frac{Q}{\sqrt{H}} =$ ……….

TABULATION OF RESULTS

A. Constant Head

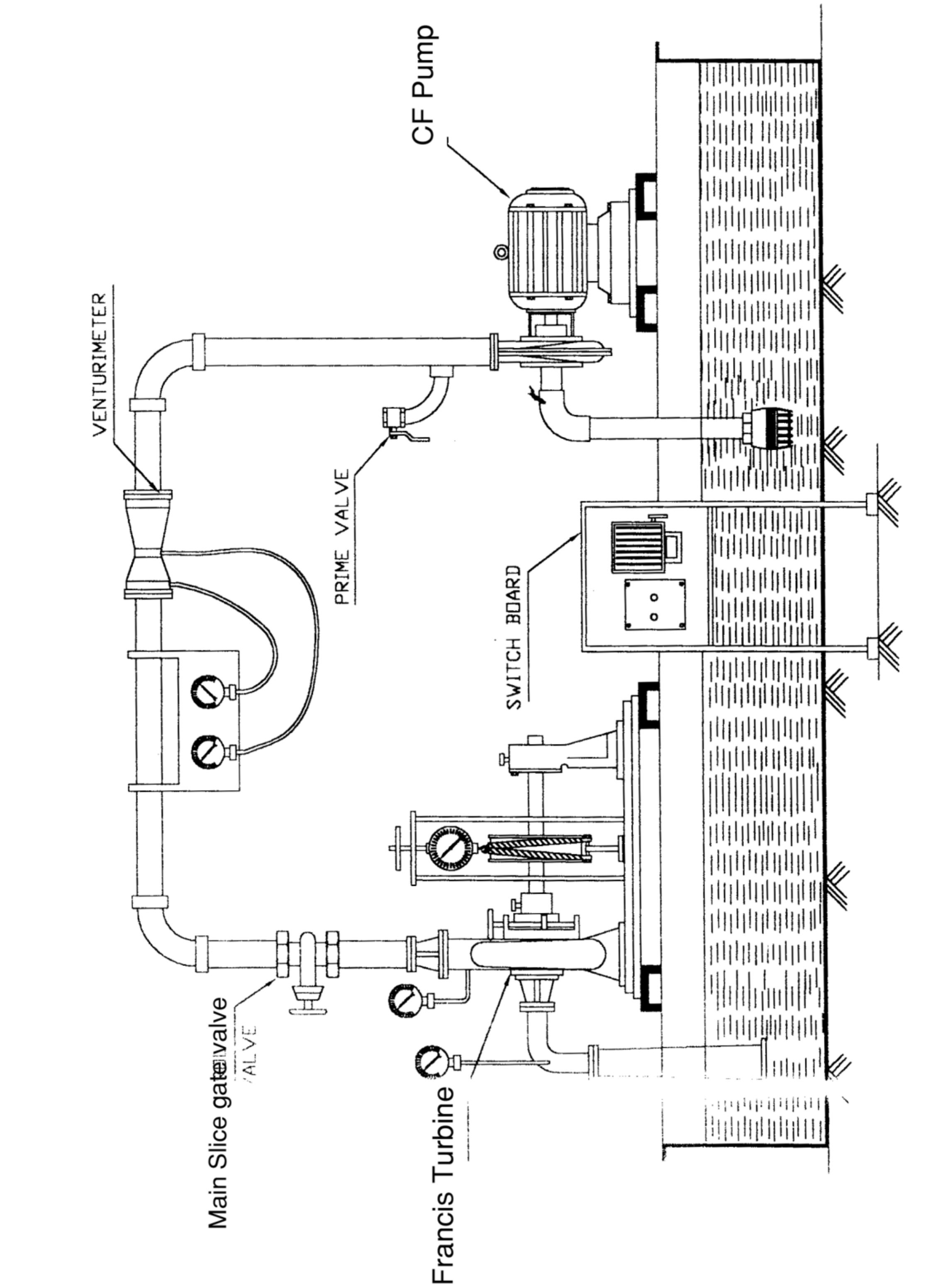
Sl. No.	Particulars	Symbol	Units								
1	Trial No.	-	-	1	2	3	4	1	2	3	4
2	Nozzle opening	-	-	← 25% →				← 50% →			
3	Supply head	H	m of water								
4	Head causing flow through venturimeter	h_w	m of water								
5	Actual discharge through the turbine	Q	m^3/s								
6	Power input to the turbine	P_i	kW								
7	Power output from the turbine	P_o	kW								
8	Overall efficiency	η_o	%								
9	Specific speed	N_s	rpm								
10	Unit speed	N_u	rpm								
11	Unit power	P_u	kW								
12	Unit discharge	Q_u	m^3/s								

