

EXPERIMENT NO.1

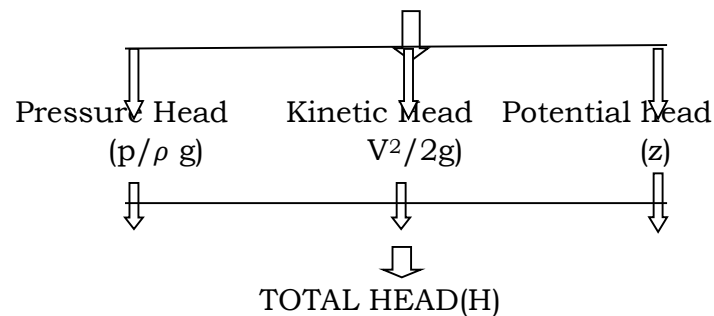
AIM OF THE EXPERIMENT: To verify Bernoulli's theorem.

APPARATUS REQUIRED:

Sl.No	Name of the Apparatus	Specification	Quantity
01	Bernoulli's Apparatus test rig		01
02	Stop watch	Digital type	01
03	Steel rule	L=30cm	01

THEORY:-

Steady State Condition



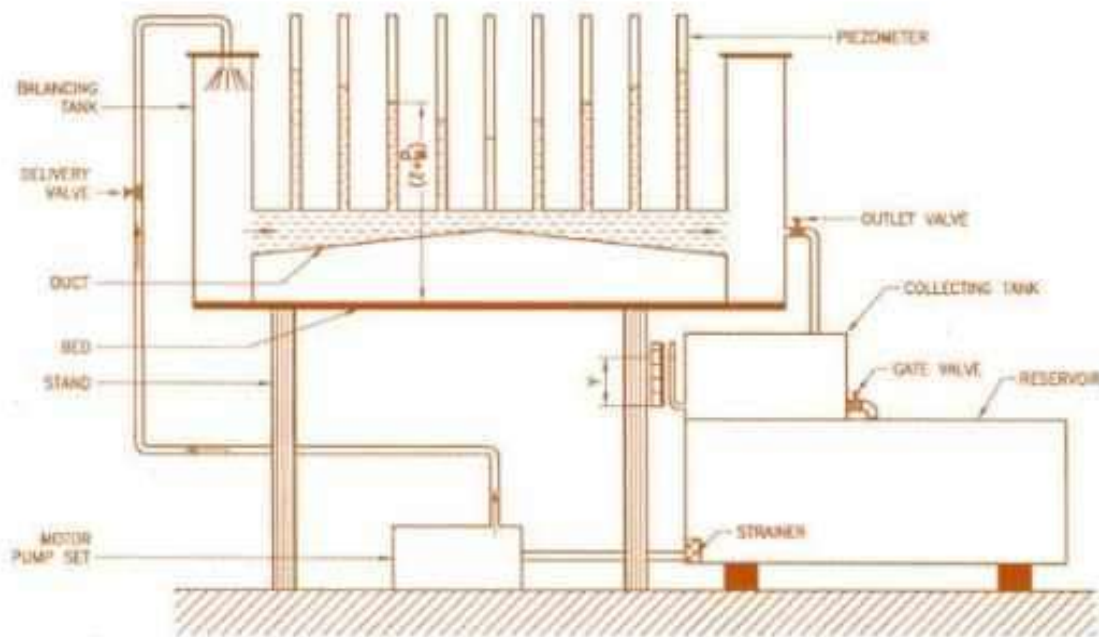
CONSTANT

$$\text{Total Head}(H) = P/\rho g + V^2/2g + Z = \text{constant}$$

Where, P/g = Pressure head, in meter

$V^2/2g$ = Velocity or kinetic head, in meter

Z = Potential head, in meter



PROCEDURE:-

- Measure the area of conduit at various gauge points.
- Open the supply valve and adjust the flow so that the water level in the inlet tank remains constant.
- Measure the height of water level (above the arbitrarily selected plane) in different piezometric tubes with the help of steel rule.
- Measure the discharge of the conduit with the help of measuring tank.
- Note the time duration by stopwatch from beginning of initial flow to end of the flow.
- Repeat the steps for two more readings.

