CHE391 Lab Report: 2023-24

Experiment No. 1: Pipe Fitting

Date of Experiment: 10/02/2024 **Date of report submission**: 14/02/2024

Group Number: 6 **Batch**: Saturday

Names of Contributing Students:

1. Milan Rastogi (210610)
2. Naveen Meenia (210655)
3. Vipin Kumar (211172)
4. Arti Yadav(210195)

Executive Summary:

Problem statement:

The objective is to determine the head losses across various flow rates and utilize this data for the calculation of friction factors.

Key Findings:

- Examine the correlation between flow rates and head losses.
- The selection of materials significantly effects head losses.
- Head losses are directly influenced by pipe diameter, presence of valves and bends in the piping systems.
- Calculate the friction factor using the Darcy-Weisbach equation.

Short Conclusion:

- Across all measured flow rates, aluminium pipes exhibit the highest loss, while copper and acrylic pipes have lower friction coefficient.
- The material dependency of head loss is evident, with aluminum pipes experiencing significantly higher increases compared to copper or acrylic pipes.
- Ball valves experience less head loss than gate valves because they have a lower KL value.

Recommendations:

- The water should be mixed with some coloring or dye. This will make it easier to take readings from the manometer as well as reduce the inaccuracies due to human error.

Lab Data Sheet:

JEET BINDRA UNIT OPERATIONS & INNOVATION LAB
DEPT. OF CHEMICAL ENGINEERING, I.I.T. KANPUR

Date: 10/Feb/24

LAB DATA SHEET

Experiment Name: Pipe Fitting

		Name of students	Roll No.
ChE -	391A		
Exp. No. -	01	1. Naveen Meena	210655
Group No. -	06	2. Milan Rastogi	210610
Name & Sign of T.A.		3. Arti Yadav	210195
Surabhi Sharma 10/2/24 SS		4. Vipin Kumar	211172

Objective: To study the losses of head due to various fittings in pipelines, friction in straight line

Relevant Equation(s):

$$K = f\frac{L}{D}$$

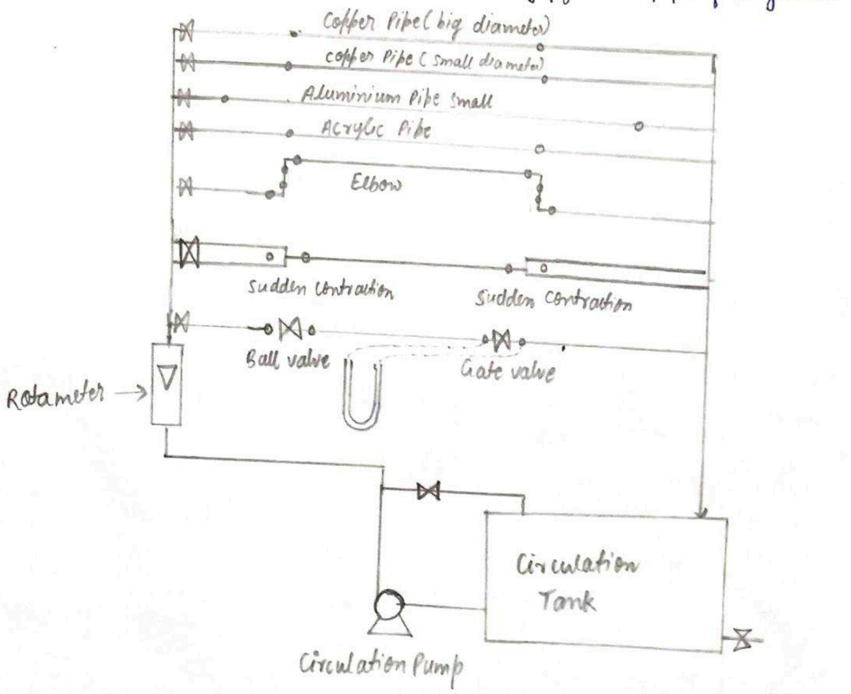
$$h_L = \frac{k_L (V_1 - V_2)^2}{2g}$$

$$h_L = k_L \frac{V^2}{2g}$$

$$h_f = \frac{4fLV^2}{2gd}$$

where;
$h_L \rightarrow$ Minor loss or head loss
$k_L \rightarrow$ Loss coefficient
$V \rightarrow$ Velocity of fluid
$V_1 \rightarrow$ Velocity of fluid in Pipe of small diameter
$V_2 \rightarrow$ velocity of fluid in pipe of large dia