Sl. No.	Particulars	Symbol	Units								
1	Trial No.	-	-	1	2	3	4	1	2	3	4
2	Nozzle opening	-	-	← 75% →				← 100% →			
3	Supply head	H	m of water								
4	Head causing flow through venturimeter	h_w	m of water								
5	Discharge through the turbine	Q	m^3/s								
6	Power input to the turbine	P_i	kW								
7	Power output from the turbine	P_o	kW								
8	Overall efficiency	η_o	%								
9	Specific speed	N_s	rpm								
10	Unit speed	N_u	rpm								
11	Unit power	P_u	kW								
12	Unit discharge	Q_u	m^3/s								

B. Constant Speed

Sl. No.	Particulars	Symbol	Units								
1	Trial No.	-	-	1	2	3	4	1	2	3	4
2	Nozzle opening	-	-	← 25% →				← 50% →			
3	Supply head	H	m of water								
4	Head causing flow through venturimeter	h_w	m of water								
5	Discharge through the turbine	Q	m^3/s								
6	Power input to the turbine	P_i	kW								
7	Power output from the turbine	P_o	kW								
8	Overall efficiency	η_o	%								
9	Specific speed	N_s	rpm								
10	Unit speed	N_u	rpm								
11	Unit power	P_u	kW								
12	Unit discharge	Q_u	m^3/s								

Sl. No.	Particulars	Symbol	Units								
1	Trial No.	-	-	1	2	3	4	1	2	3	4
2	Nozzle opening	-	-	← 75% →				← 100% →			
3	Supply head	H	m of water								
4	Head causing flow through venturimeter	h_w	m of water								
5	Discharge through the turbine	Q	m^3/s								
6	Power input to the turbine	P_i	kW								
7	Power output from the turbine	P_o	kW								
8	Overall efficiency	η_o	%								
9	Specific speed	N_s	rpm								
10	Unit speed	N_u	rpm								
11	Unit power	P_u	kW								
12	Unit discharge	Q_u	m^3/s								



FRANCIS TURBINE

EXPT. No. 4 Date:…………..

FRANCIS TURBINE

Aim: To study the performance characteristics of a Francis Turbine

Theory:

1. Type, working principle and construction of Francis Turbine.
2. Use of draft tubes and Types of draft tubes

Apparatus: 3.72 kW (5 HP) Francis Turbine, 15 HP CF pump, Venturimeter, Rope brake Dynamometer, Tachometer, Pressure gauges etc.

Experimental Set Up:

Draw a neat sketch of Francis turbine and explain the working principle.

Procedure:

(A). For Constant Head:

1. Keep the guide vane at the required opening (say $3/8^{th}$) and Prime the pump.
2. Close the main gate valve and start the pump.
3. Open the gate valve for required discharge after the pump-motor switches from star to delta mode (this is indicated by the jump in the motor speed). The desired head is to be maintained through out the experiments so as to achieve the constant head condition.
4. Measure the speed of the turbine under no load condition.
5. Load the turbine by adding weights in the weight hanger. Open the brake drum cooling water gate valve for cooling the brake drum.
6. Note down the following readings under steady conditions:
   i) Speed of the turbine using Tachometer.
   ii) Pressure gauge readings across the venturimeter.
   iii) Pressure gauge and Vacuum gauge readings at inlet and outlet of the turbine.
   iv) Weight added in the weight hanger.
7. Repeat the experiments for different loads.

