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FRANCIS TURBINE EXPERIMENT

OBJECTIVE:

To determine the performance characteristics of a small scale francis turbine.

SCOPE:

Francis turbine is a type of reaction turbine that ~~only~~ converts only some part of available total head of fluid into kinetic energy so that the fluid entering the runner has pressure energy too. They operate in a water head from 40 to 600m (medium be heads) and are primarily used for electrical power production. Study of its characteristics enables one to decide its speed or head at which it will have to run for maximum efficiency during operation.

APPARATUS:

a) Francis turbine set

b) Tachometer.

THEORY:

It consists of fixed guide vanes called stay vanes, adjustable guide vanes called wicket gates, rotating blades called runner blades. Flow enters tangentially at high pressure, is turned towards the runner by the stay vanes as it moves along the spiral casing or volute and then passes through the wicket gates with a large tangential velocity component. Momentum is exchanged between the fluid and the runner as the runner rotates and there is a large pressure drop.

Unlike impulse turbine, the water completely fills the casing of a reaction turbine. For this reason, a reaction turbine generally produces more power than an impulse turbine of the same diameter, net head and volume rate flow.

Francis turbine usually drives an alternator and hence, its speed must be constant. Since the total head available is constant and dissipation of energy by throttling is undesirable, the regulation at part load is achieved by varying the guide vane angle. This is possible because there is no requirement for the speed ratio to remain constant.

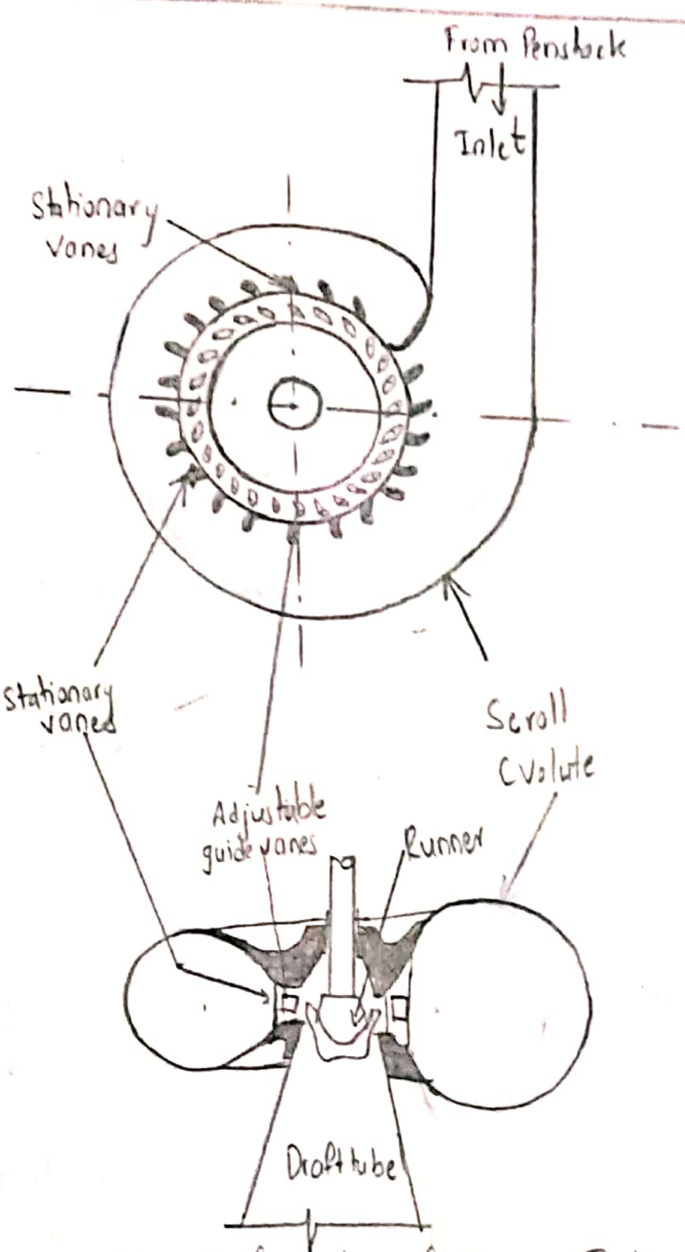

Fig: Configuration of Francis Turbine

a) Hydraulic Power Input $= \gamma Q H$

where, γ (ρg) = Specific weight in N/m^3

Q = Discharge in m^3/s

H = Effective head in meter

$= (P_1 - P_0)$

where P_1 = Inlet Pressure

P_0 = Draft Tube Pressure

b) Mechanical Power Output = $\frac{2\pi NT}{60}$

where, N = Speed in rpm

T = Torque in Nm.

c) Efficiency = $\frac{Output}{Input} \times 100\%$

EXPERIMENTAL PROCEDURE:

i) The closing of the guide vanes was checked, the pump delivery valve was closed and the pump was started allowing it to run for few minutes.

ii) The pony brake arrangement was set to minimum resistance.

iii) The guide vane was set to full open condition. At this stage, following readings were recorded: a) Manometer reading on orifice
b) Vee Notch reading
c) Brake load
d) Inlet Pressure and
e) Draft tube pressure

iv) The pump delivery valve was gradually opened to get an inlet pressure of about 18m of water and the turbine was allowed to run for few minutes at full speed.

v) Following readings were recorded: a) Manometer reading on orifice
b) Vee Notch Reading
c) Brake load
d) Inlet Pressure
e) Draft Tube Pressure
f) Speed.

Cooling water was applied to the brake drum at regular intervals and oil was applied through oil drop device on the wheel.

vi) The procedures were repeated for ~~two~~ one setting of adjustable guide vane (2/3 open ~~and 1/3 open~~).

Number of observations	Guide Vane Setting	Torque Gange in N.	Inlet Pressure m of water	Draft tube pressure m of water	Orifice reading mm of water	Vee Note of wat…
1						
2						
3	Full open					
4						
5						
6						
1						
2						
3	2/3 Open	26	18	0.2	28	125
4		34	26	0.9	24	120
5		49	31	1	36	123
6		50	33.9	1.1	[illegible]	125
1		59	36.5	1.2	48	127
2		65	38	1.4	[illegible]	136
3	1/3 Open					
4						
5						
6						

25, 26, 27, 28, 29, 30

CALCULATION :

a) Orifice discharge Q_a.

b) Vee notch discharge Q_a.

c) Mean discharge as average of (a) and (b).

d) Efficiency for each reading.

d) Effective head

e) Hydraulic power input

f) Mechanical power input

g) Effective

h) Show the figure the apparatus and simple …

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OBSERVATIONS:

~~Total a~~ Torque area radius = 0.248m.

No. of Obs.	Guide Vane Setting	Torque Gangue (in N.)	Inlet Pressure (m of water)	Draft Tube Pressure (m of water)	Orifice reading (mm of water)	Vee Notch (mm of water)	Speed (in rpm)
1	2/3 Open	26	18	0.2	2.8	125	2134
2	2/3 Open	34	26	0.9	3.4	120	2845
3	2/3 Open	44	31	1	3.6	123	3188
4	2/3 Open	50	33.9	1.1	3.9	125	3349
5	2/3 Open	59	36.5	1.2	4.8	127	3513
6	2/3 Open	65	38	1.4	5.3	130	3559

Calculation

Sample Calculation:-

(a) Orifice Discharge $(Q_{a_1}) = C_d \sqrt{2gh}\, A$

$= 0.98 \sqrt{2 \times 9.81 \times 2.8 \times 10^{-3}} \times \pi\, 0.06^2/4$

$= 6.4945 \times 10^{-4}\, m^3/s.$

(b) Vee-notch discharge $(Q_{a_2}) = \frac{8}{15} C_d \sqrt{2g} \tan(\theta/2) \times H^{5/2}$

$= \frac{8}{15} \times 0.98 \times \sqrt{2 \times 9.81} \times \tan\left(\frac{45}{2}\right) \times (125 \times 10^{-3})^{5/2}$

$= 5.2975 \times 10^{-3}\, m^3/s.$

(c) Mean $(Q_a) = \frac{Q_{a_1} + Q_{a_2}}{2} = 2.974 \times 10^{-3}\, m^3/s.$

P_1 (Inlet pressure) = 18m

P_2 (Draft tube pressure) = 0.2m.

