APL103 Experimental Methods
Experiment 8 Lab Report
Conservation of Mechanical Energy

1. Aditya Agrawal(2021AM10198)
2. Swapnil Kashyap(2021AM10782)

Objective:

To evaluate the different components of mechanical energy possessed by a fluid element at different sections of a converging-diverging duct and thus appreciate the limitations of Bernoulli's equation applied to incompressible flows.

Practical Relevance:

In our daily lives, we consume a lot of water for various reasons. This water is delivered through taps connected to a network of pipes of different sizes, which in turn receive water from an overhead tank or a pump. How does one estimate pumping losses or calculate the flow at various points?
One of the equations used in such engineering calculations is Bernoulli's equation (principle of conservation of mechanical energy). The present experiment illustrates this principle as applied to simple practical flow systems and also highlights its limitations.

Theoretical Background:

The law of conservation of energy, as applied to fluid systems, is essentially the first law of Thermodynamics. If we consider mechanical energy, only we have three contributions namely: a) potential energy; b) kinetic energy, and c) pressure energy If we make some simplifying assumptions, then the expression for conservation of mechanical energy per unit volume becomes,

$$p+(\tfrac{1}{2})\rho V^2+ \rho gz = \text{constant} = \text{total energy per unit volume}, \qquad (1)$$

where p is the pressure, V is the fluid velocity, ρ is the density, and g is the acceleration due to gravity.
In engineering applications, equation (1) is usually expressed in terms of head of energy per unit weight, and then this form of Bernoulli's equation is,

$$p/\rho g + V^2/2g + z= h + V^2/2g = \text{constant} = H. \qquad (2)$$

('h', is the piezometric head, and 'H' is the total head)
The assumptions are that the fluid is ideal ($\mu = 0$), it is incompressible (ρ=constant), and that the flow is irrotational, steady, and uniform. In a real flow, these assumptions are violated, and some energy loss does occur; hence, Bernoulli's equation is strictly not valid. This experiment helps highlight these limitations.

Experimental set-up:

The rig consists of a constant-head supply tank connected to a converging-diverging duct with piezometric tubes, a volumetric tank at the outlet, a sump, and a pump. A schematic diagram of the setup is shown in Figure 1.

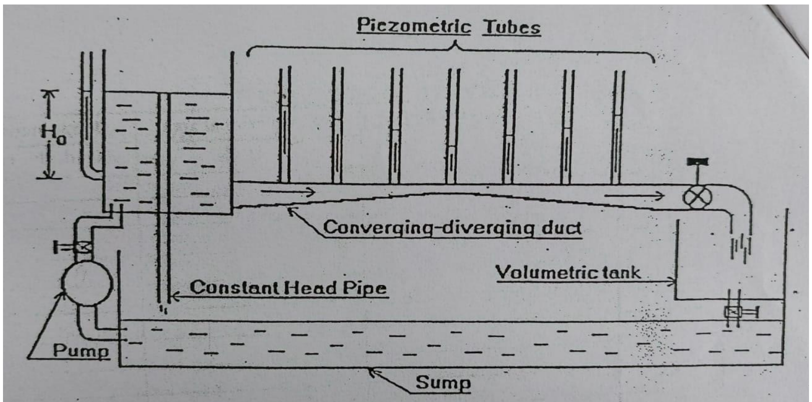


Figure 1: Schematic diagram of the set-up

Procedure:

1) Measure the location of each piezometric tube with respect to the supply tank outlet and the area of the cross-section of the converging-diverging duct at these locations (if these are not given).
2) Adjust the flow rate control valve at the exit of the converging-diverging duct to any setting and also adjust the constant head pipe to a reasonable height. Next, adjust the flow rate of the pump so that the overflow from the constant head pipe is quite small and there are no surges in the tank.
3) Measure the supply tank head, H_o.
4) Measure the piezometric head in each tube.
5) Determine the flow rate using either the volumetric or gravimetric method.
6) Repeat steps 2 through 5 for one more flow rate, obtained either by changing the supply tank head or the valve setting at the exit of the converging-diverging duct.

Observations:

a) Cross-sectional area of the volumetric tank, A= (36x46.5) cm² = 0.1674 m^2

b) Supply tank head, H_0 = 22.8 cm

c) Time taken for a 0.1 m rise in the volumetric tank level, $\triangle t$ (s):

1)26.54 2) 26.20 3) 26.03

Average $\triangle t$ = 26.257 sec

d) Volume flow rate, Q=(0.1 A)/$\triangle t$ = 637.544 cm^3/sec

e) Observation Table

Tube No.	Distance from tank x(m)	Cross-sectional area a(cm^2)	Piezometric Head h(cm)
1	5.5	8.46	19.4
2	11.5	7.87	19
3	17.2	7.3	18.2
4	22.9	6.74	17.5
5	28.7	6.17	17
6	34.3	5.62	16
7	40.2	5.03	14.1
8	45.6	4.5	12.5
9	51.6	5.08	13.2
10	57.2	5.65	13.8
11	62.8	6.2	14.3
12	68.5	6.76	14.8
13	74.2	7.32	15.3
14	80.5	7.95	15.5
15	86.2	8.57	16.2