(B) For Constant Speed:

For constant speed tests, the procedure of experimentation remain same as above except that the main sluice valve has to be adjusted to vary the inlet head and discharge for varying loads (at a given guide vane opening position).

The experiments can be repeated for other guide vane positions.

WARNING:

1. Do not the start the motor without priming the pump.
2. Do not start the motor without closing the delivery sluice valve completely.
3. Only after the starter has changed to delta mode from the star mode (this is indicated by the jump in the motor speed), the delivery valve should be opened.
4. Starter tripping indicates that the motor is overloaded, and this will occur if the pump discharge is above the normal range. Under such circumstances, after the motor is restarted ensure that the flow is maintained within the normal range. As the motor is designed to run at 400-440 Volts, starter may also trip when the supply voltage is low (i.e less than about 380 Volts). In such a case, operate the motor-pump set at reduced flow rates. The turbine output will be correspondingly lower than the design value of 5 HP (3.7 kW).

Note: Do not operate the motor at very low voltages of 350 Volts and below, as this will draw excessive current leading to motor coil burnout.

Observations:

Inlet pipe diameter, D_1=100 mm = 0.1 m,
Brake drum diameter, D_b =0.3 m,
Effective diameter of the drum, D = 0.315 m,
Venturimeter coefficient, C_d =0.98
Venturimeter throat diameter, D_2= 0.6 D_1,
Rope diameter, d_r = 0.015 m,
Weight of the hanger, T_0 = 1.0 kg,

Observation Table:

Sl. No.	Across Turbine		Across Venturimeter		Speed of the Turbine N (RPM)	Weight on hanger T_1 (kg)	Spring balance reading T_2 (kg)
	Inlet Pressure P (kg/cm^2)	Outlet Gauge, V (mm of Hg) (Vac)	I/L Pressure P_1 (kg/cm^2)	Throat pressure P_2 (kg/cm^2)			

Specimen Calculation:

To determine the flow the turbine:

1. Area of the inlet pipe, $A_1 = \frac{\pi}{4} D_1^2 =$ -------- m^2.
2. Area of the throat, $A_2 = \frac{\pi}{4} D_2^2 =$ ----------- m^2.
3. Water head causing flow, h = (P_1-P_2) x 10 = ………… m of water.
4. Actual discharge through the venturimeter, $Q = C_d \frac{A_1 A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}} =$ --------------m^3/s

To determine the head available at inlet of the turbine:

Head available for the turbine, $H = \left(P + \frac{V}{760}\right) x10 =$ ------------- m of water

Power available at inlet of the turbine:

Input power, $P_{in} = \frac{\rho Q g H}{1000} = \frac{1000 Q g H}{1000} = 9.81 Q H =$ ------------ kW

Turbine output power:

Weight added to hanger, T_1 = -----------kg
Spring balance reading, T_2 = ------------kg
Net load on the brake drum, $T = (T_1 + T_0 - T_2)$ = ---------- kg
Speed of the turbine, N = --------- RPM
Turbine output power, $P_{out} = \frac{\pi D N x 9.81 T}{60,000}$ = ------------- kW

