NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

Aim

To verify Bernoulli's equation experimentally.

Objective

1. To calculate the total energy head $\left(\frac{P}{\rho g} + \frac{v^2}{2g} + z\right)$ at different points of variable area duct.
2. To plot a graph between total energy head (E) v/s distance (s)

Theory

Bernoulli's Theorem states that for the continuous flow of ideal fluid, the total energy at any section of the flow will remain same, provided there is no subtraction or addition of energy at any point.

For steady and incompressible flow of ideal fluid the Bernoulli equation is.

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 = E$$

In word, sum of pressure energy head, kinetic energy head and potential energy head at different two locations along with the same stream line is constant. Energy head is defined as energy per unit weight.

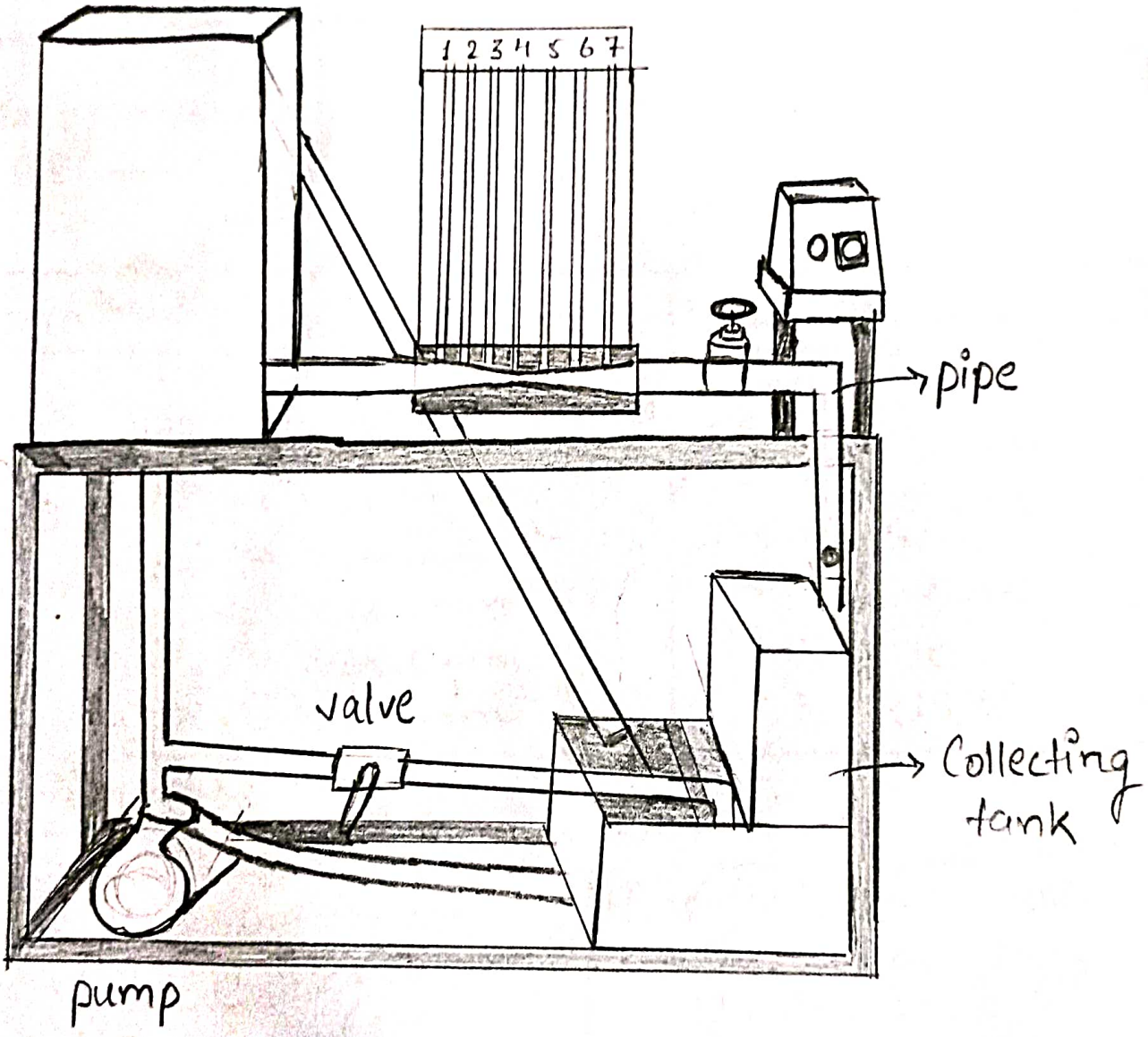
Apparatus

A variable area duct, an overhead tank for supply of constant head, a measuring tank to measure volume flow rate(Q), motor, pump and necessary pipe line assembly along with a by-pass valve and a delivery valve.