Line Diagram:



Pipe Fitting

Table for line-1 (opper pipe (Big Dia)

S.No.	h1 cm	h2 cm	f_i LPH
1.	491	484	300
2.	486	484	600
3	496	488	900
4	488	475	1200
5	503	485	1500
6	494	480	1350

Table for Line-2 (opper Pipe (small dia)

S.No.	h1 cm	h2 cm	f_i LPH
1.	513	510	300
2.	508	508	600
3	529	508	900
4	529	494	1200
5	535	494	1350
6	542	494	~~1500~~ 1470

Table for Line-3 (Aluminium Pipe) small

S.No.	h1 cm	h2 cm	f_i LPH
1.	424	384	300
2.	465	364	600
3.	529	314	900
4.	607	252	1200
5.	648	218	1350
6.	680	192	1470

Table for Line-4 (Acrylic Pipe)

S.No.	h1 cm	h2 cm	f_i LPH
1.	333	328	300
2.	353	347	600
3.	390	376	900
4.	443	417	1200
5.	468	438	1350
6.	493	456	1470

Table For Elbow (linear to upper)

S.No.	h1 cm	h2 cm	f_i LPH
1.	591	590	300
2.	597	591	600
3.	607	597	900
4.	621	602	1200
5.	630	604	1350

table for Elbow(Upper to straight)

S.No.	h1 cm	h2 cm	f_i LPH
1.	397	398	300
2.	404	400	600
3.	416	403	900
4.	434	407	1200
5.	443	409	1350

volume collected in 1min = 650 ml

Surabhi Sharma
10/2/24

Table for Elbow (Straight to down)

S.No.	h1 cm	h2 cm	f_i LPH
1.	398	400	300
2.	402	400	600
3.	410	404	900
4.	423	409	1200
5.	431	412	1350

Table for Elbow (Lower to straight)

S.No.	h1 cm	h2 cm	f_i LPH
1.	344	343	300
2.	348	344	600
3.	355	346	900
4.	371	351	1200
5.	378	355	1350

Table for Flange sudden Enlargement

S.No.	h1 cm	h2 cm	f_i LPH
1.	331	335	300
2.	332	345	600
3.	334	362	900
4.	338	390	1200
5.	340	405	1350

Table for for sudden Contraction

S.No.	h1 cm	h2 cm	f_i LPH
1.	356	350	300
2.	370	349	600
3.	397	348	900
4.	435	345	1200
5.	457	344	1350

Table for ball Valve

P (bar)

S.No.	p1 ~~cm~~ (bar)	p2 ~~cm~~ (bar)	f_i LPH
1.	0.069	0.086	300
2.	0.151	0.186	600
3.	0.302	0.374	900
4.	0.531	0.657	1200
5.	0.663	0.821	1350

Table for ~~Glove~~ Gate Valve

P (bar)

S.No.	p1 ~~cm~~ (bar)	p2 ~~cm~~ (bar)	f_i LPH
1.	0.076	0.056	300
2.	0.162	0.109	600
3.	0.332	0.213	900
4.	0.575	0.362	1200
5.	0.700	0.437	1350

X Table for Glove Valve

S.No.	h1 cm	h2 cm	f_i LPH
1.			
2.			
3.			
4.			
5.			

