Experiment - 2
Flow through a pipe of sudden expansion

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1. Aim :

To determine Head loss due to flow through a pipe of sudden expansion.

2. Apparatus :

Required apparatus for performing this experiment are:

- A digital manometer (for measurement of pressure)

- Pipe with 3 different diameters and of sudden expansion

- A fan

3. Theory :

A horizontal pipe(as shown in figure) of area A_1 is suddenly enlarged to the area A_2

Section 1-1 : Section before expansion. Section 2-2 : Section after expansion. P_1, A_1, u_1 is the pressure,area and velocity at section 1-1.
P_1, A_1, u_1 is the pressure,area and velocity at section 2-2.
P_d : Pressure of the fluid eddies on the area $(A_2 - A_1)$.
Due to sudden enlargement in the diameter of pipe eddies are formed at the corners of the enlarged pipe which results in head loss across the fitting.

From equation of mass flow rate(Q) :

$$A_1 u_1 = A_2 u_2 = Q \tag{1}$$

$$A_1/A_2 = \alpha = u_2/u_1 \tag{2}$$

Applying Bernoulli's equation between section 1-1 and 2-2 :

$$P_1 + \frac{\rho_1 u_1^2}{2} = P_2 + \frac{\rho_2 u_2^2}{2} + H_l \tag{3}$$
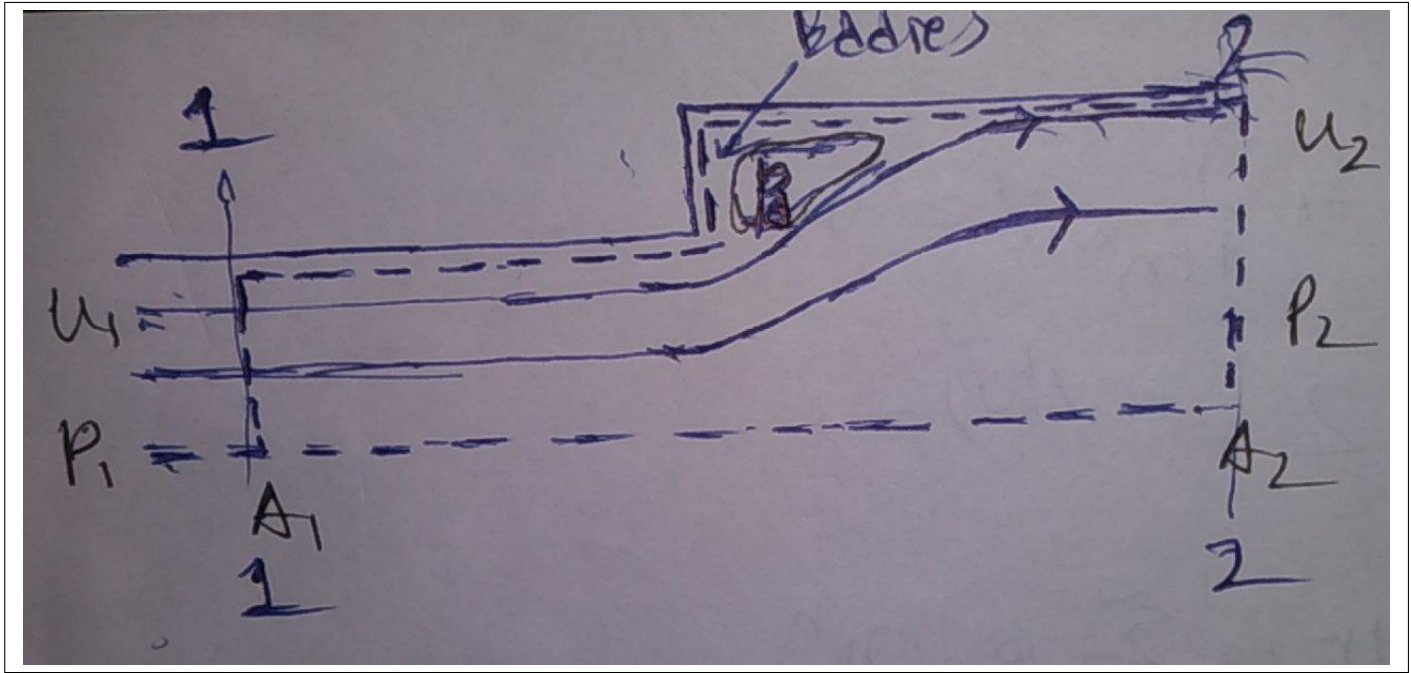
Figure 1: Headloss due to sudden expansion for flow through a pipe