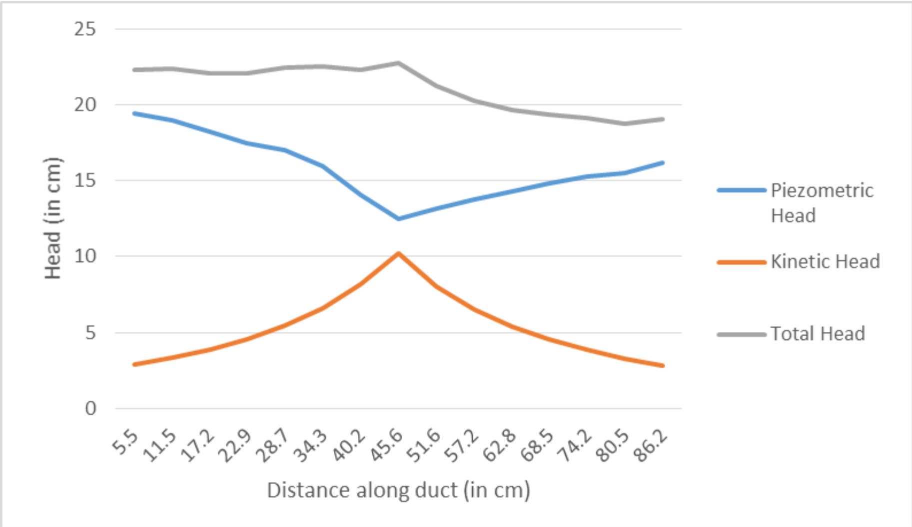
f) Data Analysis:

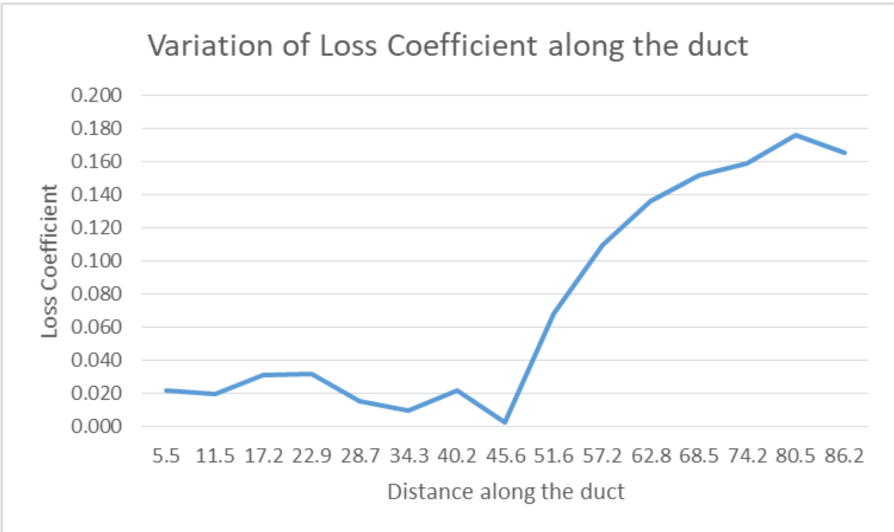
Tube No.	Distance from tank x(m)	Piezometric Head h(cm)	Flow Velocity V(cm/s)	Kinetic Energy Head(cm)	Total Head H(cm)	Loss Coefficient C
1	5.5	19.4	75.360	2.898	22.298	0.022
2	11.5	19	81.009	3.348	22.348	0.020
3	17.2	18.2	87.335	3.892	22.092	0.031
4	22.9	17.5	94.591	4.565	22.065	0.032
5	28.7	17	103.330	5.447	22.447	0.015
6	34.3	16	113.442	6.566	22.566	0.010
7	40.2	14.1	126.748	8.196	22.296	0.022

8	45.6	12.5	141.676	10.241	22.741	0.003
9	51.6	13.2	125.501	8.036	21.236	0.069
10	57.2	13.8	112.840	6.496	20.296	0.110
11	62.8	14.3	102.830	5.395	19.695	0.136
12	68.5	14.8	94.311	4.538	19.338	0.152
13	74.2	15.3	87.096	3.870	19.170	0.159
14	80.5	15.5	80.194	3.281	18.781	0.176
15	86.2	16.2	74.393	2.824	19.024	0.166

g) Plots:

Variation of Piezometric, Kinetic, and Total Heads along the Duct:





Discussion:

1. It can clearly be observed that the actual value of the total head is lesser than the theoretical value, which ideally should have been equal to the supply tank head H_0. This loss has been caused due to major and minor losses. The major losses include the frictional energy loss caused by the viscous effects of the medium and the roughness of the pipe wall. Minor losses are due to pipe fitting, changes in the flow direction, and the flow area. As we move away from the initial point, the losses start increasing in magnitude due to the accumulation of the losses, which can be inferred from the plot of loss coefficient C_d vs distance along the duct.

2. A few sources of error are:
   I. Parallax error while taking note of the readings.
   II. There might be changes in the temperature of the fluid due to the conduction of heat from the pipes and the surroundings, causing the density to change.
   III. We are taking the average value of flow velocity, this may cause a deviation from the actual values.

   Methods for improving the experiment:
   I. We should ensure that the pipes are as smooth and frictionless as possible.
   II. The flow pipes should be made of insulating material in order to prevent temperature fluctuations.
   III. The use of clean water will prevent inhomogeneity in the density of the fluid.