TECHNICAL SPECIFICATION:-

- Length of the discharge tank(l)= 30cm
- Breadth of the discharge tank(b) = 30cm
- Area of the measuring tank (a) = l x b =30 * 30= 900 cm²

OBSERVATIONS:-

- Depth of water collected in discharge tank, h = 5 cm
- Volume of water collected in the tank, q = a x h = 4500 cm³
- Time of collection (t) =30 sec

CALCULATION TABLE:-

Tube no	Area of flow of tubes, A in (cm ²)	Discharge, Q = q/t in (cm ³ /s)	Velocity of flow V in cm/s V= Q/A	Velocity Head , $V^2/2g$ in cm	Pressure Head , $P/\rho g$ in cm	Datum Head Z, in cm	Total Head(H)= $P/\rho g + V^2/2g + Z$ (m) (v +vi + vii)	Remark
(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)	(viii)	(ix)
01	14	150	10.71	0.058	23	3.5	26.558	
02	12	150	12.5	0.079	22.5	3.0	25.579	
03	10	150	15	0.114	22	2.5	24.614	
04	8	150	18.75	0.179	21.5	2.0	23.679	
05	10	150	15	0.114	22	2.5	24.614	
06	12	150	12.5	0.079	22.5	3.0	25.579	
07	14	150	10.71	0.058	23	3.5	26.558	

CONCLUSION

Hence we have successfully verified Bernoulli's Theorem and we see that the total head in all the sections of the Bernoulli's apparatus test rig is constant. The slight variation (if any) is due to losses.

EXPERIMENT NO.2

AIM OF THE EXPERIMENT:-

To determine the co-efficient of discharge (C_d) from venturi meter.

APPARATUS REQUIRED:-

SL.NO	EQUIPMENT	SPECIFICATION	QUANTITY
01	Venturi meter test rig		01
02	Stopwatch	Digital	01
03	Steel Rule	L=30cm	01

THEORY:-

A venturi meter is an instrument used to measure the rate of discharge at different sections of the pipe line. A venturi meter consists of 3-parts:-

- Converging section
- Throat section
- Divergent Section

Co-efficient of discharge, $C_d = \frac{Q_{act}}{Q_{th}}$

Where, $Q_{act} = \frac{l \times b \times h}{t}$

l = length of discharge tank

b = breadth of discharge tank

h = height of of discharge tank

t = time taken in sec.

$$Q_{th} = \frac{A_1 \times A_2 \times \sqrt{2gH}}{(\sqrt{A_1^2 - A_2^2})}$$

Where, A_1 = inlet area of venturi meter

A_2 = Outlet area of venturi meter

EXPERIMENTAL PROCEDURE:-

- Set the manometric pressure tube to atmospheric pressure by opening the upper valve
- Now the supply of water may be controlled by the stop valve.
- One of the valves of any pipe may be opened and close all of other three valves/pipes.
- Note the discharge reading for the particular flow by measuring the height of the discharge tank.
- Note the time taken by stopwatch for the particular flow.
- Note the reading for the pressure head from the U-tube manometer, with its corresponding reading of discharge.
- Now take three readings for this pipe and calculate C_d for that instrument using formula given above.
- Now close this valve and open another valve having different diameter pipe and repeat this procedure as mentioned above. Three such readings also taken and calculate C_d .
- Similarly take readings for all other diameter pipe and calculate C_d in each case.