(d) Effective Head $(H) = P_1 - P_2 = 17.8m.$

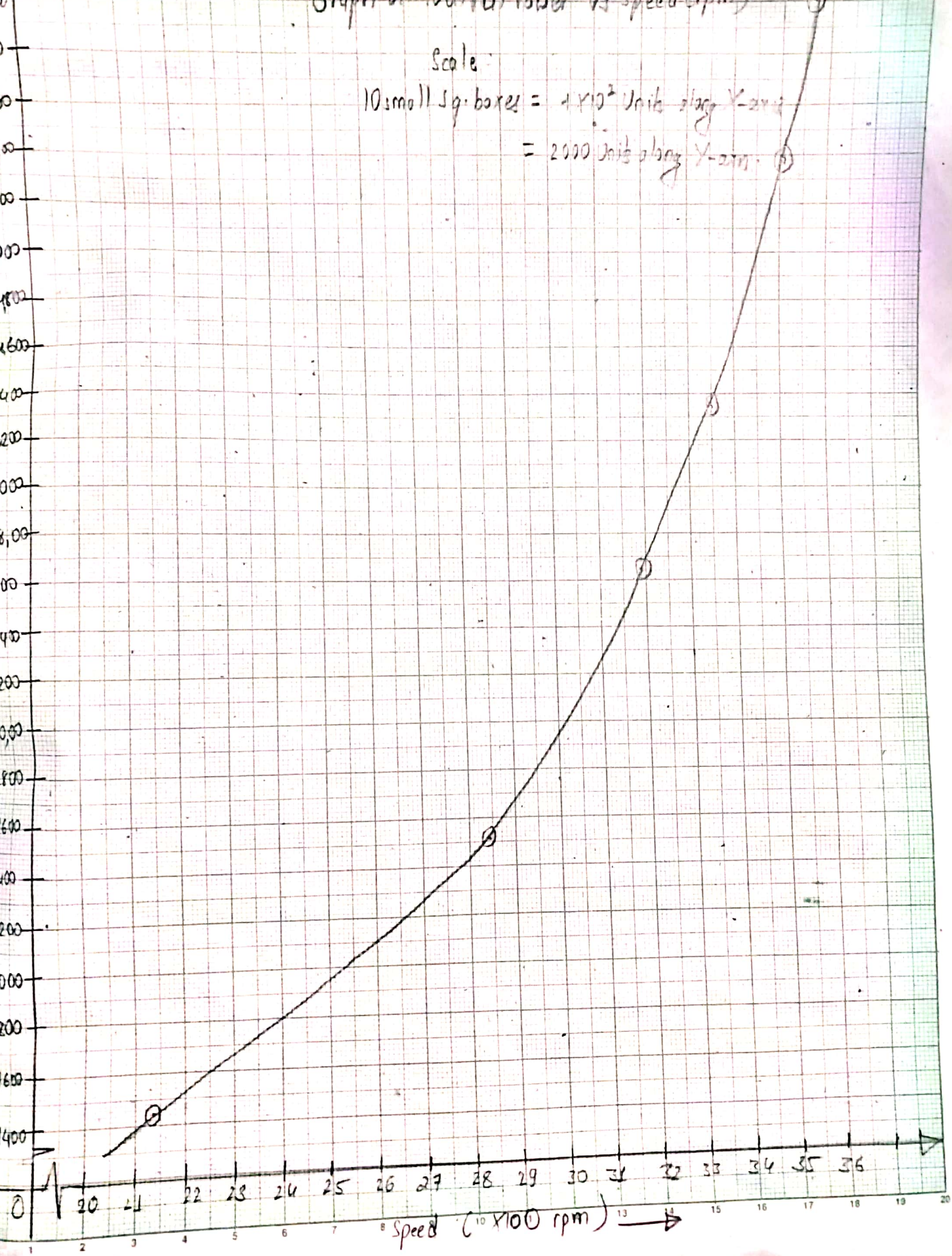
(e) Hydraulic power input $= \gamma Q H = 9810 \times (2.974 \times 10^{-3}) \times (17.8) = 519.314 W.$

f) Torque $(T) = F \times r$ = gauge reading × torque area radius

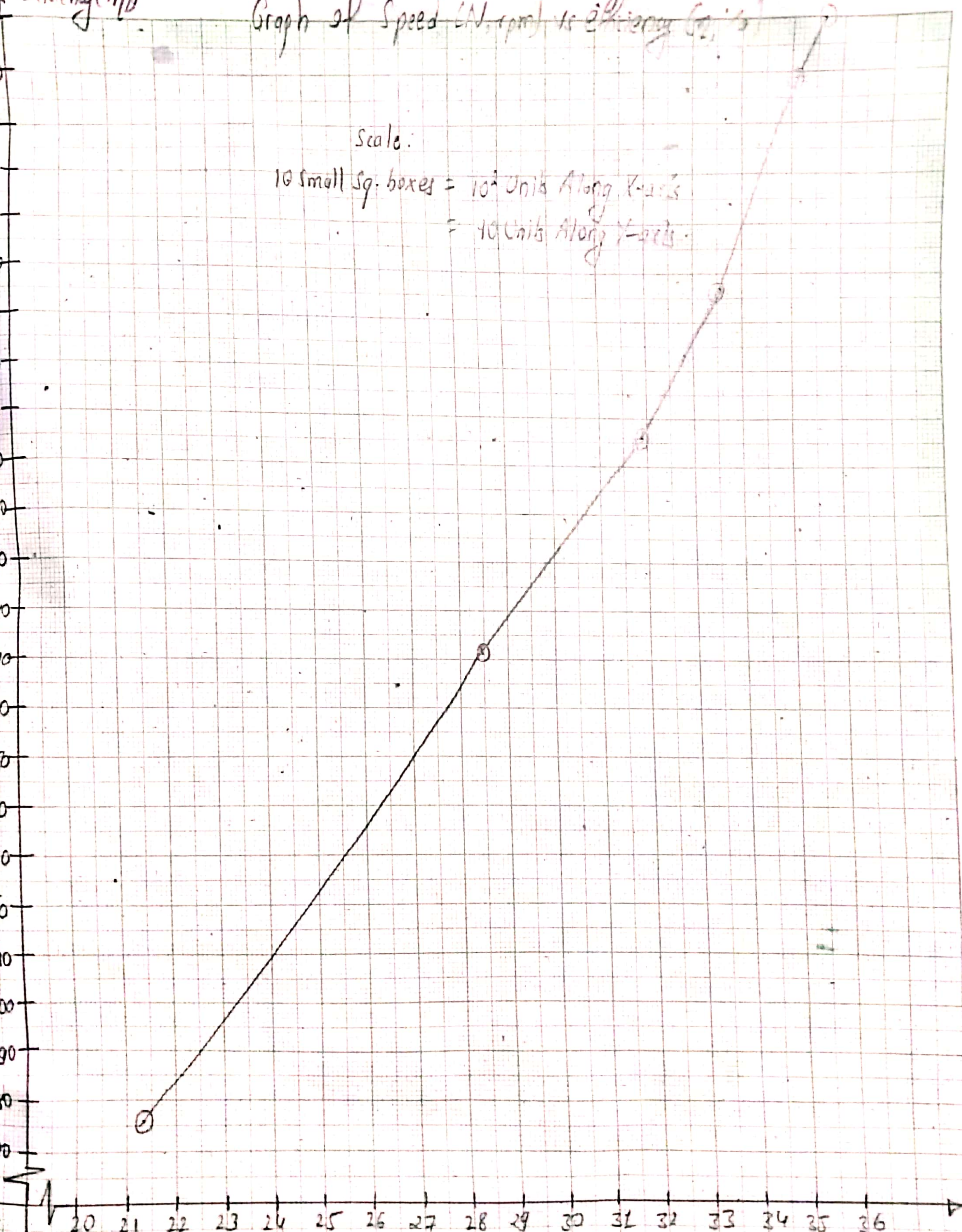
$= 26 \times 0.248 = 6.448\ N/m$

(g) Mechanical power output $= \frac{2\pi NT}{60} = \frac{2 \times \pi \times 2134 \times 6.448}{60} = 1440.95 W.$

(h) Efficiency $(\eta) = \frac{\text{Power output}}{\text{Power input}} = \frac{1440.95}{519.314} = 277.47\%$ (very very large)



Scale
10 small sq. boxes = 1 x 10² Units along Y-axis
= 2000 Units along Y-axis
Speed (x100 rpm)


Graph of Speed (N, rpm) vs efficiency
Scale:
10 Small Sq. boxes = 10 Units Along X-axis
= 10 Units Along Y-axis
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36

No. of Obs.	Guide-Vane Setting	Orifice discharge (Q_{a1}) m^3/s	V-notch discharge (Q_{a2}) m^3/s	Mean Discharge (Q_a, m^3/s)	Head $= P_1 - P_2$ (m)	Power input (W)	Speed (rpm)	Torque = load × radius (N/m)	Power output (KW)	Efficiency (η) (%)
1.		6.49×10^{-4}	5.298×10^{-3}	2.974×10^{-3}	17.8	519.314	2134	6.448	1440.95	276.92
2.		7.156×10^{-4}	4.78×10^{-3}	2.748×10^{-3}	25.1	676.64	2845	8.432	2512.13	371.27
3.	$2/3^{rd}$ Open	7.364×10^{-4}	5.08×10^{-3}	2.908×10^{-3}	30	855.82	3188	10.912	3642.93	425.66
4.		7.665×10^{-5}	5.298×10^{-3}	3.03×10^{-3}	32.8	974.96	3349	12.4	4348.76	446.05
5.		8.5×10^{-4}	5.512×10^{-3}	3.181×10^{-3}	35.3	1101.56	3513	14.63	5382.83	488.66
6.		8.935×10^{-4}	5.84×10^{-3}	3.367×10^{-3}	36.6	1208.91	3559	16.12	6007.89	496.9

COMMENTS:

The characteristic curve ~~of~~ For constant head curves are obtained by maintaining a constant head and gate opening on the turbine. The speed of turbine is varied by changing load on the turbine. For each value of speed, corresponding values of power and discharge are obtained. The curve of Francis turbine is a falling curve, which is due to the fact that the centrifugal heads develop which act outward and opposes the external head causing flow, eventually ~~declaring~~ decreasing the discharge as speed Increases.