Turbine efficiency

$\eta = \frac{P_{out}}{P_{in}} x100$ = --------- %

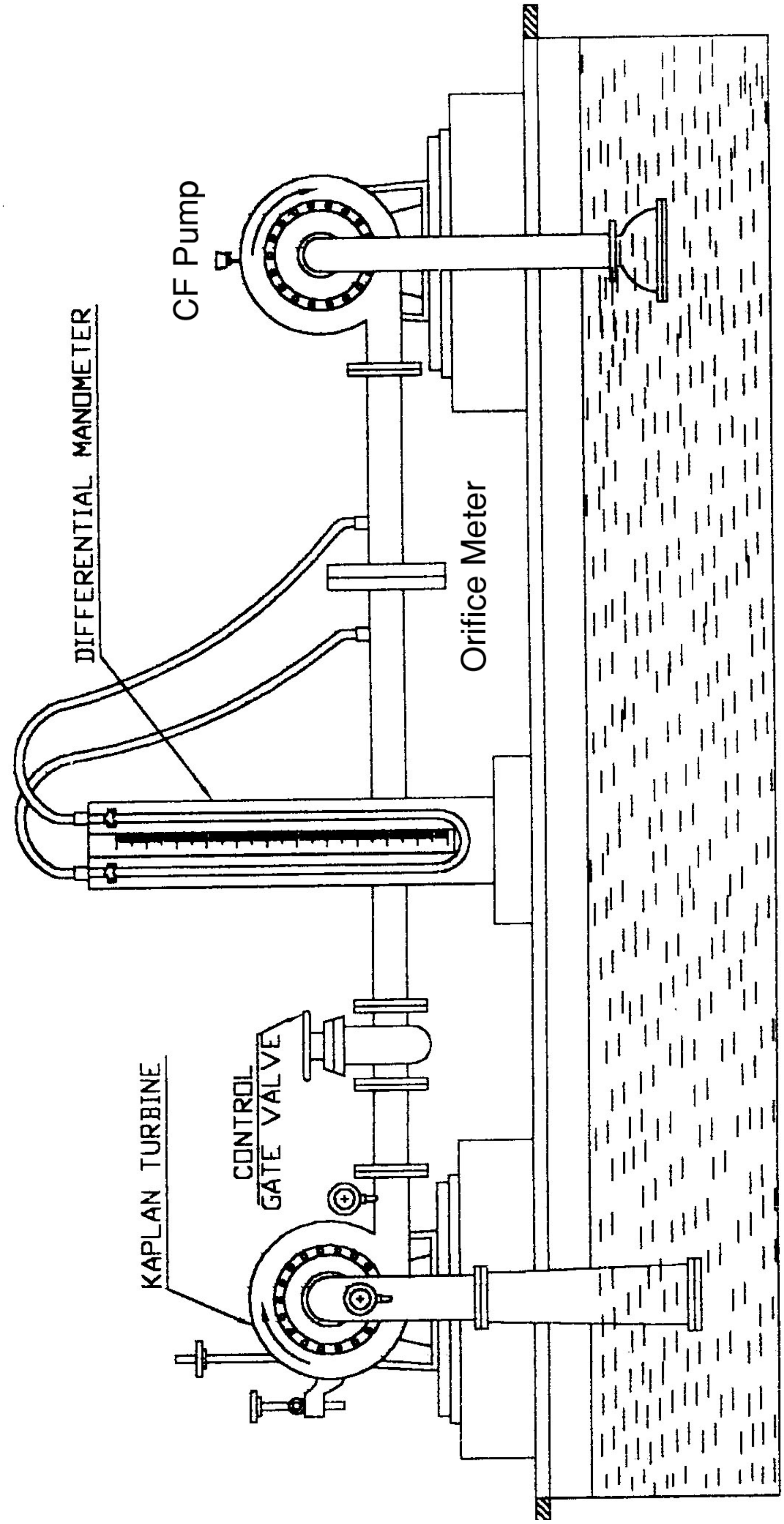
Results Table:

(A) Constant Head:

Sl. No.	Head available for the turbine $H = \left(P + \frac{V}{760}\right) x10$ m of water	Equi. Head causing flow $h = (P_1 - P_2) \times 10$ m of water	Flow rate Q (m^3/s)	Speed of turbine N RPM	Net weight on the brake drum T kgs	Turbine input power P_{in} (kW)	Turbine output power P_{out} (kW)	Efficiency of the turbine $\eta = \frac{P_{out}}{P_{in}} x100$

(B) Constant Speed:

Sl. No.	Head available for the turbine $H = \left(P + \frac{V}{760}\right) x10$ m of water	Equi. Head causing flow $h = (P_1 - P_2) \times 10$ m of water	Flow rate Q (m^3/s)	Speed of turbine N RPM	Net weight on the brake drum T kgs	Turbine input power P_{in} (kW)	Turbine output power P_{out} (kW)	Efficiency of the turbine $\eta = \frac{P_{out}}{P_{in}} x100$



KAPLAN TURBINE

EXPT. No. 5 Date:…………..