Surabhi Sharma
10/2/24

Theory:

The loss of energy in pipe systems due to changes in flow conditions, such as bends, and expansions, and the presence of fittings like elbows, tees, valves, and reducers, is a significant aspect to consider. These alterations in the pipe geometry lead to changes in flow velocity, causing separation of the flow from the boundary and the formation of eddies, resulting in energy dissipation. To quantify these losses, engineers employ the K-value method, also known as the Velocity Head method. By utilizing the Bernoulli equation between two points with known conditions, such as between a reservoir surface and a pipe outlet, engineers can assess the pressure loss accurately. Unlike the Equivalent Length method, the K-value method offers a more accurate assessment of pressure losses as it can be tailored to varying flow conditions, such as Reynolds Number.

Formula Used:

$$K = f\frac{L}{D} \qquad h_L^{fittings} = K_L\frac{V^2}{2g}$$

$$h_L^{contraction} = K_L\frac{V^2}{2g} \qquad h_L^{expansion} = K_L\frac{(V_1^2 - V_2^2)}{2g}$$

$$h_L^{friction} = \frac{4fLV^2}{2gd}$$

Where,

f = Friction factor

d = Diameter of pipe

g = Acceleration due to gravity

V = Mean velocity of fluid

L = Distance between the pressure point

Equipment and Materials Required: Pump, Water Supply, Rotameter, Digital Manometer, Pipes of Different Materials, Kmno4 Solution, Water Manometer.

Apparatus :

Observations and Calculations:

calculations :

for Copper Pipe :- friction coefficients for straight pipes, taking large diameter copper pipe.

$\boxed{Q = 900 \text{ LPH}} = \cancel{8.33 \times 10^{-5} \text{ m}^3/s}$

$Q = 0.00025 \text{ m}^3/s$

$H = h_1 - h_2 = 0.008 \text{ m}$ $\quad H_L = H\left(1 - \frac{\rho_{air}}{\rho_{water}}\right)$

$HL \text{ (Head loss)} = 0.008 \text{ m}$

velocity = Q/A $\quad$ where $\rho_{air} = 1.19 \frac{kg}{m^3}$

$\rho_{water} = 1000 \frac{kg}{m^3}$

$A = \pi r^2 = \pi(0.014)^2$

$= 6.15 \times 10^{-4} \text{ m}^2$ $\quad \therefore H_L = H(0.99881)$

velocity $= \frac{0.00025}{6.15 \times 10^{-4}} = 0.406 \text{ m/s}$

$h_L = k_L \frac{v^2}{2g}$

$k_L = \frac{2gh_L}{v^2} = 0.952184 \simeq 0.952$

$h_f = \frac{4fLv^2}{2gd}$ (Darcy-Weisbach)

$f = \frac{h_f 2gd}{4Lv^2} = \frac{0.008 \times 2 \times 9.8 \times 0.028}{4 \times 1.3 \times (0.406)^2}$

$= 0.00513$

$= 5.13 \times 10^{-3}$

for copper (small diameter) :-

$A = \pi(r^2) = \pi(0.011)^2 = 3.800 \times 10^{-4}$

$V = \frac{0.00025}{3.8 \times 10^{-4}} = 0.658 \text{ m/s}$; $h_L = 0.021 \text{ m}$

$k_L = \frac{2gh_L}{v^2} = 0.952596 \simeq 0.952$

$$f = \frac{h_f \, 2gd}{4LV^2} = 0.00403$$
$$\simeq 4.03 \times 10^{-3}$$

for Aluminium Pipe

$R = 0.00635\,m \quad L = 2.52\,m$

$Q = 900\,LPH = 0.00025\,m^3/s$

$H = h_1 - h_2 = 0.215\,m$

$h_L = 0.215\,m$

$A = \pi(r^2) = \pi(0.00635)^2$
$= 1.266 \times 10^{-4}\,m^2$

$V = Q/A = 1.973\,m/s$

$$k_L = \frac{2gh_L}{V^2} = 1.083$$

$$f = \frac{h_f \, 2gd}{4LV^2} = \frac{0.215 \times 2 \times 9.8 \times 0.0127}{4 \times 2.52 \times (1.973)^2}$$
$$= 0.00136 = 1.36 \times 10^{-3}$$

for Acrylic Pipe

$R = 0.0127\,m \quad L = 2.52\,m$

$Q = 900\,LPH \rightarrow Q = 0.00025\,m^3/s$

$h_L = 0.014\,m$

$A = \pi(0.0127)^2 = 5.064 \times 10^{-4}\,m^2$

$V = Q/A$
$= 0.493\,m/s$

$$k_L = \frac{2gh_L}{V^2} = 1.128$$

$$f = \frac{h_f \, 2gd}{4LV^2} = \frac{0.014 \times 2 \times 9.81 \times 0.0254}{4 \times 2.52 \times (0.493)^2}$$
$$= 0.00284$$
$$\simeq 2.84 \times 10^{-3}$$