Francis turbine can be very suitable for Nepal because:

1. In Francis turbine, the variation in operating head can be easily controlled.
2. The ratio of max^m to min^m operation can be made upto ~~to~~ 2 in Francis turbine.
3. The operating head can be utilized even when the variation in tailwater level is relatively large when compared to total head.
4. Mechanical efficiency decreases slower with wear.
5. The size of runner, power house req^d is small and economical.
6. It is suitable for low to medium head and as most of the hydropower plants in Nepal are RoR and PROR it can be proven efficient.

PELTON WHEEL TURBINE

OBJECTIVES:

To determine the performance characteristics of a model Pelton Wheel.

SCOPE:

Pelton turbine is an impulse turbine and is used for generating electricity at high head hydropower projects. To operate turbine at maximum efficiency, the head or speed is kept constant. The study of performance characteristics enable one to understand the operating condition for which maximum efficiency is obtained.

APPARATUS:

Pelton wheel model with supply system.

THEORY:

The Pelton wheel extracts energy from the impulse of moving water as opposed to water's dead weight like the traditional overshoot water wheel.

The basic working formulae are:

a) Hydraulic power input $= \gamma Q H$

where, γ = specific wt. in N/m^3

Q = Discharge in m^3/s

H = Head in m.

b) Mechanical Power Output $= 2\pi NT/60$

where, N = Speed in rpm

T = Torque in Nm

c) Efficiency $= \dfrac{\text{Output}}{\text{Input}} \times 100\%$

d) Specific Speed: $N_{ST} = \dfrac{NP^{1/2}}{H^{5/4}}$

Sketch of Apparatus With Description.

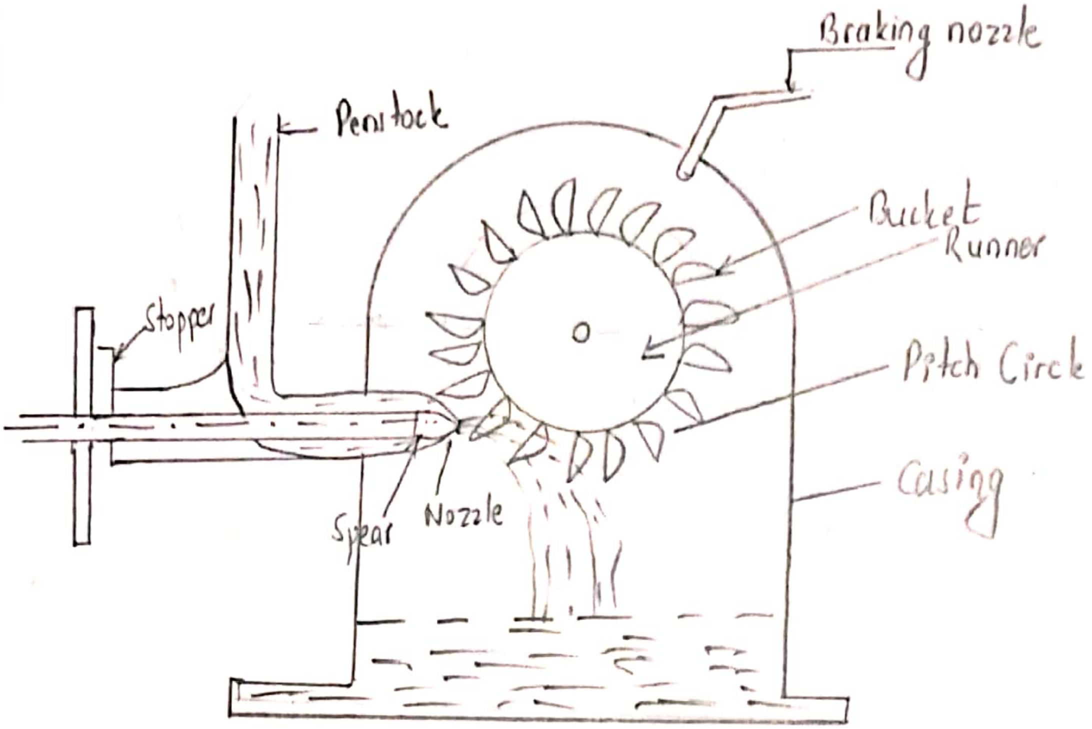


Fig: Schematic Diagram of Pelton Turbine

Components of Pelton Turbine:

i) **Runner with bucket:** Runner /impeller of Pelton turbine consists of a circular disc on the periphery of which no. of buckets are fixed.

ii) **Nozzle:** The water coming from the reservoir through penstock is accelerated to a certain velocity by means of a nozzle.

iii) **Spear:** The spear is a conical needle valve operated in an axial direction depending upon the size of the unit. It controls the amount of water striking the bucket of runner.

iv) **Casing:** Casing is used to prevent splashing of water & to discharge water to tail race. It is made up of cast iron or steel plate.

v) **Breaking jet:** When the nozzle is completely closed by moving the spear in forward direction, the amount of water striking the runner is zero. However, the runner due to inertia goes on revolving for a long time. To stop the runner in a short

V notch, $45°$

Inlet Pressure = 20 meter head

Lever Area = 25cm or 0.25m

Number of observations	Veo Notch reading mm	Speed rpm.	Brake Load N
1	68	1163	22
2	56	1174	34
3	~~70~~ 92	1293	56
4	~~89~~ 107	1291	67
5	115	1272	71
6	111	1296	80
7			
8			
9			
10			

CALCULATION :

25, 26, 27, 28, 29, 30

a) Actual discharge Q_a.

b) Hydraulic power input.

c) Mechanical power input.

d) Efficiency for each reading.

e) Show the sketch or figure of the apparatus and simple description

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PRESENTATION :

a) Show a sample calculation

b) Present the result in a tabular form.

Number of observation	Discharge Q m^3/s	Hydraulic power input		Mechanical Power output				Efficiency %
		Head m of water	Power QH watt	Speed N	Load	Torque T Nm	Power	
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

c) Plot output power versus speed and efficiency of the turbine versus speed.

COMMENTS: Comment on the characteristics, maximum operation efficiency and suitability of Pelton wheel in hydro power projects in Nepal.

time, a small nozzle is used which directs the jet of water on the back of the buckets. This jet of water is called breaking jet.

vi) Governor: The speed of turbine runner is required to be maintained constant so that electric generator can be coupled directly to turbine. Therefore, a device called governor is used to measure and regulate the speed of turbine runner.

OBSERVATIONS:

Inlet Pressure = 20m head

Lever Area = 25cm or 0.25cm

For V-notch $\frac{\theta}{2} = 45°$.

No. of Obs.	Vee Notch Reading mm	Speed rpm	Brake Load, N
1	68	1163	22
2	56	1174	34
3	92	1243	56
4	107	1291	67
5	115	1272	71
6	111	1296	80

SAMPLE CALCULATION:

We have, triangular notch in the laboratory having $\theta = 90°$. $\frac{\theta}{2} = 45°$

$\tan\frac{\theta}{2} = 1$, which is used in calculation.

Discharge through notch is given as:

$$Q_{notch} = \frac{8}{15} C_d \sqrt{2g} \tan\frac{\theta}{2} H^{5/2}$$

For right angled notch, if $C_d = 0.6$,

$\therefore$ Qnotch $= \frac{8}{15} \times 0.6 \times \sqrt{2 \times 9.81} \times \tan 45° \times H^{5/2}$

$= 1.417 H^{5/2}$ (R.K. Rajput Page 512)

For Vnotch: 68mm = 0.068m,

Qnotch $= 1.417 \times 0.068^{5/2}$

$= 1.708 \times 10^{-3} m^3/s$.

Head of water (H) at inlet = 20m

Specific weight of water (γ) = 9810 N/m³

$\therefore$ Power input (P_i) = $\gamma Q H$

$= 9810 \times 1.708 \times 10^{-3} \times 20$

$= 335.23$ Watt

Speed of turbine in rpm (N) = 1163

load to break (L) = 22 N

load arm (r) = 0.25m

Torque (T) = 22 × 0.25 = 5.5Nm.