TECHNICAL SPECIFICATION:-

Length of discharge tank, $l=40\text{cm}=0.4\text{m}$,

Breadth of the discharge tank, $b=30\text{ cm}=0.3\text{m}$

Height of discharge tank, $h=100\text{cm} = 0.10\text{m}$,

Inlet dia of Venturimeter, $D_1=2.5\text{cm} = 0.025\text{ m}$

Inlet Area(A_1) $=\pi/4 \times (D_1)^2 = \pi/4 \times (0.02)^2 = 0.000490\text{ m}^2$

Outlet dia of venturimeter(throat dia), $D_2=1.25\text{cm} =0.0125\text{ m}$

Outlet Area(A_2) $=\pi/4 \times (D_2)^2 = \pi/4 \times (0.01)^2 = 0.000122\text{ m}^2$

Specific gravity of mercury(S_g) $= \frac{\rho_{Hg}}{\rho_{H_2O}} = \frac{13600}{1000} = 13.6$

Specific gravity of water(S_o) $= \frac{\rho_{H_2O}}{\rho_{H_2O}} = \frac{1000}{1000} = 1$

CALCULATION TABLE:-

SL NO.	MANOMETER READING (m)		$Q_{act} = \frac{l \times b \times h}{t}$ (m^3/sec)	$Q_{th} = \frac{A_1 \times A_2 \times \sqrt{2gH}}{(\sqrt{A_1^2 - A_2^2})}$ (m^3/sec)	$C_d = Q_{act}/Q_{th}$	Avg C_d
	Net head(H)= (m)	TIME FOR 10cm rise (Second)				
01	0.037	35	0.000342	0.000382	0.895	0.9348
02	0.050	27	0.000432	0.000444	0.9729	
03	0.072	24	0.000500	0.000534	0.9363	

CONCLUSION

From the above experiment we have calculated the co-efficient of discharge (C_d) of venturimeter to be 0.9348.

EXPERIMENT NO. 3

AIM OF THE EXPERIMENT:-

To determine the C_c , C_v , C_d from orifice meter.

APPARATUS REQUIRED:-

SL.NO	EQUIPMENT	SPECIFICATION	QUANTITY
01	Orifice meter test rig		01
02	Stopwatch	Digital	01
03	Steel Rule	L=30cm	01

THEORY:

An orifice plate is a device used for measuring the volumetric flow rate. It uses the same principle as a Venturi nozzle, namely Bernoulli's principle which states that there is a relationship between the pressure of the fluid and the velocity of the fluid. When the velocity increases, the pressure decreases and vice versa. An orifice plate is a thin plate with a hole in the middle. It is usually placed in a pipe in which fluid flows. When the fluid reaches the orifice plate, with the hole in the middle, the fluid is forced to converge to go through the small hole; the point of maximum convergence actually occurs shortly downstream of the physical orifice, at the so-called *vena contracta* point. As it does so, the velocity and the pressure changes. Beyond the *vena contracta*, the fluid expands and the velocity and pressure change once again. By measuring the difference in fluid pressure between the normal pipe section and at the *vena contracta*, the volumetric and mass flow rates can be obtained from Bernoulli's equation. Orifice plates are most commonly used for continuous measurement of fluid flow in pipes. This experiment is process of calibration of the given orifice meter.

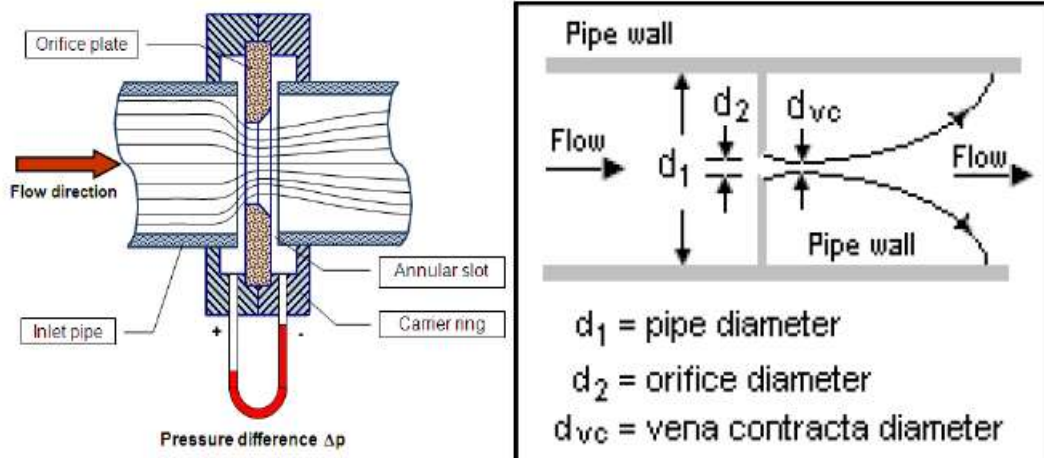


Fig.1. Orifice Plate

Procedure:

N.B.: Keep the delivery valve open while start and stop of the pump power supply.