Experimental Procedure

Keeping all the valves in the pipe line assembly closed, fully open the by-pass valve. Now switch on the pump by closing the by-pass valve partially. In this condition run the pump until water over flow from the overhead tank. Now the delivery valve provided at the end of the variable area duct is opened appropriately and collect the water for certain time which will help to calculate the volume flow rate Q at that opening of the delivery valve. Now for this opening of delivery valve, measure the pressure energy head ($h = \frac{p}{\rho g}$) at seven different points of the variable area duct by seven piezometer tubes respectively. Then slowly close the delivery valve and repeat all the measurements as it is done in case of previous opening of the delivery valve.

Experimental Setup



Observations.

Given data:

~~Length of measuring tank~~.

Area of measuring tank = $0.076 m^2$.

$g = 9.81 m/s^2$

Test points	Diameter, d (mm)	Distance from ref. point S(m)
1	$d_1 = 28$ mm	$S_1 = 0.04$ m
2	$d_2 = 23.5$ mm	$S_2 = 0.0785$ m
3	$d_3 = 18.5$ mm	$S_3 = 0.092$ m
4	$d_4 = 14$ mm	$S_4 = 0.1105$ m
5	$d_5 = 18.5$ mm	$S_5 = 0.13585$
6	$d_6 = 23.5$ mm	$S_6 = 0.1562$
7	$d_7 = 28$ mm	$S_7 = 0.19155$

Observation table

Sl. No.	Measuring tank Reading			Piezometric tube reading (cm) $h_i = \frac{P_i}{\rho g}$ cm of water head $(i = 1,2,3,4,5,6,7)$						
	H(initial)	H(final)	Time (t)	h_1	h_2	h_3	h_4	h_5	h_6	h_7
1	6.2	10.5	21.02	32.15	31.5	29.7	22.8	26.7	28.5	29.4
2	10.5	17.6	21.54	29.8	28.7	25.4	13	21.6	24.4	25.8
3	7.2	16.4	20.99	27.8	26.3	21.5	4.5	17	20.5	22.5

Result Sheet

Sl. No.	$Q = \frac{AH}{t}$ m^3/s	$V_i = \frac{4Q}{\pi d_i^2}$ m/s ($\times 10^{-3}$ m³/s) $(V_i^2/2g)$ m of water head where $i = 1,2,3,4,5,6$ & 7							$E_i = \frac{V_i^2}{2g} + \frac{P_i}{\rho g} = \left(\frac{V_i^2}{2g} + \frac{h_i}{100}\right)$ m of water head where $i = 1,2,3,4,5,6$ & 7						
		$\frac{V_1^2}{2g}$	$\frac{V_2^2}{2g}$	$\frac{V_3^2}{2g}$	$\frac{V_4^2}{2g}$	$\frac{V_5^2}{2g}$	$\frac{V_6^2}{2g}$	$\frac{V_7^2}{2g}$	E_1	E_2	E_3	E_4	E_5	E_6	E_7
1	0.000155	3.25	6.54	17.05	51.9	17.05	6.54	3.25	0.32	0.32	0.314	0.27	0.28	0.29	0.29
2	0.000251	8.43	17.0	44.2	134.9	44.2	17.0	8.43	0.30	0.30	0.29	0.264	0.26	0.261	0.266
3	0.000333	14.9	30.03	78.2	238.4	78.1	30.03	14.9	0.292	0.292	0.29	0.28	0.24	0.23	0.23

Sample Calculation

tank height $(h) = \frac{17.6 - 10.5}{100} = 0.071$

time $t = 21.54$ sec.

$V_i = \frac{4Q}{\pi d_i^2}$, where $i = 1,2,3,4,5,6$ & 7

$\therefore V_1 = \frac{4 \times 2.57 \times 10^{-4}}{\pi (0.028)^2} = 0.406$ m/s.

$\therefore Q = \frac{AH}{t} = \frac{0.076 \times 0.071}{21.54}$

$= 2.51 \times 10^{-4}$ m³/sec

similarly; $V_2 = 0.57$ m/s.