Minor Losses :-

For elbow (linear to upper) :

$Q = 900$ LPH

$h_L = h_2 - h_1 = 0.01\,m$

$V = 0.657\ m/s$

$K_L = \frac{2gh_L}{V^2} = 0.454$

$R = 0.011\ m$

$L = 0.071\,m$

For elbow (upper to straight) :

$Q = 900$ LPH

$h_L = 0.013\,m = h_2 - h_1$

$V = 0.657\ m/s$

$k_L = \frac{2gh_L}{V^2} = 0.589$

for elbow (straight to down) :

$Q = 900$ LPH

$h_L = h_2 - h_1 = 0.013\,m$

$V = 0.657\ m/s$

$k_L = \frac{2gh_L}{V^2} = 0.272$

For elbow (lower to straight) :

$Q = 900$ LPH

$h_L = h_2 - h_1 = 0.013\,m$

$V = 0.657\ m/s$

$k_L = \frac{2gh_L}{V^2} = 0.408$

For sudden Enlargement :-

$Q = 900$ LPH $\quad k_L = \frac{2gh_L}{(V_1 - V_2)^2}$

$h_L = h_2 - h_1 = 0.028\ m$

$V_1 = 0.982\ m/s = Q/A_1$

$V_2 = 0.406\ m/s = Q/A_2$

$$k_L = \frac{2 \times 9.8 \times 0.028}{(0.982 - 0.406)^2} = 1.653$$

for Sudden contraction :

$Q = 900 LPH = 0.00025\ m^3/s$

$h_L = 0.049 m$

$V = Q/A = 0.406\ m/s$

$$k_L = \frac{2gh_L}{V^2} = \frac{2 \times 9.8 \times 0.049}{(0.406)^2} = 5.832$$

Ball valve :-

$\Delta P = 7.2 \times 10^{+3}$ Pa $\quad Q = 900 LPH$

$\rho = 1000\ kg/m^3$

$D = 0.016 m$

$$\Delta h_L = \frac{\Delta P}{\rho g} = \frac{7200}{1000 \times 9.8} = 0.735\ m$$

$$k_L = \frac{2gh_L}{V^2} = \frac{2 \times 9.8 \times 0.735}{(Q/A)^2} = 11.58$$

Gate Valve

$Q = 900 LPH$

$D = 0.016 m$

$\Delta P = 11900$ Pa

$$h_L = \frac{11900}{1000 \times 9.8} = 1.219\ m$$

$$k_L = \frac{2gh_L}{V^2} = 19.20$$

Calculation of Re (Reynold's No.)