1. Switch on the power supply to the pump.
2. Adjust the delivery flow control valve and note down manometer heads (h_1 , h_2) and time taken for collecting 10 cm rise of water in collecting tank (t). (i.e. Initially the delivery side flow control valve to be kept fully open and then gradually closing.)
3. Repeat it for different flow rates

4. Switch off the pump after completely opening the delivery valve.

Calculation:

The actual rate of flow, $Q_a = A \times h / t \text{ (m}^3/\text{sec)}$

Where A = Area of the collecting tank = length x breadth (m^2)

h = Height of water(10 cm) in collecting tank (m),

t = Time taken for 10 cm rise of water (sec)

The Theoretical discharge through orifice meter,

$$Q_t = (a_1 a_2 \sqrt{2g H}) / \sqrt{(a_1^2 - a_2^2)} \quad \text{m}^3/\text{sec}$$

Where, H = Differential head of manometer in m of water

$$= 12.6 \times h_m \times 10^{-2} \text{ (m)}$$

g = Acceleration due to gravity ($9.81\text{m}/\text{sec}^2$)

Inlet Area of orifice meter in m^2 , $a_1 = \pi d_1^2 / 4$,

Area of the throat or orifice in m^2 , $a_2 = \pi d_2^2 / 4$

The co-efficient of discharge,

$$C_d = \text{Actual discharge} / \text{Theoretical discharge} = Q_a / Q_t$$

Tabulation:

Inlet Dia. $D = 25 \text{ mm} = 0.025 \text{ m}$

Orifice Dia. $d = 12.5 \text{ mm} = 0.0125 \text{ m}$

Measuring area in collecting tank, $A = 0.4 \times 0.3 \text{ m}^2 = 0.12 \text{ m}^2$

Inlet area, $a_1 = 0.00049 \text{ m}^2$

Orifice area, $a_2 = 0.000122 \text{ m}^2$

SL No.	Manometer Reading (in m)	Time for 10cm rise t	Actual Discharge Q_a	Theoretical Discharge Q_t	Coefficient of Discharge C_d	Avg C_d
		second	m^3/sec	m^3/sec		
1	0.102	28.91	0.000415	0.000636	0.652	0.648
2	0.146	23.39	0.000502	0.000761	0.659	
3	0.210	20.72	0.000579	0.000912	0.634	

CONCLUSION

From the above experiment we have calculated the co-efficient of discharge (C_d) of orifice meter to be 0.648.

EXPERIMENT NO.4

AIM OF THE EXPERIMENT:

To determine the overall efficiency of a centrifugal pump by measuring the input power and output power.

APPARATUS REQUIRED:

- Centrifugal pump test rig
- Motor with energy meter
- Stopwatch
- Pressure gauges (delivery and suction)
- Measuring tank
- Flow control valve

THEORY:

A centrifugal pump converts mechanical energy from a motor into hydraulic energy of water.

Hydraulic Power Output

$$P_{out} = \rho g Q H$$

Where,

- Q = Discharge (m^3/s)
- H = Total head developed (m)
- ρ = Density of water (1000 kg/m^3)
- $g = 9.81 \text{ m/s}^2$

Input Power

Obtained from wattmeter or calculated as

$$P_{in} = V I \cos \phi$$

Overall Efficiency

$$\eta = \frac{P_{out}}{P_{in}} \times 100$$

PROCEDURE:

1. Check for proper priming of the centrifugal pump.
2. Start the pump and allow it to run until steady flow is established.
3. Fully open the delivery valve; then gradually close it to set required discharge.