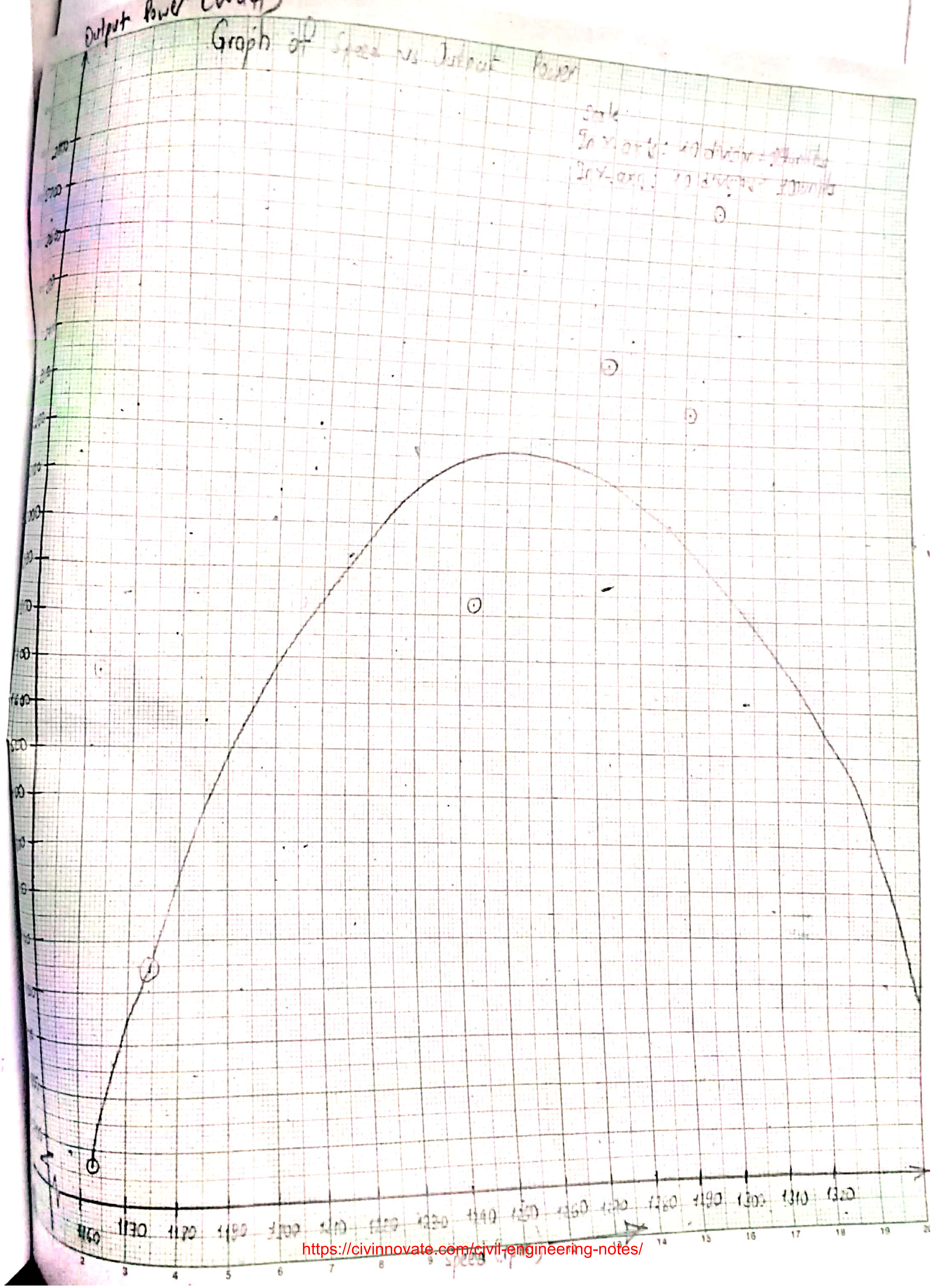
Power Output (P_o) = $\frac{2\pi NT}{60}$

$= \frac{2\pi \times 1163 \times 5.5}{60}$

$= 669.84$ Watt

Efficiency $= \frac{P_o}{P_i} = 199.82\%$

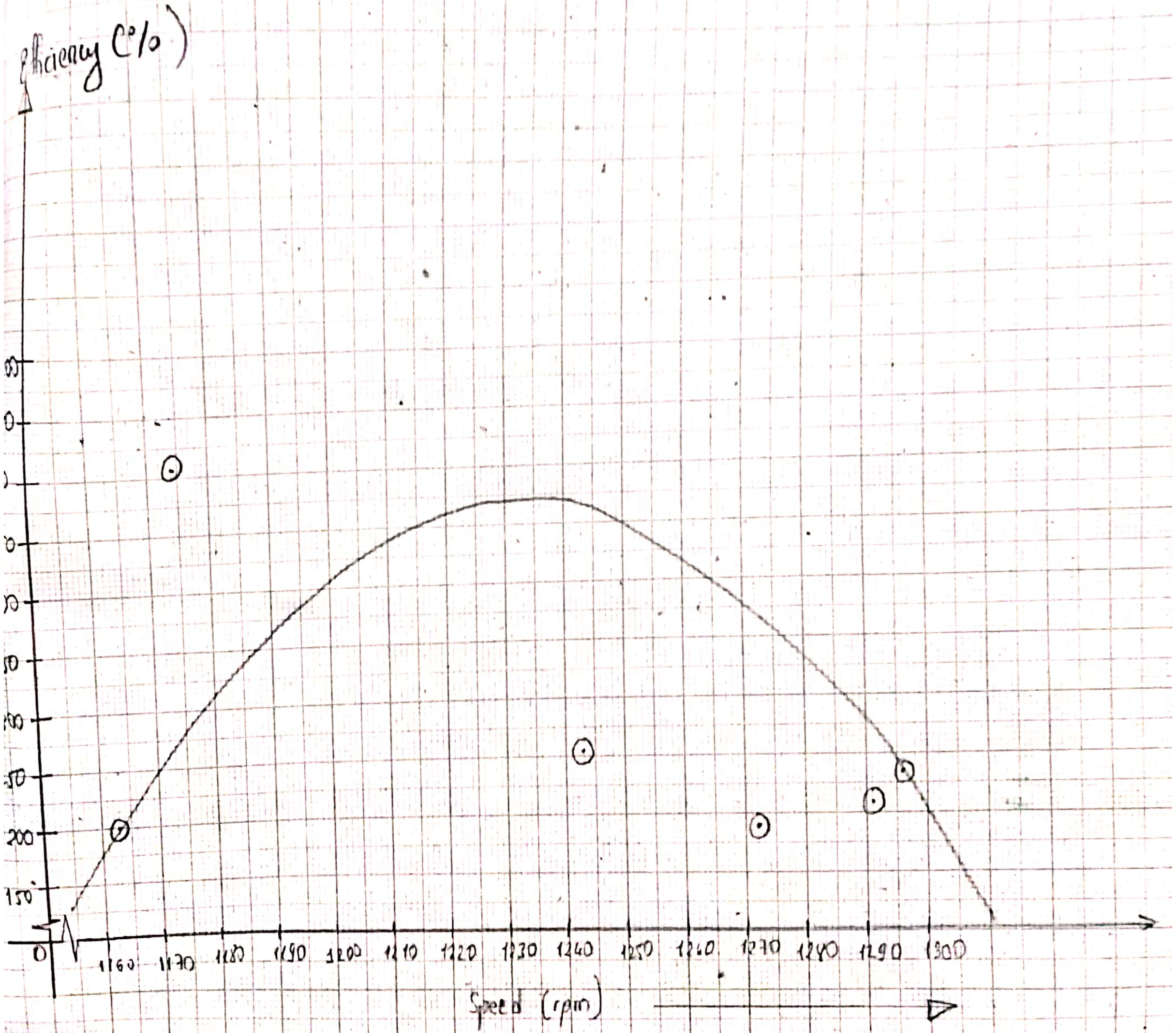
$\frac{1}{\text{Efficiency}} = 50.05$


Output Power (watt)
Graph of Speed vs Output Power
Scale
Speed
1160
1170
1180
1190
1200
1210
1220
1230
1240
1250
1260
1270
1280
1290
1300
1310
1320

Graph of Efficiency of turbine vs Speed

Along X-axis, 10 small sq. boxes = 10 Units

Along Y-axis, 10 divisions = 50 Unit



No. of Obs	Discharge Q (m^3/s)	Hydraulic Power Input		Mechanical Power Output				Efficiency %
		Head (m) of H_2O	Power QH Watt	Speed (rpm)	Load (N)	Torque T (Nm)	Power	
1.	1.708×10^{-3}	20	335.23	1163	22	5.5	669.86	199.82
2.	1.051×10^{-3}	20	206.32	1174	34	8.5	1044.99	506.49
3.	3.638×10^{-3}	20	713.74	1243	56	14	1822.31	255.32
4.	5.307×10^{-3}	20	1041.19	1291	67	16.75	2264.49	217.49
5.	6.355×10^{-3}	20	1246.85	1272	71	17.75	2364.36	189.63
6.	5.817×10^{-3}	20	1141.26	1296	80	20	2714.34	237.84

COMMENTS:

From the experiment, the efficiency of pelton wheel at different speeds along with their power input and output were determined. The efficiencies at most of the observation conditions were found greater than 100% which may be due to instrumental and observation error. The graph between p. between power vs speed and efficiency vs speed were also plotted and the data were used to plot graph of parabolic nature showing gradual increase and then decrease in efficiency as well as ~~spee~~ power output with variation in speed. Thus, the speed for most efficient power generation could be determined using graphs plotted.

Also it was clear that Pelton wheel turbine is suitable for high head and low discharge conditions of operation.

CENTRIFUGAL PUMP EXPERIMENT

OBJECTIVES:

To determine the operating characteristics of a centrifugal pump.

SCOPE:

Centrifugal pumps are extensively used in industries, water supply, irrigation system and for lifting water in residential building. The operating characteristics of the pump should be understood which includes determining efficiency, capacity etc.