$V_3 = 0.93$ m/s $V_4 = 1.62$ m/s $V_5 = 0.93$

$V_6 = 0.57$ $V_7 = 0.40$

$V_1^2/2g = 0.00843$

$V_2^2/2g = 0.0170$

$V_3^2/2g = 0.0442$

$V_4^2/2g = 0.135$

$V_5^2/2g = 0.0442$

$V_6^2/2g = 0.0170$

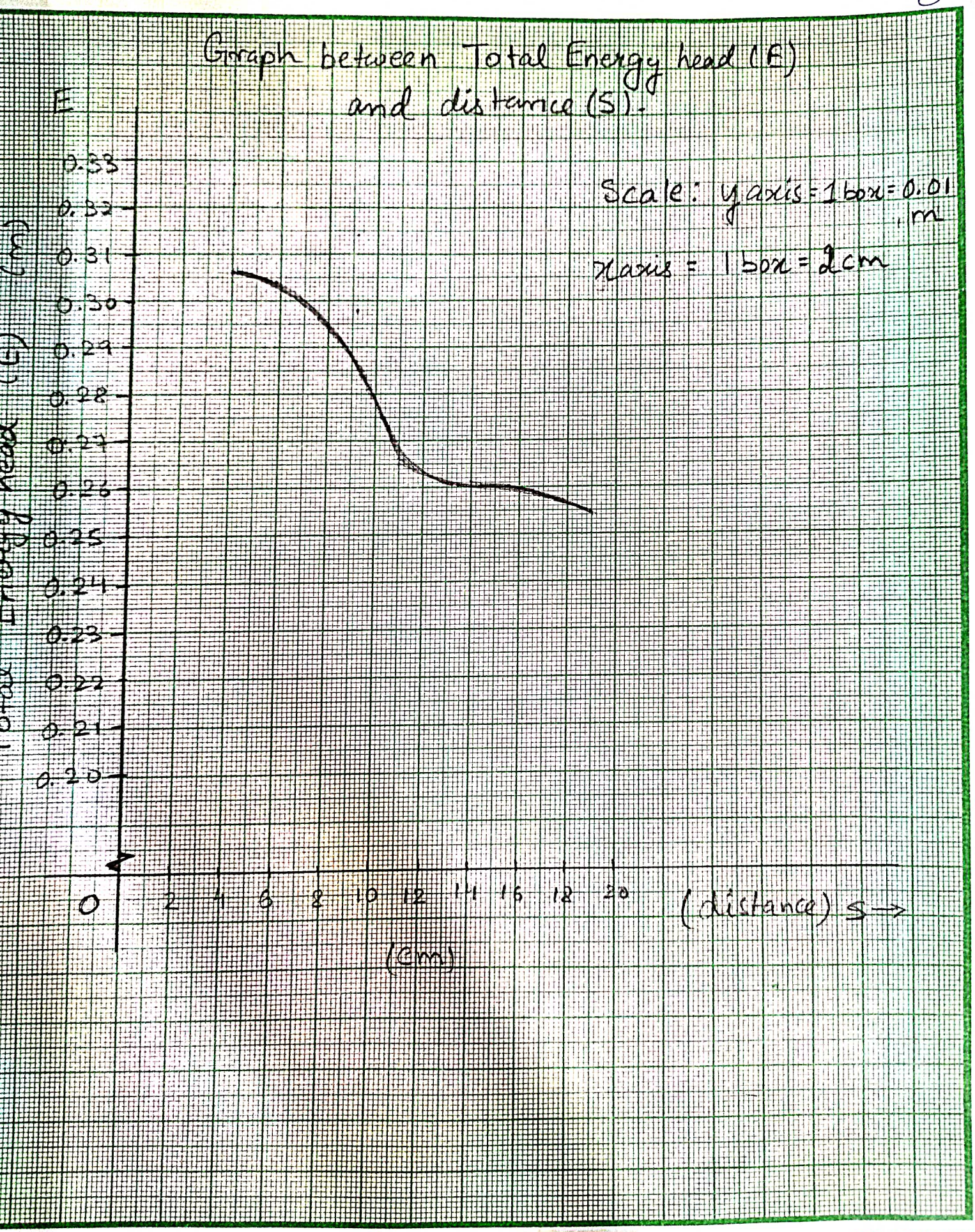
$V_7^2/2g = 0.0084$

$\therefore E_1 = \frac{V_1}{2g} + \frac{h_1}{100} = 0.3064$

similarly: $E_2 = 0.3040$ $E_3 = 0.298$ $E_4 = 0.2649$ $E_5 = 0.2602$

$E_6 = 0.261$ $E_7 = 0.266$

Graph between Total Energy head (E) and distance (S).



Conclusion:

According to bernoulli's theorem, total energy should remain conserved but since it is a real fluid and not ideal so the energy is decreasing as the fluid flows due to dissipating action of faction and viscous forces. Also there may be leakage.

Precautions

1) Time should be noted carefully.
2) All pipe should be tight to prevent any leakage.
3) parallax error should be avoided.