volume collected in one minute = 650 ml

Q, flow rate = $1.083 \times 10^{-5}\ m^3/s$

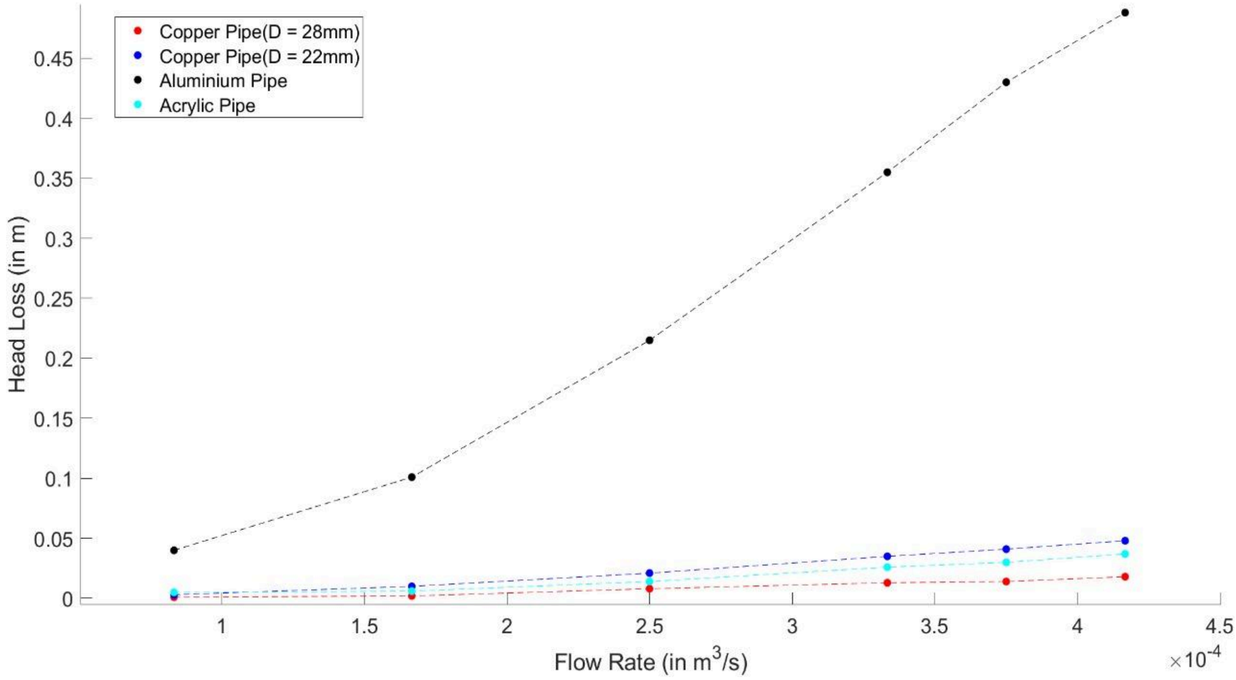
$\eta = 0.001$ Pa·s , D = 28 mm = 0.028 m

$$Re = \frac{\rho V d}{\eta} = \frac{4\rho Q}{\pi d \eta} = \frac{4 \times 1000 \times 1.083 \times 10^{-5}}{\pi \times 0.028 \times 0.001}$$