APPARATUS:

a) Pump testing Unit

THEORY

Centrifugal pumps range in size from small units, such as circulating pumps used in domestic central heating systems, to large pumps, such as are used to raise great amount of water in hydropower pumped storage scheme. The centrifugal pump is a rotodynamic machine which imparts momentum to a fluid, which then causes the fluid to move into the delivery chamber or outlet. It converts energy supplied from a motor or turbine, first into kinetic energy and then into potential energy. Some basic formulae used are:

a) Mechanical power input = $\frac{2\pi NT}{60}$ Watt

where, N = Revolutions per minute

T = Torque = F × torque arm radius (Nm)

F = load in N.

b) Hydraulic Power output = ρQH Watts

H = Total Head (in m) (Suction + delivery) ×10.3

Discharge through venturimeter is given by:

$Q = 0.0938\ \sqrt{H}$ litres/sec (Changed into m^3/s)

H = Head of mercury in mm.

c) Efficiency = $\frac{\text{Output P}}{\text{Input P}} \times 100\%$

Sketch of Centrifugal Pump with its Components :

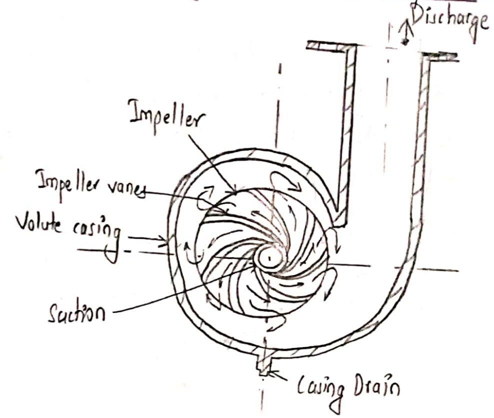


Fig : Centrifugal Pump

An impeller, consisting of a disc which carries a number of curved vanes, rotates within a fixed chamber. The motor driving the impeller imparts angular velocity to the impeller. The impeller vanes then transfer this kinetic energy to the fluid passing into the centre of the impeller by spinning the fluid, which travels outward along the vanes to the impeller casing at increasing flow rates.

This K.E is then converted into P.E (in the form of an increase in head) by the impeller casing (a volute or a circular casing fitted with diffuser vanes) which provides a resistance to the flow created by the impeller and hence decelerates the fluid. The fluid decelerates again in the outlet pipes. As the mass flow rate remains constant, this decrease in velocity produces a corresponding increase in pressure as described by Bernoulli's equation.

EXPERIMENTAL PROCEDURE:

a) The pump was started with both valves open.
b) By adjusting the speed controller, the pump was brought to speed of 2800rpm and max^m flow through the system.
c) The suction pressure was recorded and delivery pressure through dial gauge was noted.
d) The manometer reading on the venturimeter was recorded.
e) The flow was adjusted in stages by operating the discharge valve.
f) Again, suction pressure, delivery pressure and manometer reading were recorded.
g) Five different readings were taken until the Hg manometer read 350mm

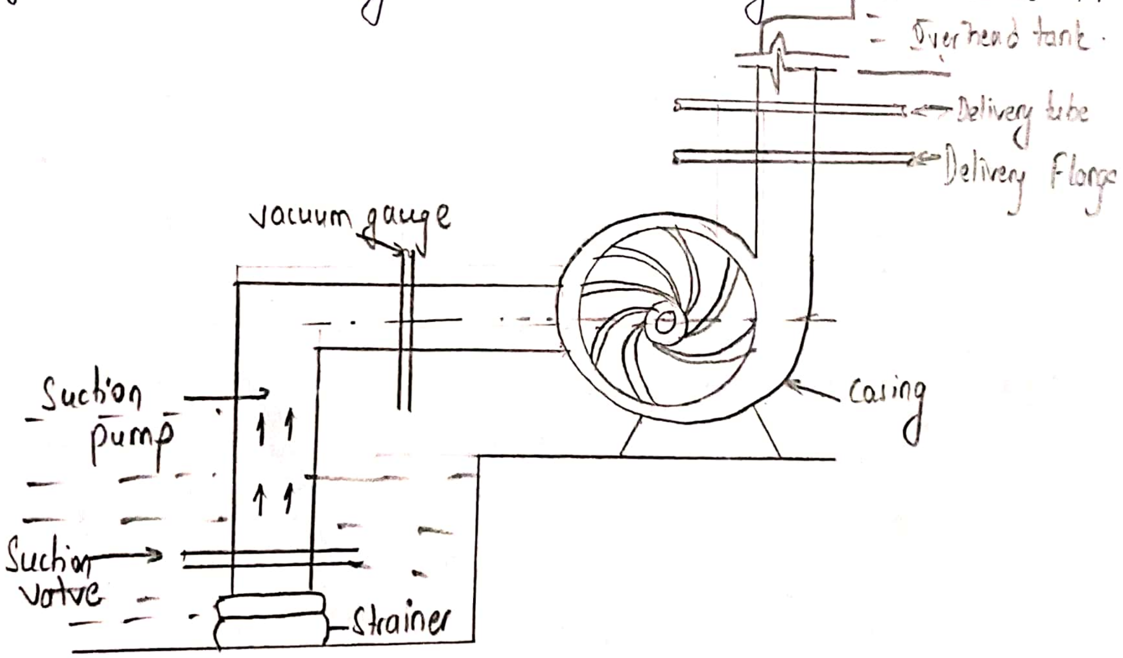


Fig: Experimental setup of Centrifugal Pump.

Torque ... 179mm

$Watt = \frac{N \times rev/min}{53.35}$

(d) Record the manometer reading on the venturimeter.

(e) adjust the flow in stages by operating the discharge valve. adjustment so speed may be necessary at each stage.

(f) Record (c) and (d) at each flow stage.

(g) Take five different reading until the mercury manometer reads 350mm of

(h) Repeat steps (a) to (g) for pump speed of 2600 revs/ min. and 2400 revs/min.

Number of observations	Pump speed rpm	Force N	Pressure		Manometer reading mm Hg
			Suction (P_2)	Delivery (P_1)	
1	2800	5	0.05	0.38	260
2		5	0.1	0.35	241
3		5	0.16	0.3	227
4		5	0.2	0.3	215
5		5	0.3	0.25	190
1	2600	6.0	0.06	0.3	214
2		6.0	0.1	0.27	200
3		6.0	0.15	0.25	189
4		5.0	0.1	0.2	171
5		5.0	0.267	0.2	153
1	2400	5	0.06	0.2	172
2		5	0.1	0.2	162
3		5	0.15	0.18	145
4		5	0.2	0.16	132
5		5	0.3	0.1	108

CALCULATION : 25, 26, 27, ~~28~~, 29, 30

a) Discharge through the pump

b) Mechanical power point

c) Hydraulic power point.

d) Efficiency.

PRESENTATION :

a) Show a sample calculation

b) Present the result in a tabular form.

c) Plot pressure versus discharge

Power discharge

Efficiency versus discharge

d) Show the figure of the apparatus and simple description.

OBSERVATION:

No. of Obs.	Pump Speed (rpm)	Force (N)	Pressure: Suction (P_2)	Pressure: Delivery (P_1)	Manometer reading (mm of Hg)
1.	2800	5	0.05	0.38	260
2.		5	0.1	0.35	241
3.		5	0.16	0.3	227
4.		5	0.2	0.3	215
5.		5	0.3	0.25	190
1.	2600	6	0.06	0.3	214
2.		6	0.1	0.27	200
3.		6	0.15	0.25	189
4.		65	0.2	0.2	171
5.		65	0.27	0.2	153
1.	2400	5	0.06	0.2	172
2.		5	0.1	0.2	162
3.		5	0.15	0.18	145
4.		5	0.2	0.16	132
5.		5	0.3	0.1	108

Sample Calculation:

Pump Speed = 2800 rpm

Force = 4N

Suction Head = 0.05m

Delivery Head = 0.38m

Manometer Reading = 260 mm of Hg.

Discharge through venturimeter = 0.0938 H

= 0.0938 × 260 = 24.388 l/s.

∴ Q = 0.00244 m^3/s

Now,

Hydraulic power output = $\gamma Q H$ Watt

= 9810 × 0.00244 × (0.05 + 0.38) × 10.3

= 106.014 Watt.

Mechanical Power Output $= \dfrac{2\pi N T}{60}$ Watt

$= \dfrac{2\pi \times 2800 \times (5 \times 0.179)}{60}$ Watt $[\because T = F \times r = F \times 0.179]$