4. Measure:

- a) Delivery head from pressure gauge
- b) Suction head (if provided)
- c) Time taken to collect water in the measuring tank
- d) Wattmeter/voltmeter-ammeter readings

5. Calculate discharge

$$Q = \frac{Volume}{Time}$$

6. Calculate total head

$$H = \left(\frac{P_d - P_s}{\rho g} \right) + (z_d - z_s)$$

7. Compute P_{out} , P_{in} , and efficiency.

8. Repeat for 4–5 different discharge values.

CALCULATION:

Discharge

Assume 40 litres collected in 20 sec:

$$Q = \frac{0.04}{20} = 0.002 \text{ m}^3/\text{s}$$

Total Head

Delivery pressure = 1.2 kg/cm²

Suction pressure = -0.2 kg/cm²

$$H = \frac{(1.2 - (-0.2)) \times 10^4}{1000 \times 9.81}$$

$$H = \frac{1.4 \times 10^4}{9810} = 1.43 \text{ m}$$

Output Power

$$P_{out} = 1000 \times 9.81 \times 0.002 \times 1.43 = 28.0 \text{ W}$$

Input Power

If wattmeter reading = 60 W:

$$P_{in} = 60 \text{ W}$$

Efficiency

$$\eta = \frac{28}{60} \times 100 = 46.6\%$$

PRECAUTIONS

- Ensure pump is properly primed before starting.
- Avoid running the pump without water.
- Keep suction line air-tight.
- Take all readings at steady state.
- Do not operate the pump against a closed valve for a long time.

CONCLUSION:

The overall efficiency of the centrifugal pump is found to be between 40% – 60% (typical range), depending on operating conditions.

EXPERIMENT NO. 5

AIM OF THE EXPERIMENT:

To calibrate the given pressure gauge using a dead-weight pressure tester and determine the error at different pressures.

APPARATUS:

1. Dead-weight pressure gauge tester
2. Test pressure gauge
3. Set of dead weights
4. Hydraulic oil

THEORY:

Dead-weight tester applies known pressure based on:

$$P = \frac{W}{A} = \frac{mg}{A}$$

where

- m = mass (kg)
- $g = 9.81 \text{ m/s}^2$
- $A = \frac{\pi D^2}{4}$ is piston area

This standard pressure is compared with the gauge reading to find the error.

- Piston diameter $D = 10 \text{ mm} = 0.01 \text{ m}$
- Area:

$$A = \frac{\pi D^2}{4} = \frac{\pi(0.01)^2}{4} = 7.85 \times 10^{-5} \text{ m}^2$$

CALCULATIONS:

Sample point: 1 bar

Pressure needed =

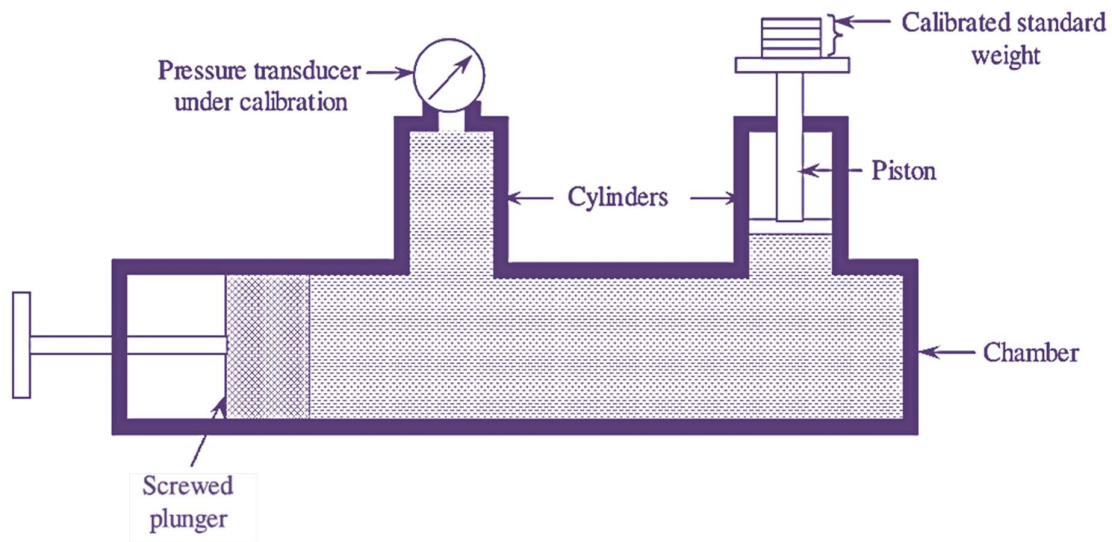
$$P = 1 \text{ bar} = 1 \times 10^5 \text{ Pa}$$