KAPLAN TURBINE

Aim: To study the characteristics of a Kaplan Turbine
Apparatus: 3.72 kW (5 HP) Francis Turbine, 20 HP Mixed flow pump, Orifice meter, Rope brake Dynamometer, Tachometer, Pressure gauges etc.
Theory:
1. Type, working principle and construction of Kaplan Turbine
2. Use of draft tubes
3. Types of draft tubes

Experimental Set-up
Sketch and explain the experimental setup

Experimental Procedure:

(A) For Constant Head:
1. Keep the guide vane at the required opening (say $4/8^{th}$) and Prime the pump.
2. Close the main gate valve and start the pump.
3. Open the gate valve for required discharge after the pump motor switches from star to delta mode (this is indicated by the jump in the motor speed).
4. Load the turbine by adding weights in the weight hanger. Open the brake drum cooling water valve for cooling the brake drum.
5. Note down the following readings:
   a) Speed of the turbine using Tachometer
   b) Manometer deflection readings across the Orifice meter.
   c) Pressure gauge and Vacuum gauge readings across the turbine.
   d) Weight added in the weight hanger.
6. Repeat the experiments for different loads maintaining the constant head.
7. Experiments can be repeated for different guide vane openings.

(B) For Constant Speed:
1. For constant speed tests, the main sluice valve has to be adjusted to vary the inlet head and discharge for varying loads (at a given guide vane opening position).
2. Follow the steps 1 to 6 as in Part-A for different loads.
3. The experiments can be repeated for other guide vane positions.

WARNING:

1. Do not the start the motor without priming the pump.
2. Do not start the motor without closing the delivery sluice valve completely.
3. Only after the starter has changed to delta mode from the star mode (this is indicated by the jump in the motor speed) the delivery valve should be opened.
4. Starter tripping indicates motor overload and this will occur if the pump discharge is above the normal range. When the motor is restarted, ensure that the flow is maintained within the normal range.
5. As the motor is designed to run at 400-440 Volts, starter will also trip when the supply voltage is low (i.e less than about 380 Volts). In such a case, operate the motor-pump set at reduced flow rates. The turbine output will be correspondingly lower than the design value of 5 HP (3.7 kW).

Note: Do not operate the motor at very low voltages of 350 Volts and below, as this will draw excessive current leading to motor coil burnout.

Observations:

Inlet pipe diameter, D_1=262 mm = 0.262 m, Orifice diameter, D_2= 0.75 D_1,
Brake drum diameter, D_b =0.3 m,
Rope diameter, d_r = 0.015 m, Effective diameter of the drum, D = 0.315 m,
Weight of the hanger, T_0 = 1.0 kg,
Orifice meter coefficient, C_d =0.6

Observation Table:

Sl. No.	Across Turbine		Manometer readings across Orifice meter		Speed of the Turbine N (RPM)	Weight on hanger T_1 (kg)	Spring balance reading T_2 (kg)
	Inlet Pressure P (kg/cm^2)	Outlet Gauge, V (mm of Hg) (Vac)	Left leg reading h_1 mm of Hg	Left leg reading h_2 mm of Hg			

Specimen Calculation:

<u>To determine the flow</u>:

1. Inlet pipe diameter, D_1 = 0.262 m, Area of the inlet pipe, $A_1 = \frac{\pi}{4} D_1^2 =$ ------ m^2

   Diameter of the Orifice meter at throat, D_2=0.75 x D_1 = 0.1965 m, $A_2 = \frac{\pi}{4} D_1^2 =$ --------m^2

   Coefficient of discharge for the Orifice meter, C_d = 0.6

2. Water head causing flow, h = (h_1-h_2) x 12.6 = ………… m of water

3. Actual discharge through the Orifice meter, $Q = C_d \frac{A_1 A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}$ = --------------m^3/s

4. **<u>To determine the head available at inlet of the turbine</u>**:

   Turbine inlet pressure gauge reading, P = --------- kg/cm^2

   Turbine outlet vacuum gauge reading, V = --------- mm of Hg

   Head available for the turbine, $H = \left(P + \frac{V}{760} \right) x10$ = -------------- m of water

5. **<u>Power available at inlet of the turbine</u>**:

   Input power, $P_{in} = \frac{\rho QgH}{1000} = \frac{1000 QgH}{1000} = 9.81 QH$ = ------------ kW

6. **<u>Turbine output power</u>**:

   Weight added to hanger, T_1 = -----------kg

   Spring balance reading, T_2 = ------------kg

   Net load on the brake drum, T = $(T_1 + T_0 - T_2)$ = ---------- kg

   Speed of the turbine, N = --------- RPM

   Turbine output power, $P_{out} = \frac{\pi D N x 9.81 T}{60{,}000}$ = ------------- kW

7. **<u>Turbine efficiency</u>**

   $\eta = \frac{P_{out}}{P_{in}} x100$ = --------- %

Results Table:

(A) Constant Head:

Sl. No.	Head available for the turbine $H=\left(P+\frac{V}{760}\right)x10$ m of water	Equi. Head causing flow h = (h_1-h_2) x 12.6 m of water	Flow rate Q (m^3/s)	Speed of turbine N RPM	Net weight on the brake drum T kgs	Turbine input power P_{in} (kW)	Turbine output power P_{out} (kW)	Efficiency of the turbine $\eta=\frac{P_{out}}{P_{in}}x100$

(B) Constant Speed:

Sl. No.	Head available for the turbine $H=\left(P+\frac{V}{760}\right)x10$ m of water	Equi. Head causing flow h = (h_1-h_2) x 12.6 m of water	Flow rate Q (m^3/s)	Speed of turbine N RPM	Net weight on the brake drum T kgs	Turbine input power P_{in} (kW)	Turbine output power P_{out} (kW)	Efficiency of the turbine $\eta=\frac{P_{out}}{P_{in}}x100$

EXPT. No. 6 Date:………….

Trial on Air Compressor

Performance test on a two-stage single acting reciprocating air compressor

Object : To run the reciprocating air compressor and to determine the volumetric efficiency and isothermal efficiency for various values of delivery pressure and to draw the graphs of :
i) Volumetric efficiency Vs pressure ratio and
ii) Isothermal efficiency Vs pressure ratio.

Theory :

1. What is an air compressor ?.
2. What are the uses of compressed air ?.
3. How are air compressors classified ?.
4. Distinguish between single acting and double acting compressors.
5. Distinguish between single stage and multi-stage compressors.
6. List the advantages of multi-stage compression.
7. Terminology used in air compressor practice.
8. Define: i) Bore ii)T.D.C. iii)B.D.C. iv)Stroke v) Stroke length
   vi) Clearance volume v) Stroke volume vi) Total volume
   vii) Piston displacement viii) Piston speed.
9. Define: i) FAD ii) Volumetric efficiency referred to suction conditions
   iii) Volumetric efficiency referred to ambient conditions
   iv) Isothermal efficiency v) indicated power vi) Shaft power
   vii) Mechanical efficiency viii) Adiabatic efficiency
   ix) Polytropic efficiency.

Experimental set-up:

Draw a neat sketch of the experimental set up and explain it.

Procedure :

1. Note down the barometer reading in mm of mercury and the room temperature in ^{o}C.
2. Close the outlet valve of the receiver and check the manometer connections.
3. Switch on the motor connected to the compressor and allow the pressure to build up in the receiver. The pressure of air in the receiver is indicated by the pressure gauge mounted on the receiver.
4. Slowly open the outlet valve so as to maintain the constant required delivery pressure.
5. Note down the following readings:
   i) Delivery pressure gauge reading.
   ii) Speed of the compressor shaft.
   iii) Speed of the motor.
   iv) Water manometer reading in mm of water.
   v) Dynamometer spring balance reading.
6. Repeat the experiment for different values of delivery pressure.
7. Tabulate all the readings and plot the required graphs