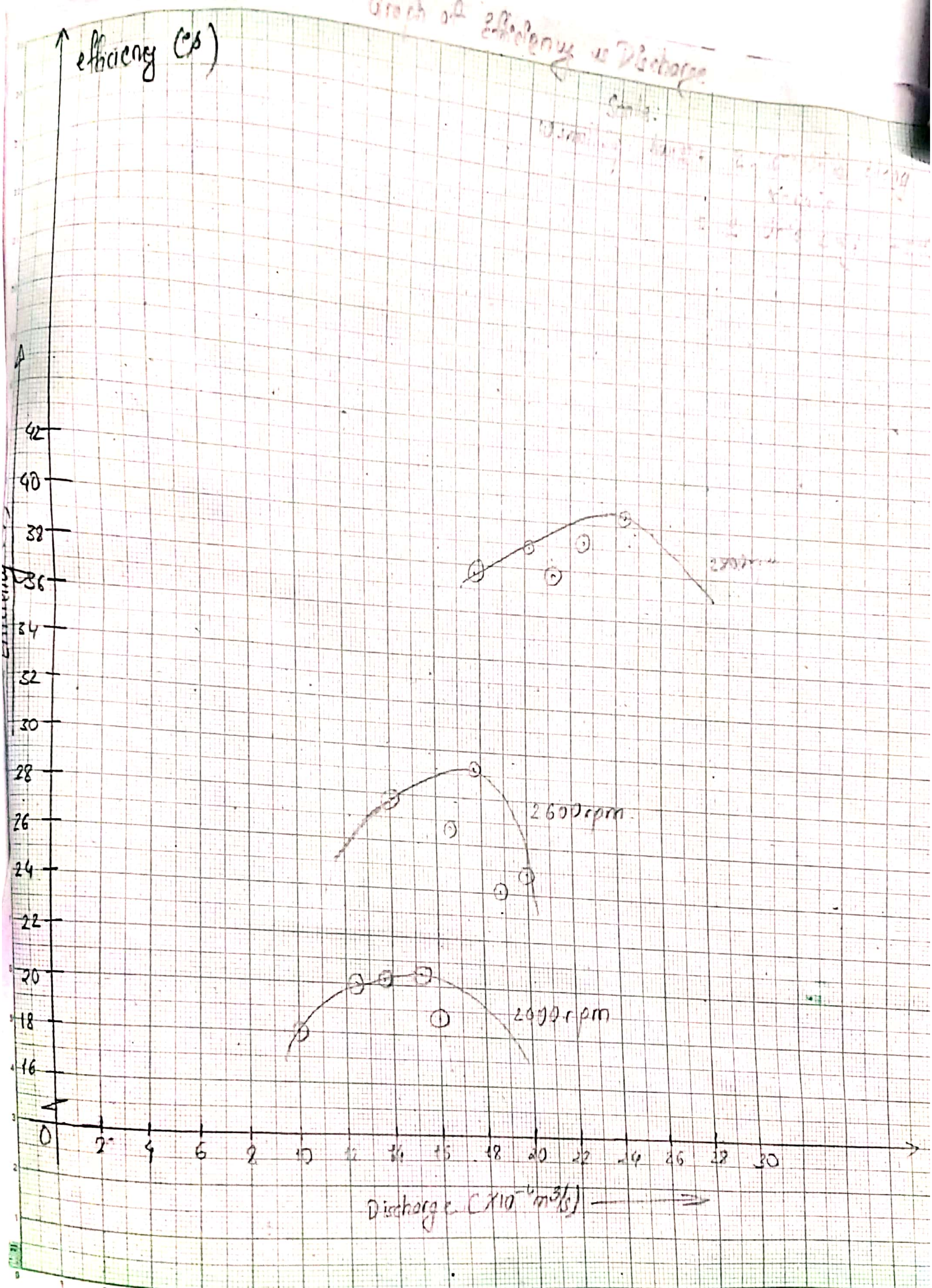
$= 262.43$ Watt

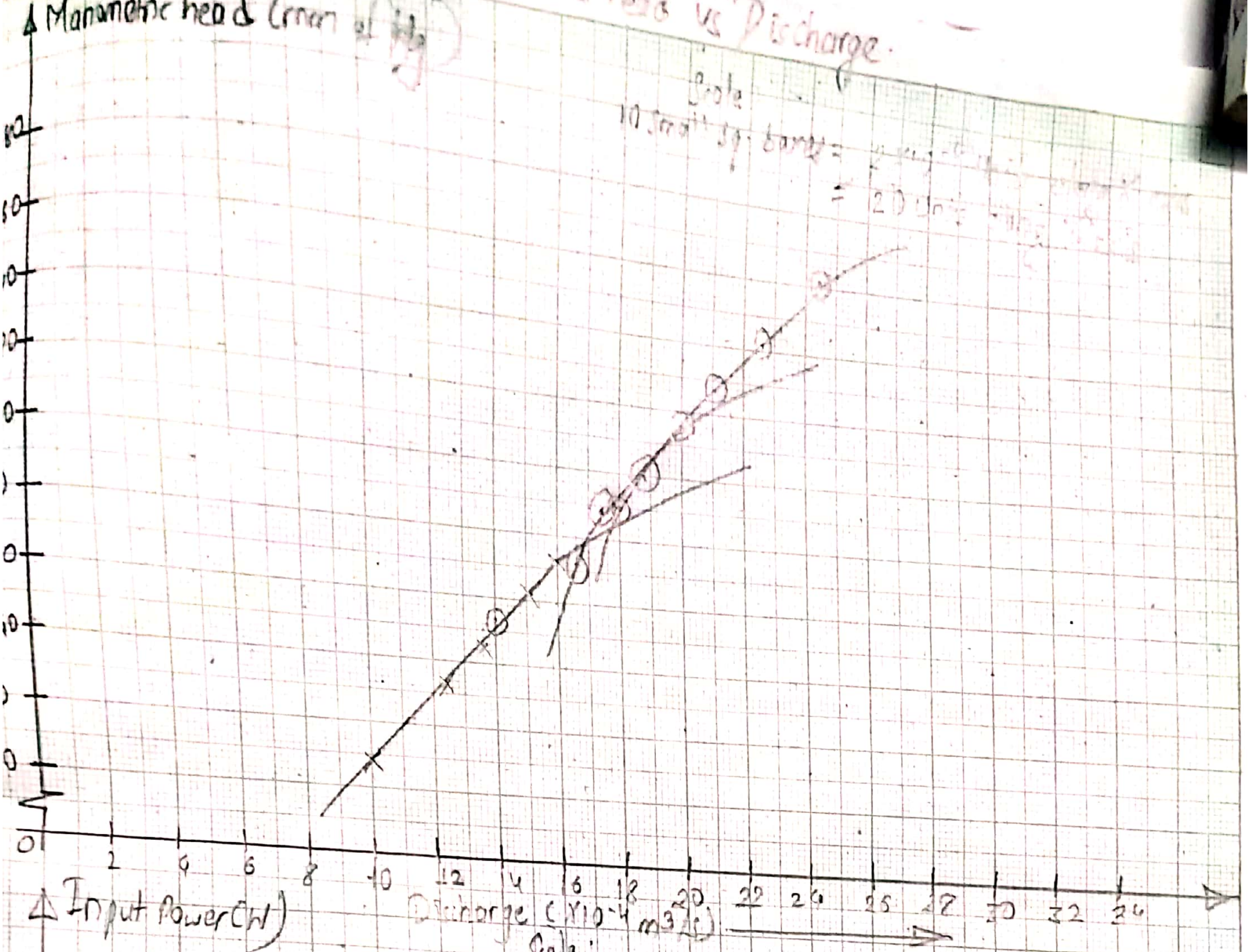
Then, Efficiency $(\eta) = \dfrac{\text{Power Output}}{\text{Power Input}} \times 100\% = \dfrac{106.016}{262.43} \times 100\%$

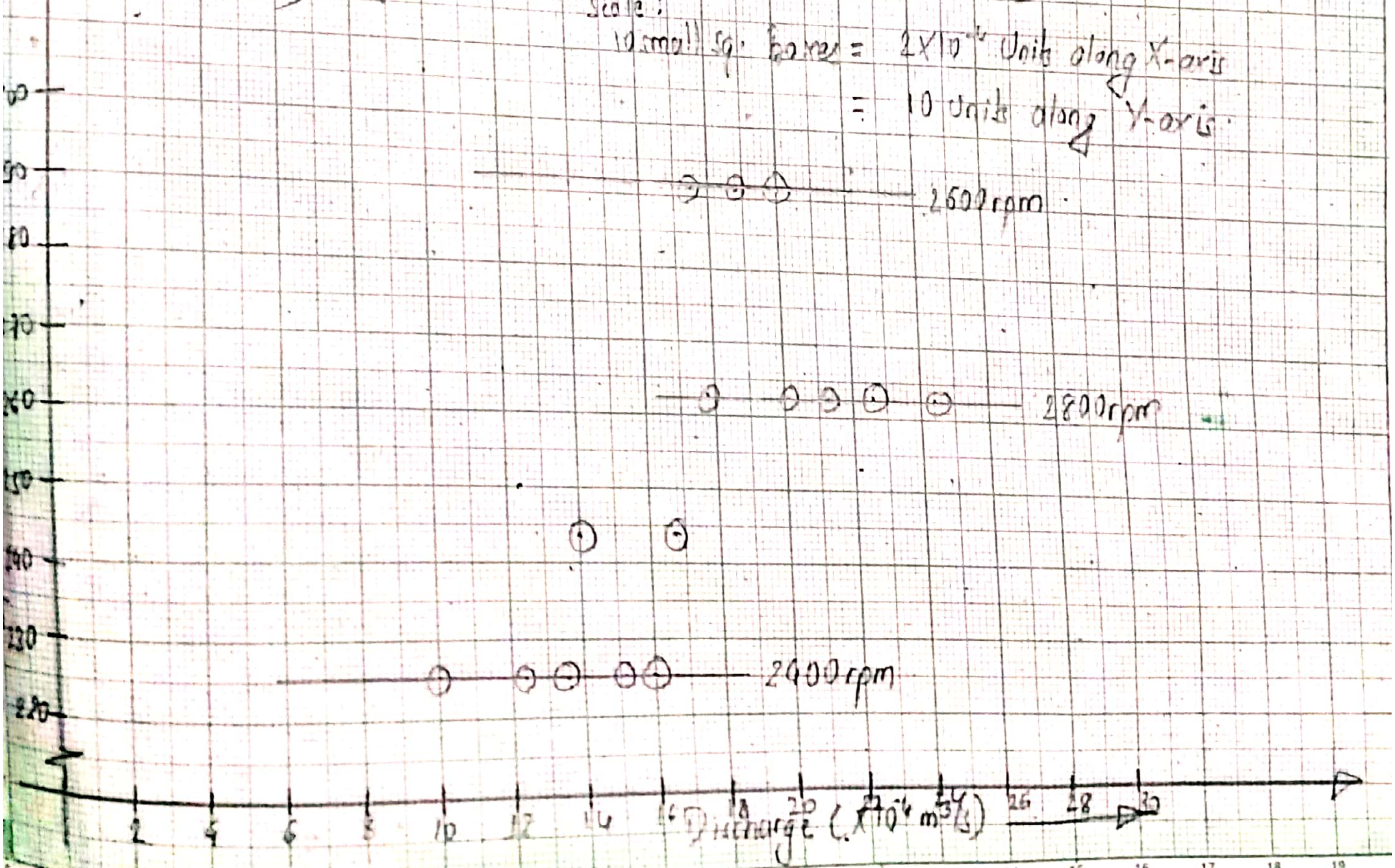
$= 40.4\%$

CALCULATION TABLE:

S.No.	Speed (rpm)	Head (m)	Discharge (m3/s)	Power Output (W)	Torque (Nm)	Power input (W)	Efficiency (η)%
1.	2800	4.429	0.00244	106.014	0.895	262.43	40.4
2.		4.635	0.00226	102.761	0.895	262.43	39.16
3.		4.738	0.00213	99	0.895	262.43	37.72
4.		5.15	0.00202	102.05	0.895	262.43	38.89
5.		5.665	0.00178	98.921	0.895	262.43	37.69
1.	2600	3.708	0.0020	72.751	1.074	292.42	24.88
2.		3.811	0.00188	70.286	1.074	292.42	24.04
3.		4.12	0.00177	71.538	0.895	292.42	29.36
4.		4.12	0.00167	64.667	0.895	243.68	26.54
5.		4.841	0.00160	66.486	0.895	243.68	27.28
1.	2400	2.678	0.00160	42.034	0.895	~~243~~ 224.94	18.69
2.		3.09	0.00152	46.076	0.895	224.94	20.48
3.		3.4	0.00 ~~137~~ 136	45.361	0.895	224.94	20.17
4.		3.708	0.00 ~~136~~ 124	45.106	0.895	224.94	20
5.		4.12	0.001[illegible]	40.417	0.895	224.94	17.967


efficiency (%)
42
40
38
36
34
32
30
28
26
24
22
20
18
16
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
2600 rpm
2000 rpm
Discharge (×10⁻⁴ m³/s)





② Graph of Input Power (Shaft) vs Discharge

COMMENTS:

After this experiment was performed in the laboratory, the variation of discharge with change in head, with change in power and change in efficiency were represented in the tabular as well as graphical form. The constant efficiency (iso-efficiency) curve which thus can be plotted by combining all 3 curves can help us locate the regions where the pump would operate with maximum efficiency.

The characteristics graphs obtained are, however, not as they should be, which might be because of following reasons:

i) The calibrations used were not accurate, ~~use of~~ analog method of measurements were practised.

ii) The pump was run with delivery valve completely closed.

iii) The flow wasn't stabilized before taking readings.

RECIPROCATING PUMP EXPERIMENT

OBJECTIVES:

To determine the operating characteristics of a reciprocating pump.

SCOPE:

The adaptability of a reciprocating pump for different heads can be known from the characteristics of the pump. The relationship between the efficiency and speed or head will help us in selecting speed or head at which pump has to run for maximum efficiency.

APPARATUS:

a) Reciprocating pump , torque area radius = 15cm
b) Stop watch

THEORY:

Reciprocating pump is a positive displacement pump in which the liquid is sucked and then 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. These pumps usually have one or more chambers which are alternatively filled with liquid to be pumped and then emptied again. As such the discharge of liquid pumped by these pumps almost wholly depends on the speed of the pump.

Formulae:

a) Mechanical Power Input = $\frac{2\pi NT}{60}$ watt

where, N = Speed in rpm
T = F * Torque arm radius
F = load in N.

b) Hydraulic Power output = ρQH

$Q = \frac{V}{T}$ or 1kg/1000lit = $1m^3/s$.

(d) Record the suction and delivery pressures.

(e) Measure discharge through the pump by timing the mass collected in the calibrated tank with the help of a stop watch.

(f) Increase the delivery pressure by closing the delivery valve in stages of Bar until the pressure of 4 bar is reached. It might be essential to adjust the speed to keep it at 20 rev/min. at each stage.

(g) At each stage take observations (c) to (a)

(h) Repeat the observations for 15 rev/ min. and 10 rev/ min.

OBSERVATION :

Torque arm radius =

Number of observations	Motor speed rev/sec.	Pump speed rev/min.	Load F E	Pressure		Mass of water collected kg	Time sec.
				Delivery pd (P_1) bar	Suction Ps (P_2) Bar		
1			3.5	0.25	-0.025	5	21.19
2			4	0.75	-0.075	5	24.19
3	20		4.5	1.00	-0.1	5	24.6
4			4.5	1.25	-0.125	5	25.58
5			4.5	1.5	-0.15	5	26.67
1							
2							
3	15						
4							
5							
1							
2							
3	10						
4							
5							

CALCULATION :

25, 26, 27, 28, 29, 30

a) Discharge through the pump

b) Mechanical power point

c) Hydraulic power point.

d) Efficiency.

PRESENTATION :

a) Show a sample calculation

b) Present the result in a tabular form.

Q_a = Discharge in m^3/s
H = Head in m of water

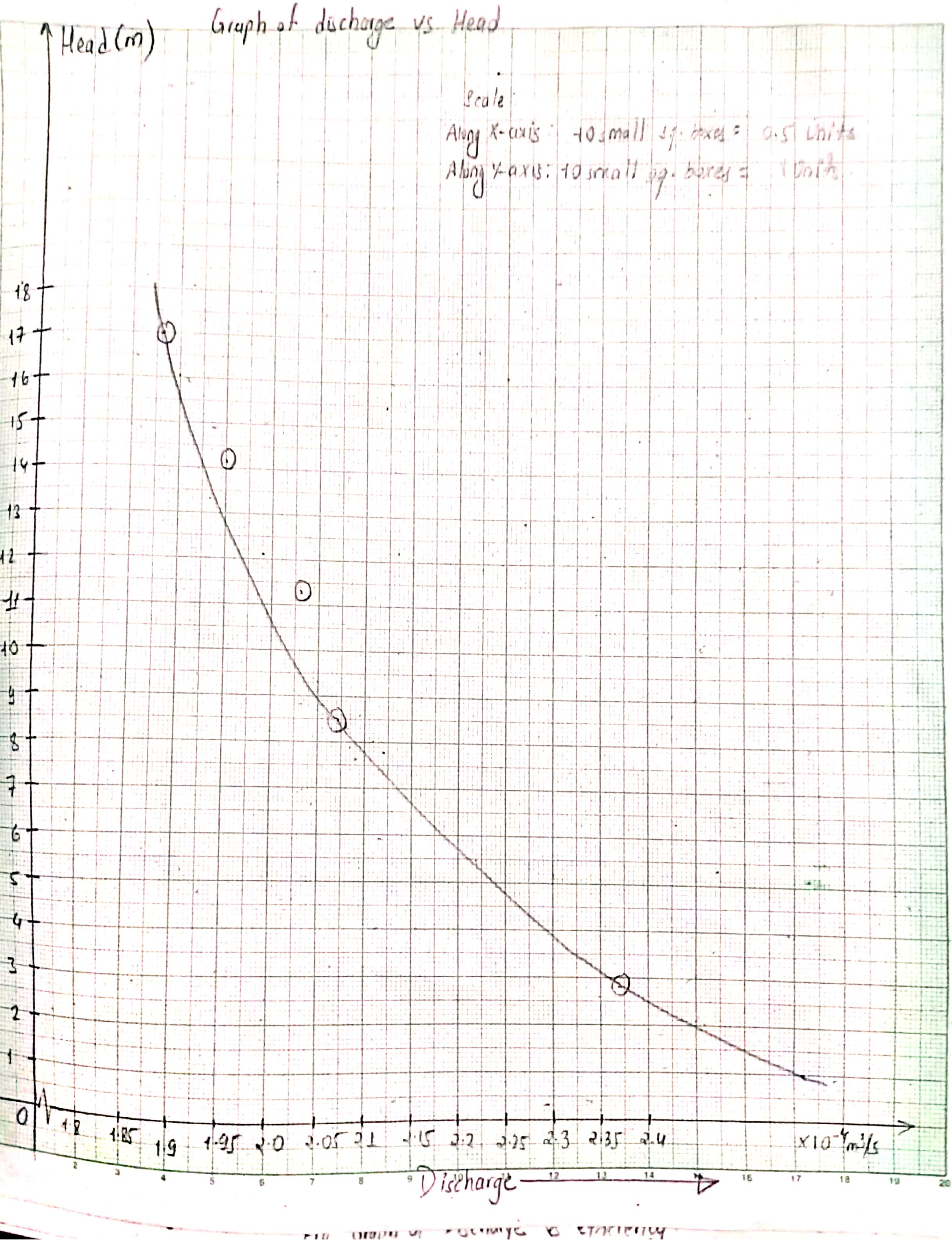
c) Efficiency $= \frac{output}{input} \times 100\ \%$

PROCEDURES:

a) The pump was started, both suction and delivery valves were opened by keeping the speed minimum.
b) By moving the speed controlling dial, the speed was increased to 20rev/min (motor speed), the voltage was checked not to exceed 3 Ampere.
c) The torque measuring balance was adjusted and the force was noted.
d) Suction and delivery pressures were recorded.
e) Discharge through the pump was measured by timing the mass collected in the calibrated tank with the help of stop watch.
f) The delivery pressure was increased by closing the delivery valve in stages of Bar until the pressure of 4 bar was reached.
g) The observation (c) to (d) were taken at each stage.
h) The observations were repeated for 15rev/min & 10rev/min.