Required mass:

$$m = \frac{PA}{g} = \frac{(1 \times 10^5)(7.85 \times 10^{-5})}{9.81} = 0.80 \text{ kg}$$

Similarly:

Pressure (bar)	Mass (kg)
1	0.80
2	1.60
3	2.40
4	3.20
5	4.00



TABULATIONS:

Sl. No.	Applied Pressure (bar)	Gauge Reading (bar)	Error $P_g - P$ (bar)
1	1	1.02	+0.02
2	2	2.03	+0.03
3	3	3.05	+0.05
4	4	4.05	+0.05
5	5	5.08	+0.08

PRECAUTIONS:

- Remove air from system (bleeding).
- Rotate piston for free floating.
- Place weights gently.
- Take ascending and descending readings.

CONCLUSION:

The pressure gauge was calibrated using a dead-weight tester.

Maximum error observed = +0.08 bar.

Gauge shows a slight positive deviation.

EXPERIMENT NO. 6

AIM :

TO determine operating characteristics of Francis Turbine.

INTRODECTION

The Hydraulic turbine are classified according to the type of energy available at the inlet of the turbine, direction of flow through the vanes. The Hydraulic turbines mainly of two types:

1. Impulse Turbine
2. Reaction Turbine

Francis Turbine is axial flow reaction turbine. If the water flows parallel to the axis of the rotation of the shaft the turbine is known as axial flow turbine. And of the head at the inlet of the turbine is the sum of pressure energy and kinetic energy and during the flow of water through runner at part of pressure energy is converted into kinetic energy, the turbine is known as reaction turbine.

The main parts of a Francis Turbine are:

1. Scroll casing
2. Guide vanes mechanism
3. Hub with vanes or runner of the turbine

EXPEREMENTAL SET-UP

This apparatus i.e. Francis Turbine is designed for laboratory experiments and study purpose and to conduct tests in metric units for the following specifications:

Net head	:	20meters
Discharge	:	200 LPM
Normal speed	:	1250 RPM
Motor & Pump	:	5 HP Monoblock Pump
Turbine Impeller	:	Cast Iron

The turbine consists of a spring casing a rooster assembly, shaft and brake drum all mounted on a sturdy support pedestal. A straight conical draught tube is provided vertically after the runner. Rope brake arrangement with suitable pulleys is provided for loading the turbine. The input into the turbine controlled by a set of guide vanes. The net supply head is measured by means of a differential pressure gauge. For the measurement of speed RPM meter is to be used.

SPECIFICATIONS :

Motor	:	AC 5.0 HP
No. of guide vanes	:	08
Brake drum diameter	:	200 mm
Rope Diameter	:	20 mm
Diameter of pipe	:	80 mm = 0.080 meter
Orifice Diameter	:	55 mm = 0.055 meter
Gauge	:	a. Pressure gauge P_1 b. Pressure gauge P_2

Double column differential type Pressure Gauge is fitted across the limbs of orifice.

Water cooling arrangement is used to cool the load drum.