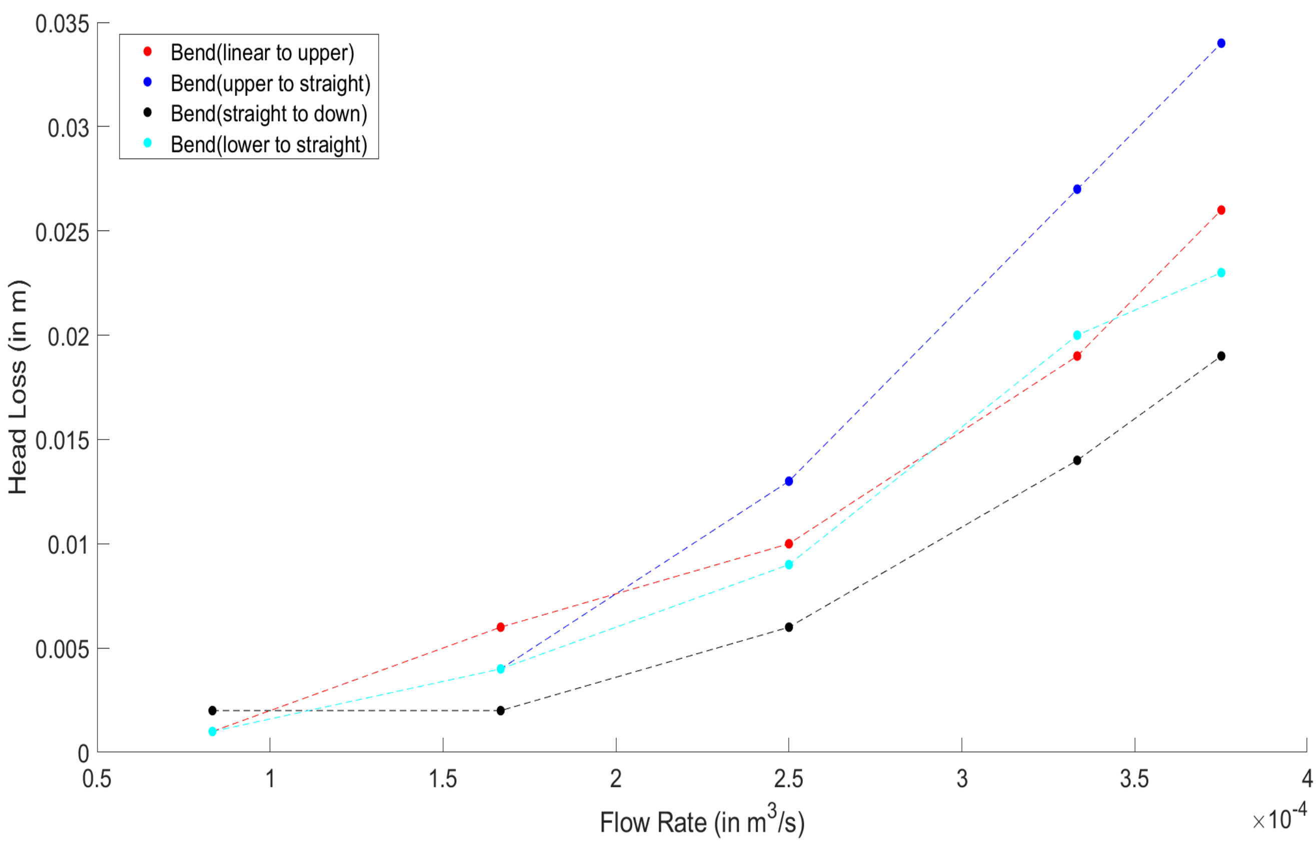
$Re = 491.355 < 2300$, hence Laminar flow