OBSERVATION

No. of Obs.	Motor Speed rev/sec.	Pump Speed rev/min.	Load F	Pressure		Mass of water collected (kg)	Time (sec.)
				Delivery (P_d) bar	Suction (P_s) Bar		
1.	20		3.5	0.25	-0.025	5	21.19
2.			4	0.75	-0.075	5	24.19
3.			4.5	1.00	-0.1	5	24.6
4.			4.5	1.25	-0.125	5	25.58
5.			4.5	1.5	-0.15	5	26.67



Graph of discharge vs Head
Head (m)
Scale
Along X-axis : 10 small sq. boxes = 0.5 units
Along Y-axis: 10 small sq. boxes = 1 Unit
Discharge
×10⁻⁴ m³/s

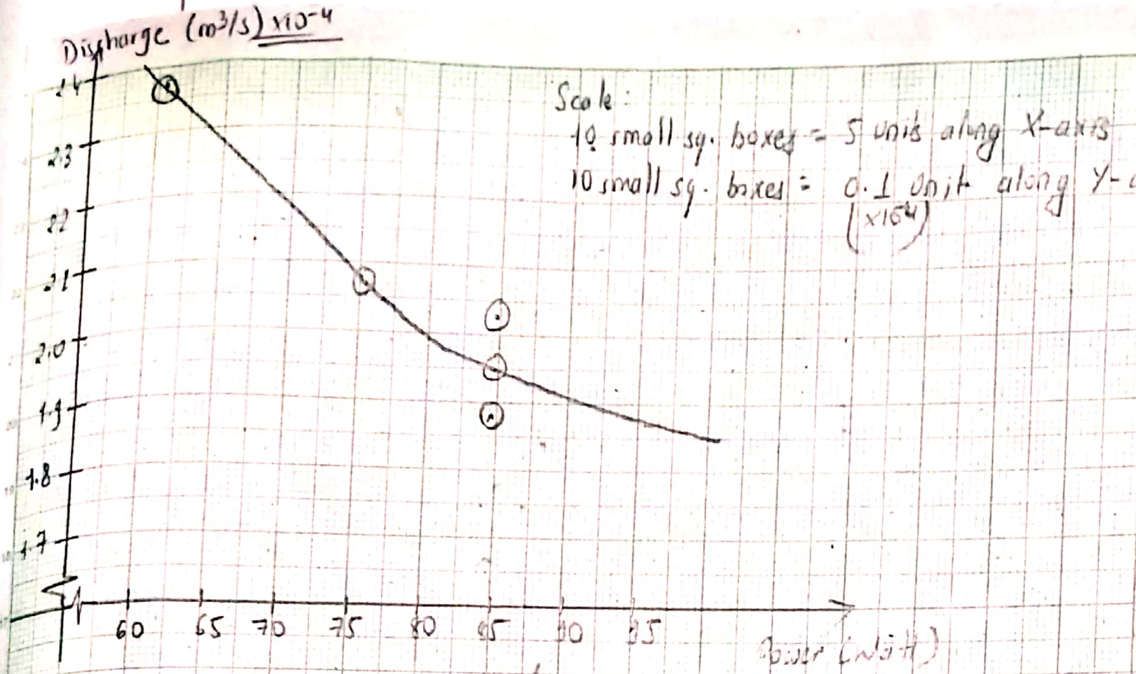


Fig: Graph of Input power vs Discharge

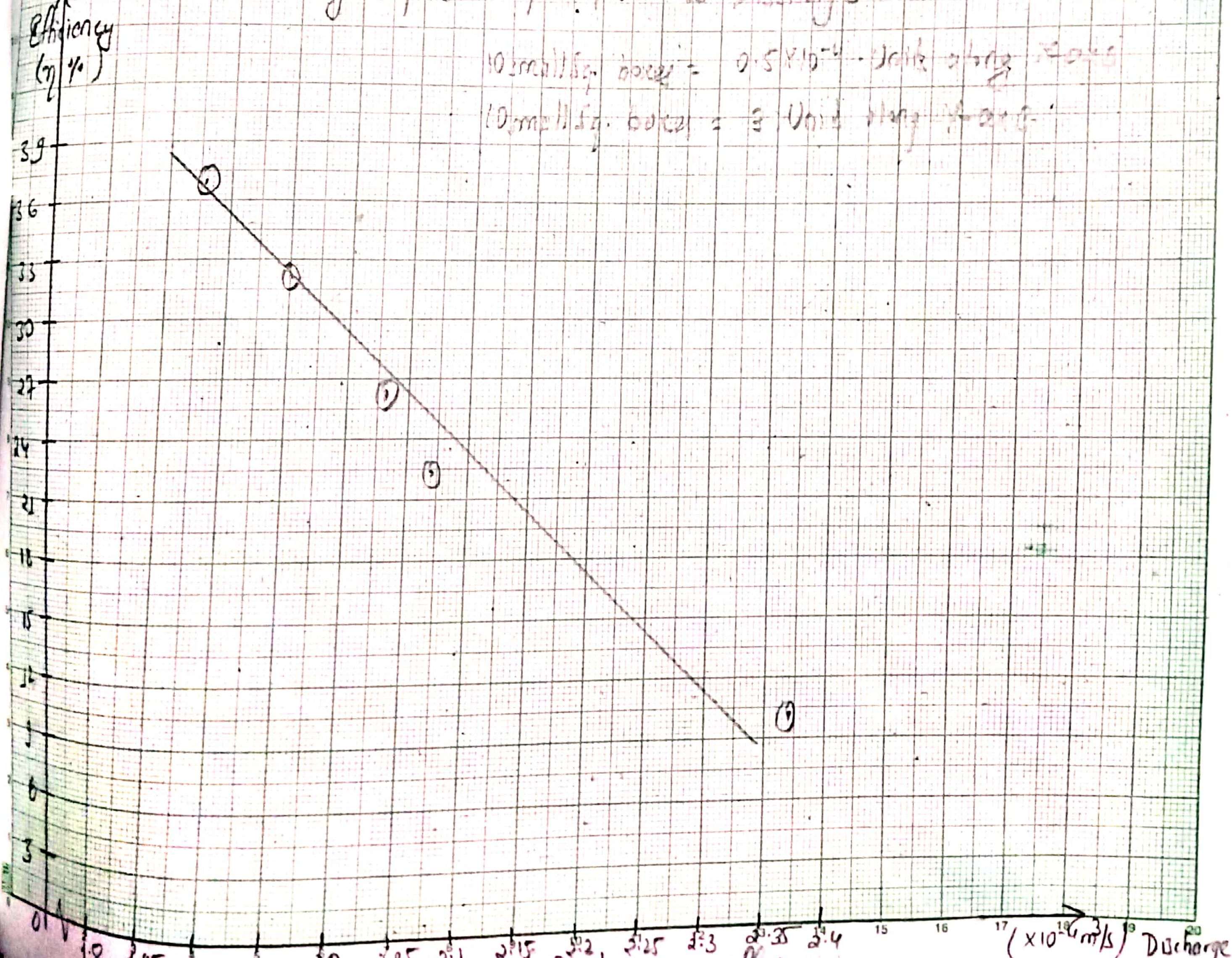


Fig: Graph of Discharge vs efficiency

SAMPLE CALCULATIONS:

Head (in m) = (Delivery head - Suction head) × 10.3
= (0.25 + 0.025) × 10.3 = 2.83 m

Discharge (Q) = V/t = 5/21.12 kg/s = 5/21.12 × 1000 m^3/s
= 2.367 × 10^{-4} m^3/s

Hydraulic Power Output (P_o) = ρQH = 9810 × 2.83 × 2.367 × 10^{-4}
= 6.573 Watt

Torque (T) = Force (F) × Lever arm = 3.5 × 0.15 = 0.525 Nm

Mechanical power input (P_i) = 2πNT/60 = 65.97 Watt.

Efficiency (η) = P_o/P_i × 100% = 9.96%

CALCULATION TABLE:

No. of Obs	Pump Speed (rps)	Head (bar)	Discharge (m^3/s)	Hydraulic Power Output (W)	Torque Nm	Mechanical Power Input (Watt)	Efficiency
1.	20	0.275	2.37×10^{-4}	6.573	0.525	65.97	9.96%
2.		0.825	2.07×10^{-4}	17.23	0.6	75.4	22.83%
3.		1.1	2.03×10^{-4}	22.59	0.675	84.8	26.64%
4.		1.375	1.95×10^{-4}	27.16	0.675	84.8	32.03%
5.		1.65	1.88×10^{-4}	31.31	0.675	84.8	36.92%

COMMENTS:

The reciprocal pump continued to operate more and more efficiently as the head or the pressure was increased, which means the pump worked more effectively at greater ~~heads~~ depth.

It was seen that the output of the pump increased with decrease in head from the graph of head vs discharge, which can be inferred that the pump, however has greater work capacity at low heads.

It was also seen that on increasing power, the pump's output decreases, which implies that the pump is used at low power providing better economy.

~~SAMPLE CALCULATION~~

Combining the results obtained from these three graphs, we can recommend that the reciprocating pump should be used at low head & low input power to obtain maximum efficiency, which is the exact scenario in the context of Terai and rural Nepal. There is lower power supply in terms of potential difference but the water table below the ground are not too far from the surface, so it is beneficial for farmers to install reciprocating pump for irrigation.