Data Sheet

Dia of L.P. piston, D_L = 110 mm
Dia of H.P. piston, D_H = 80 mm
Stroke length, L = 89 mm
Air box orifice dia, d_o = 20 mm
Coefficient of discharge of the orifice, C_d = 0.64
Dynamometer constant, C = 26675
Room temperature, t_a = ^oC
Barometer reading = Room pressure, H_a = mm of Hg
Belt transmission efficiency, η_{TR} = 90 %

Tabulation of Readings

Sl. No.	Particulars	Symbol	Units				
1	Trial No.	-	-	1	2	3	4
2	Delivery pressure gauge reading	P_g	kg/cm^2				
3	Water manometer reading	h_1	mm of water				
		h_2	mm of water				
4	Dynamometer spring balance reading	T	kgs				
5	Compressor shaft speed	N_C	RPM				
6	Motor shaft speed	N_m	RPM				

Specimen calculation:

1. Atmospheric pressure, $P_a = 101.325 \times \frac{H_a}{760}$ = …………….kPa
2. Density of air at RTP conditions, $\rho_a = \frac{P_a \times 10^3}{287.2 \times T_a}$ = …………kg/m^3.
3. Delivery pressure, $P_d = \{ 98.1 \times P_g \text{ (kg/cm}^2\text{) } \} + P_a$ = …………kPa
4. Delivery pressure ratio, $r_p = \frac{P_d}{P_a}$ = …….
5. Air head causing flow through the air box orifice,

$$h_a = \frac{\rho_w}{\rho_a} \times \frac{h_w\,(\text{in mm})}{1000} = \text{……………m of air}$$

6. Actual volume of air drawn into the compressor,

$$V_a = C_d \times \frac{\pi d_o^2}{4} \times L \times 10^{-6} \times \sqrt{2gh_a} = \quad m^3/s$$

7. Theoretical volume of air drawn into the L.P. cylinder,

$$V_{TH} = \frac{\pi D_L^2}{4} \times L \times 10^{-9} \times \frac{N_c}{60} = \quad m^3/s$$

8. Volumetric efficiency referred to RTP conditions, $\eta_{Vol,.RTP} = \frac{V_a}{V_{TH}} \times 100$ = ……%

9. Actual volume of air drawn in referred to NTP conditions,

$$V_o = \frac{P_a}{P_o} \times \frac{T_o}{T_a} \times V_a = \quad m^3/s$$

10. Volumetric efficiency referred to NTP conditions, $\eta_{Vol,NTP} = \frac{V_o}{V_{TH}} \times 100 =$ …………%

11. Actual power input to the compressor, $P_{ACT} = \frac{T \times 9.81 \times N_m}{26675} \times \eta_T =$ kW

12. Isothermal power input, $P_{ISO} = P_a \times V_a \, Ln\,(r_p) =$ …………kW

13. Isothermal efficiency $= \frac{\text{Isothermal power input}}{\text{Actual power input (shaft power)}} = \frac{P_{ISO}}{P_{ACT}} \times 100 =$ ………%

14. Adiabatic power input, $P_{ADIA} = \frac{\gamma}{\gamma - 1} \times P_a V_a \times \left\{ r_p^{(\gamma-1)/\gamma} - 1 \right\} =$ kW

15. Adiabatic efficiency, $\eta_{ADIA} = \frac{P_{ADIA}}{P_{ACT}} \times 100 =$ ………..%

16. Free air delivered, FAD $= V_a \times 60 =$ ……….m^3/min

Tabulation of Results

Sl. No.	Particulars	Symbol	Units				
1	Trial No.	-	-	1	2	3	4
2	Delivery pressure	P_d	kPa				
3	Delivery pressure ratio	r_P	-				
4	Air head causing flow	h_a	m of air				
5	Actual volume of air drawn in at RTP	V_a	m^3 /s				
6	Theoretical Volume of LP cylinder	V_{TH}	m^3/s				
7	Volumetric efficiency referred to RTP	Vol. η_{RTP}	%				
8	Actual volume of air drawn in at NTP	V_o	m^3/s				
9	Volumetric efficiency referred to NTP	Vol. η_{NTP}	%				
10	Actual power input	P_{ACT}	kW				
11	Isothermal power input	P_{ISO}	kW				
12	Isothermal efficiency	η_{ISO}	%				
13	Adiabatic power input	P_{ADIA}	kW				
14	Adiabatic efficiency	η_{ADIA}	%				
15	Free air delivered	FAD	m^3				

EXPT. No. 7 Date:…………….