Excel Link: exp1

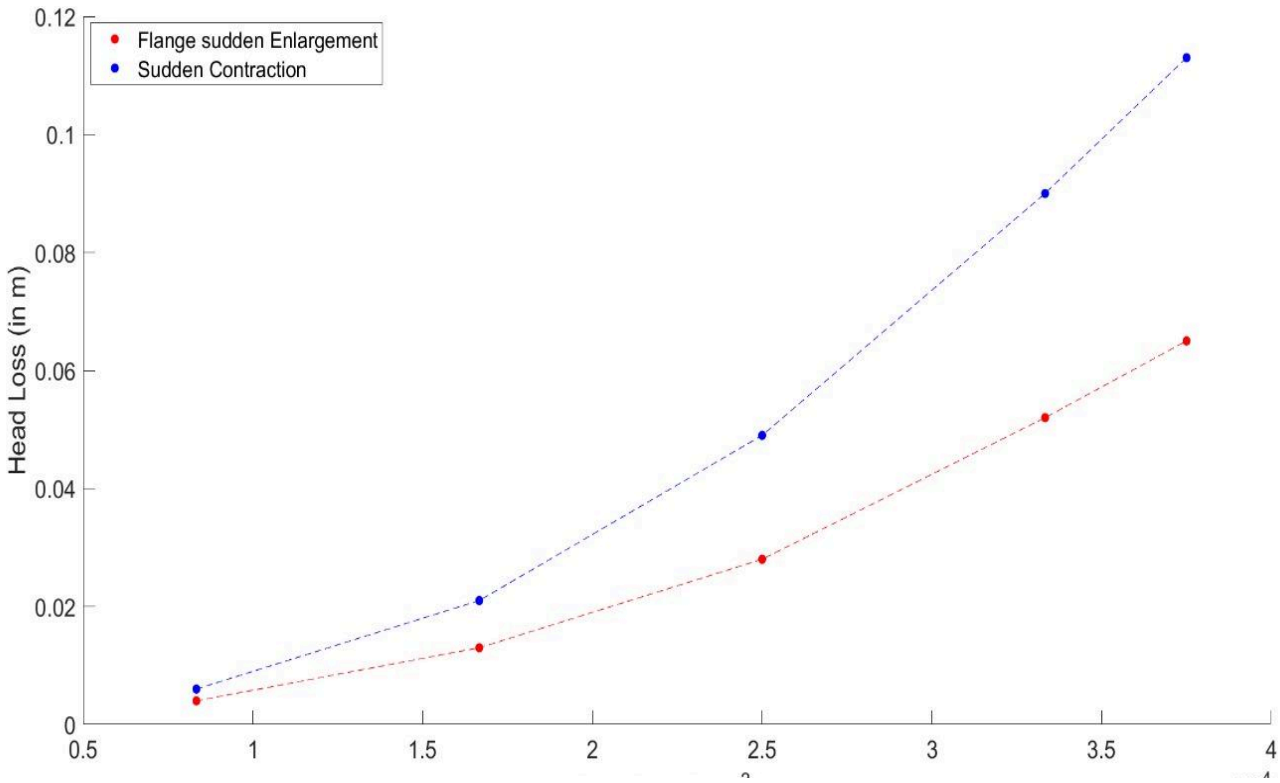
Flow through straight pipes



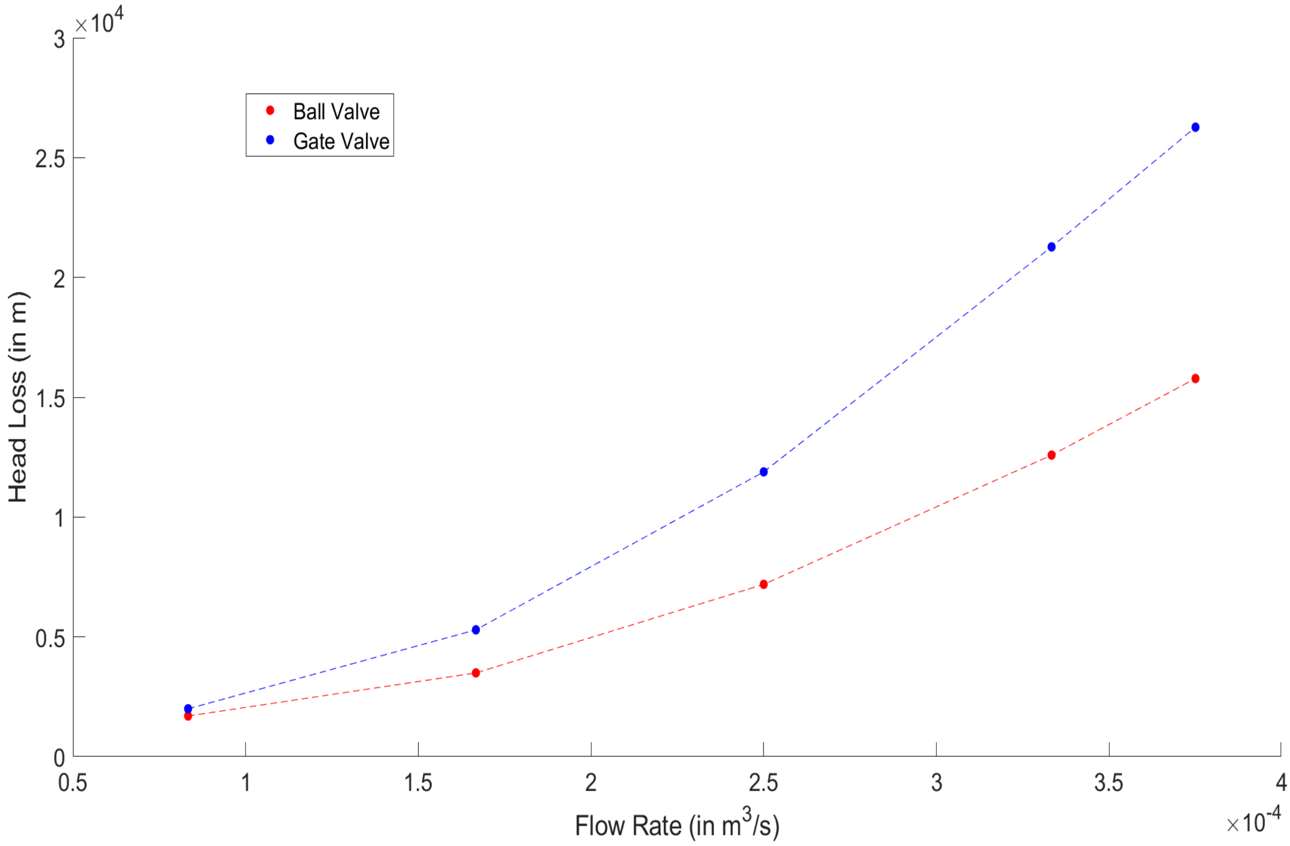
Flow through Elbow



Flow through sudden expansion and contraction



Flow through Valves



Discussions:

- It is evident from the graphs above that head loss increases as flow rate increases..
- A rotameter is a more accurate flow meter than an orifice meter.
- The head loss for the Ball Valve is higher as compared to the head loss for the Gate Valve for all flow rates..
- **Losses of Head Due to Various Fittings:** The experiments revealed significant head losses associated with fittings such as elbows, valves, and diameter changes. These losses are primarily attributed to changes in flow velocity, flow separation, and the formation of eddies.
- **Loss of Head in Fittings at Various Water Flow Rates:** Analysis of the head loss data at different flow rates indicated a nonlinear relationship between flow rate and head loss. This nonlinearity is expected due to the turbulent nature of flow and the complex interactions between the fluid and fittings.
- **Loss Coefficient Determination for Pipe Fittings:** The calculated loss coefficients (K-values) for the pipe fittings provided a quantitative measure of their impact on fluid flow.
- **Friction Coefficient for Flow-Through Straight Pipe:** The experiments conducted to determine the friction coefficient for flow through straight pipes yielded valuable insights into the resistance offered by the pipe walls to fluid flow. The head loss for aluminium is found to be much higher as compared to the head loss of copper and Acrylic pipes.

Remarks and conclusion:

- The friction factor decreases with the flow rate.(This is due to the increasing Reynold’s number and the diminishing effect of the boundary layer) Head losses vary across different types of bends of equal length.
- The KMNO4 dye was seen to move in a straight line for Reynolds number 491.35.

- While measuring the friction coefficient for flow through different pipes, the effective pipe length is taken away from the inlet and outlet regions of the pipe to eliminate entry length and exit length effects.
- We observed the Friction coefficient as follows (for F = 900LPH):
  - In Pipe 1 of copper, Friction Coefficient= 5.13 x 10^-3
  - In Pipe 2 of copper, Friction Coefficient =4.03 x 10^-3
  - In Pipe 3 of aluminum, Friction Coefficient = 1.36 x 10^-3
  - In Pipe 4 of acrylic, Friction Coefficient = 2.84 x 10^-3

Precautions:

- Do not operate the apparatus if the power supply falls below 180 volts or exceeds 230 volts.
- Avoid fully closing both the flow control valves and the bypass valve simultaneously.
- To prevent the clogging of moving parts, run the pump at least once every two weeks.
- Ensure the apparatus is kept free from dust at all times.
- Due to the significant pressure difference, utilize a DPI (Digital Pressure Indicator) for the valve.

Total Marks =30

1) Aim (1) = 1
2) Theory(2) = 2
3) Line Diagram(2) = 2
4) Observation/ Sample Calculation (calculation of table(7)+show calculation(3)) = 10

5) Results& Discussion + error analysis +Plots(5+1+4) = 5+0+4= 9
6) Remarks and Conclusion(5) = 4

In Result & Discussion part discuss your observation that you got by calculations and graph.
Conclusion part consists the extract of the your observation.

Marks obtained = 28