Momentum Equation.:

$$\rho A_2 u_2^2 - \rho A_1 u_1^2 = \rho Q(u_2 - u_1) = P_1 A_1 + P_d(A_2 - A_1) - P_2 A_2 \tag{4}$$

Generally it is observed that : $P_d \approx P_1$
So the momentum equation becomes :

$$\rho A_2 u_2(u_2 - u_1) = A_2(P_1 - P_2) \tag{5}$$

$$P_1 - P_2 = \rho u_2(u_2 - u_1) \tag{6}$$

Using eqn(6) and eqn(2) in eqn(3) we get,

$$H_l = \frac{\rho u_1^2 (1 - \alpha)^2}{2} \tag{7}$$

4. Procedure :

1. First fix the desired ports across the length of pipe of sudden expansion in the manometer.

2. Gradually increase the speed of wind flowing inside after starting the machine.

3. Take readings at that particular ports.

5. Observation :

5.1 Gauge pressure variation across the length of the pipe :

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Table 1: **Variation of Gauge Pressure across length of pipe starting from nozzle**

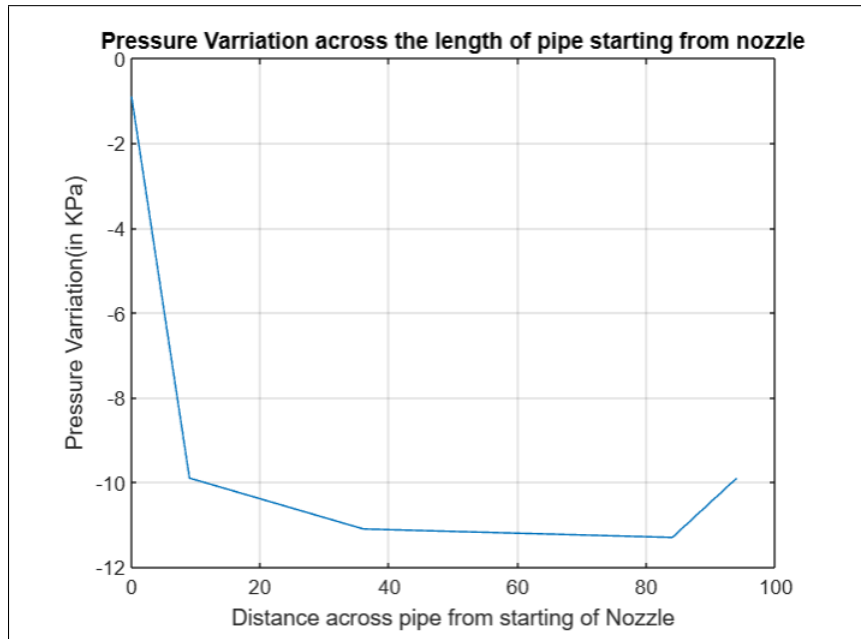| Distance from starting of nozzle(in mm)	Gauge Pressure (in KPa)
0	- 0.4
9	-0.9
36	-9.9
84	-11.1
94	-11.3
150	-9.9

Figure 2: Pressure Variation vs Distance across pipe starting from Nozzle

5.2 Pressure variation across length of for different set of data and corresponding velocity

Table 2: **Pressure variation at different distance of Pipe and corresponding flow velocity**

S.No.	P_1	P_2	P_3	$P_4(P_1)$	$P_5(P_d)$	$P_6(P_2)$	**Flow Velocity(in m/s)**
1.	-0.4	-0.9	-9.9	-11.1	-11.3	-9.9	24.90
2.	-0.5	-0.9	-10.0	-11.1	-11.3	-9.89	27.81
3.	-0.1	-0.6	-9.5	-10.1	-10.2	-8.8	12.44
4.	-0.2	-1.3	-17.5	-19.0	-19.3	-17.0	17.59
5.	-0.3	-1.3	-23.4	-25.7	-26.2	-23.0	21.54
6.	-0.23	-1.3	-17.5	-19	-19.3	-17	18.86