Trial On A Centrifugal Blower

Object : To conduct a trial on a centrifugal blower for different types of impellers and to determine the overall efficiency of the blower and to draw graphs of :

i) Head Vs Discharge and ii) Overall efficiency Vs Discharge.

Theory :

i) Nomenclature of a blower.
ii) Principle of working.
iii) Classification of blower impellers.
iv) Typical velocity triangle and characteristics.

Experimental Set-up:

Sketch and description of the experimental set up.

Experimental procedure :

e) Room pressure (Barometer reading) in mm of Hg and room temperature in ^oC.
f) Fit the required impeller.
g) Check the manometer connections.
h) Close the delivery valve and start the motor.
i) Open the delivery valve slowly to the required extent. Under steady conditions, note down the following readings:
   i) The speed of the blower.
   ii) Mercury manometer reading which gives the pressure difference between the inlet and the throat of the venturimeter.
   iii) Water manometer reading which gives the delivery pressure head.
   iv) Dynamometer spring balance reading.
j) Repeat the steps (a) to (e) for other types of impeller

Data Sheet

Barometer Reading, H_a = mm of Hg.
Room Temperature, t_a = ^oC.
Rated Speed of motor, N_m = RPM
Dynamometer constant, C = 26675

Tabulation of Reading

Trial No.	Type of impeller	Gate opening	Water manometer reading $h_w = (h_1 \sim h_2)$ mm of water	Mercury manometer reading $h_m = (h_3 \sim h_4)$ mm of Hg	Dynamometer spring balance reading T (kg)
1	Forward Curved blade (Yellow)	¼			
2		½			
3		¾			
4		Full			
1	Radial Vane (Sky blue)	¼			
2		½			
3		¾			
4		Full			
1	Backward curved blade (Green)	¼			
2		½			
3		¾			
4		Full			

Specimen Calculation

Trial No. :

1. Atmospheric pressure, $P_a = 101.325 \times \frac{H_a}{760}$ = kPa.
2. Room temperature, $T_a = (t_a + 273)$ = K
3. Density of air at R.T.P., $\rho_a = \frac{P_a}{RT_a} = \frac{P_a \; 10^3}{287.2 \times T_a}$ = kg/m^3
4. Delivery pressure head, $H_d = \frac{h_w \times \rho_w}{1000 \times \rho_a} = \frac{h_w \times 1000}{1000 \times \rho_a}$ = m of air.
5. Air head causing flow through the venturimeter, $h_a = \frac{h_m}{1000} \times \frac{\rho_m}{\rho_a}$ =

$$= \frac{h_m \times 13.6 \times 1000}{1000 \times \rho_a} = \text{ m of air}$$

6. Volume flow rate of air through the venturimeter,

$$V_a = \left\{ C_d \times \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2g} \right\} \times \sqrt{h_a} = K \times \sqrt{h_a} = 0.02 \times \sqrt{h_a} = \ldots\ldots \quad m^3/s$$

7. Power output (Power available in the air delivered),

$$P_{OUT} = \frac{\rho_a \times gH_d \times V_a}{1000} = \ldots\ldots\ldots\ldots \text{ kW}$$

8. Power input to the blower, $P_{in} = \frac{WN}{C} = \frac{9.81 \times T \times N}{26675}$ = kW.
9. Overall efficiency of the blower, $\eta_o = \frac{P_{OUT}}{P_{IN}} \times 100$ =

Graphs :

i) Delivery pressure head Vs Discharge (For all the three types of impellers).
ii) Overall efficiency Vs Discharge (for all the three types of impellers).