STANDARD DATA

g	=	Acceleration due to gravity	=	9.81 m/sec ²
ρ_w	=	Density of water	=	1000 kg/m ³
D	=	Diameter meter of brake drum	=	200 mm = 0.2 meter
C_d	=	0.64		

Diameter of orifice $d = 55 \text{ mm} = 0.055 \text{ m}$

FORMULA USED

1. TOTAL HEAD (H)

$$H = 10 \times \text{Pressure Gauge reading} = \text{meter}$$

2. WATER HEAD RATE DISCHARGE (Q)

$$Q = C_d \times \frac{(a_1 \times a_2)}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2 \times g \times (P_1 - P_2)} \text{ m}^3/\text{sec}$$

Where,

Inlet area of orificemeter at (diameter $d_1 = 0.080\text{m}$)

$$a_1 = \pi/4 \times d_1^2$$

$$a_1 = 0.005024 \text{ m}^2$$

Throat area of orificemeter at (diameter $d_2 = 0.055\text{m}$)

$$a_2 = \pi/4 \times d_2^2$$

$$a_2 = 0.002374 \text{ m}^2$$

$$g = 9.81$$

$$C_d = 0.64 \text{ (assume)}$$

$$3. \quad \text{H.P Hydraulic (Input)} = \frac{\rho_w Q H}{75} \quad \text{H.P.}$$

ρ_w = Specification weight of water = 1000 kg/ m³

$$4 \quad \text{B.H.P. (Output)} = \frac{2 \pi N T}{45000} \quad \text{H.P.}$$

$$T = (W_1 - W_2) \times D/2 \times 9.81$$

$$\text{B.H.P.} = \frac{(W_1 - W_2) \times D/2 \times 9.81 \times 2 \pi N}{45000} \quad \text{H.P.}$$

Where,

Rope with Hanger weight = 1.2 Kg

w_1 = Weight + Hanger with Rope Reading

w_2 = spring balance

D = Brake drum diameter + Rope Diameter: 200 mm + 20 mm = 0.220 meter

N = Number of R.P.M. of brake drum

5. Efficiency of Turbine (η)

$$\eta = \frac{\text{B.H.P (Output)}}{\text{H.P Hydraulic (Input)}} \times 100 \%$$

TABULATION:

SL No.	RPM (N)	Pressure Difference			Q' (Discharge)	ROPE BRAKE			BP input (HP)	BP output (HP)	$\eta_{\text{Turbine}} \left(\frac{\text{O/P}}{\text{I/P}} \times 100 \right)$
		P_1	P_2	$P = P_1 - P_2$		$w_1 = \text{Weight of hanger with rope}$	$w_2 = \text{Spring balance reading}$	$w_1 - w_2 \text{ (in kg)}$			
1	1016	1.5 $\frac{\text{kg}}{\text{cm}^2}$	0.9 $\frac{\text{kg}}{\text{cm}^2}$	1.5-0.9 = 0.6 $\frac{\text{kg}}{\text{cm}^2}$	0.005 $\frac{\text{m}^3}{\text{sec.}}$	42 kg	0.25 kg	42-0.25 = 3.95 kg	0.988 HP	0.605	61.32%

PROCEDURE:

1. Unload the Turbine if there is any load on it.
2. Fill the sump tank with sufficient amount of water.
3. Switch on the water supply to start the centrifugal pump.
4. Now open the delivery valve slowly and adjust the required head at the inlet of turbine. Simultaneously manipulate by-pass valve so as to adjust the required head.
5. Now open the supply of the water top cool load drum.
6. Now adjust the load on load drum and note the corresponding reading on fixed spring balance also measure the R.P.M increase the load slowly and note the corresponding value of spring balance .
7. Repeat the above procedure for different inlet pressures.

CONCLUSION:

Hence, we have successfully found the value of efficiency of Francis turbine.

EXPERIMENT NO. 7

AIM OF THE EXPERIMENT

To determine the coefficient of friction (Darcy friction factor f) for flow through a pipe using measured flow and pipe data, and to compute the head loss due to friction.