5.3 Variation of Headloss with velocity

Table 3: **Head losss vs Velocity**

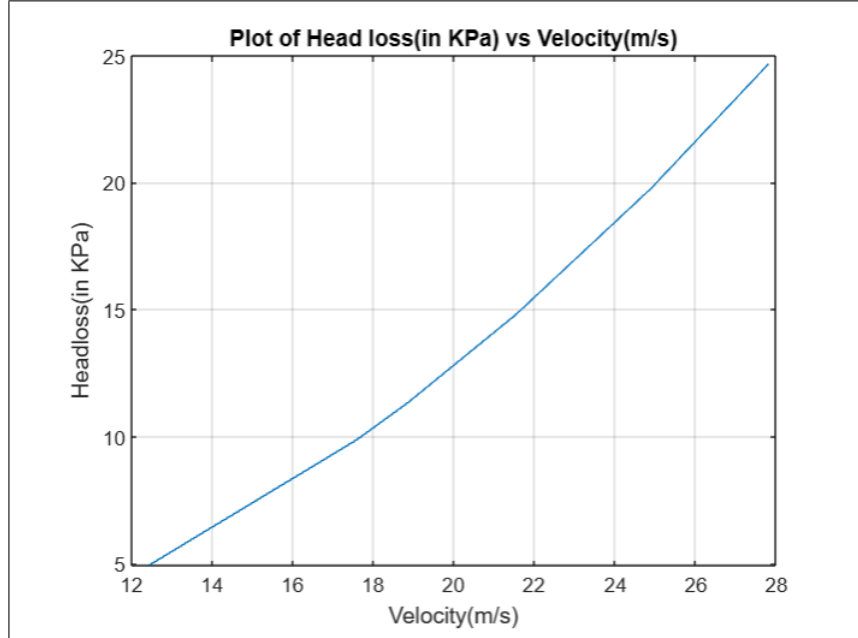| **Velocity)**	**Headloss(in KPa)**
24.90	19.777
27.81	24.670
12.44	4.936
17.59	9.870
21.54	14.800
18.86	11.333

Figure 3: Head loss vs Velocity

6.   Calculations :

Calculations are shown for data 1 : We know,

$$\alpha = \frac{A_4}{A_1} = \frac{d_4^2}{d_1^2} = \frac{12^2}{34^2} = 0.1246 \tag{8}$$

Due to sudden expansion, head loss per unit volume :

$$v_1 = \sqrt{\frac{2P_1}{\rho}} = \sqrt{\frac{2 \times 400}{1.293}} = 24.90 m/s \tag{9}$$

$$v_4 = \frac{A_1 v_1}{A_4} = \frac{d_1^2 v_1}{d_4^2} = \frac{34^2 \times 24.90}{12^2} = 199.892 m/s \tag{10}$$

Head loss per unit volume(H_L)(Due to sudden expansion) $=$

$$\frac{\rho v_4^2 (1 - \alpha)^2}{2} \tag{11}$$

$$= \frac{1}{2} \times 1.293 \times 199.892^2 \times (1 - 0.1246)^2 \tag{12}$$

$$= \frac{1}{2} \times 1.293 \times 199.892^2 \times (1 - 0.1246)^2 = 19777.69 Pa \tag{13}$$

For boundary layer ,head loss per unit volume :

$$H_b = P_3 - P_4 = -9.9 - (-11.1) = 1.2 KPa = 1200 Pa \tag{14}$$

Therefore Total loss $= (19.78 + 1.2)$ Kpa $= 20.98$ KPa
Percentage loss $= \frac{Headlossduetoexpansion}{Totalloss} \times 100 = 94.28\%$

7.   Sources of Error:

- Error in Manometer.

- Error in taking readings due to frequent changes in reading

- Error due to environmental effect like temperature,pressure change.

8.   Conclusion :

- From calculation of Headloss due to sudden expansion,Boudary Layer Headloss(due to viscous force) and total Headloss we have observed that Headloss due to sudden expansion is the most of the Total Headloss.

- There is a pressure drop across the length of pipe due to sudden expansion which is called Dead air Pressure.

- From observed data and graphical representation we have observed as velociy of flow increases Headloss also increases.

- From data we observed that pressure decreases gradually then increases a little across the length of pipe.

- Pressure before expansion is almost same as pressure after expansion.