APPARATUS

- Pipe test section (length L , diameter D)
- Volumetric flow measurement device / flowmeter or collecting tank & stopwatch
- Pressure taps / manometer (optional)
- Stopwatch, measuring tape, thermometer
- Fluid: water (assumed at 20 °C for worked example)

THEORY

Darcy–Weisbach equation for head loss due to friction:

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

Reynolds number:

$$\text{Re} = \frac{\rho V D}{\mu}$$

For laminar flow ($\text{Re} < 2000$): $f = \frac{64}{\text{Re}}$.

For turbulent flow, one can use Colebrook (implicit) or an explicit approximation like Swamee–Jain:

$$f = 0.25 \left[\log_{10} \left(\frac{\varepsilon}{3.7D} + \frac{5.74}{\text{Re}^{0.9}} \right) \right]^{-2}$$

where ε = absolute roughness of the pipe.

CALCULATIONS:

Pipe internal diameter $D = 50 \text{ mm} = 0.050 \text{ m}$

Pipe length between measurement points $L = 10.0 \text{ m}$

Measured volumetric flow $Q = 0.0020 \text{ m}^3/\text{s}$

Fluid = water at 20 °C: $\rho = 998 \text{ kg/m}^3$, $\mu = 1.002 \times 10^{-3} \text{ Pa}\cdot\text{s}$

Pipe absolute roughness (steel, example): $\varepsilon = 4.5 \times 10^{-5} \text{ m}$

$g = 9.80665 \text{ m/s}^2$

STEP BY STEP CALCULATIONS

Step 1 — Cross-sectional area A

$$A = \frac{\pi D^2}{4} = \frac{\pi (0.050)^2}{4} = \pi \times 0.000625 = 0.0019634954 \text{ m}^2$$

(use $A = 1.9635 \times 10^{-3} \text{ m}^2$)

Step 2 — Mean velocity V

$$V = \frac{Q}{A} = \frac{0.0020}{0.0019634954} = 1.018591636 \text{ m/s}$$

(round to $V = 1.0186 \text{ m/s}$)

Step 3 — Reynolds number Re

$$Re = \frac{\rho V D}{\mu} = \frac{998 \times 1.018591636 \times 0.050}{1.002 \times 10^{-3}}$$

Compute numerator: $998 \times 1.018591636 \times 0.050 = 50.726270086$ (N.B. units $\text{kg}\cdot\text{m}/\text{s}^2$ cancel appropriately)

Then

$$Re = \frac{50.726270086}{1.002 \times 10^{-3}} = 50\,726.2701$$

Step 4 — Head loss due to friction h_f

$$h_f = f \frac{L}{D} \frac{V^2}{2g} = 0.02384 \times \frac{10.0}{0.050} \times \frac{(1.0186)^2}{2 \times 9.80665}$$

Compute intermediate terms:

- $\frac{L}{D} = \frac{10}{0.05} = 200$
- $V^2 = 1.0186^2 = 1.0375$ (approx)
- $\frac{V^2}{2g} = \frac{1.0375}{19.6133} = 0.05291 \text{ m}$

Now

$$h_f = 0.02384 \times 200 \times 0.05291 = 0.02384 \times 10.582 = 0.2522 \text{ m}$$

Result: head loss due to friction $h_f \approx 0.252 \text{ m}$.

PROCEDURE:

1. Measure pipe internal diameter D and distance between taps L .
2. Measure volumetric flow Q (or measure velocity directly). Record temperature.
3. Compute A , V , Re . Decide laminar/turbulent.
4. For turbulent flow, use an appropriate formula (Colebrook/Swamee-Jain) with pipe roughness ϵ to get f ; for laminar use $f = 64/Re$.
5. Compute h_f from Darcy-Weisbach and compare with measured head difference (from manometer/pressure taps) to find experimental f if desired:

$$f_{\text{exp}} = \frac{2g h_f}{(L/D) V^2}$$

6. Repeat for different Q to get f vs Re .

CONCLUSION

- Mean velocity
- Reynolds number $Re \approx 5.07 \times 10^4$ (turbulent)
- Friction head loss $h_f \approx 0.252$ meter $L = 10$ m