Gazi University
Chemical Engineering Department

ChE 380 Chemical Engineering Laboratory I

5A FRICTION LOSSES

PURPOSE

- The purpose of the experiment is to determine the energy losses due to friction by considering of the pressure difference when a non-compressible fluid in the cylindrical flat pipe passes through the connection elements such as valves, elbows, sudden contraction and sudden expansion.

For an incompressible fluid flowing through a pipe the following equations apply:

$$Q = \nu_1 A_1 = \nu_2 A_2 \qquad \text{(Continuity)}$$

$$z_1 + \frac{P_1}{\rho g} + \frac{v_1^2}{2g} = z_2 + \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + \sum h_L \qquad \text{(Bernoulli)}$$

Q: Volumetric flow rate (m^3/s)
V: Mean Velocity (m/s)
A: Cross sectional area (m^2)
z: Height (m)
P: Static pressure (N/m^2)
h_L: Head Loss (m)
ρ: Density (kg/m^3)
g: Acceleration due to gravity (9.81 m/s^2)

HEAD LOSSES

a) Head Loss in Straight Pipes:

The head loss along a length, L, of straight pipe of constant diameter, d, is given by the expression;

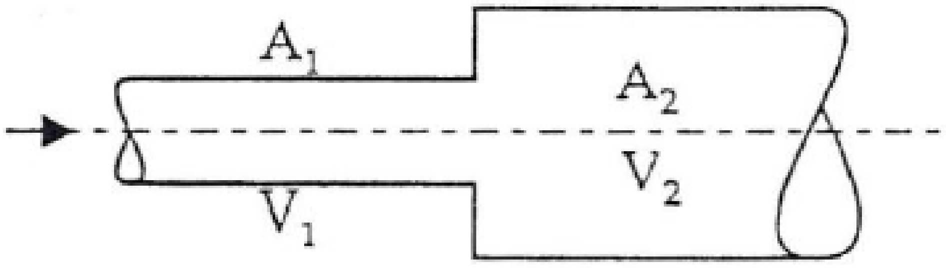
$$h_L = 4f\frac{Lv^2}{2gd}$$

where f is a dimensionless constant which is a function of the Reynolds number of the flow and the roughness of the internal surface of the pipe.

b) Head Loss due to Sudden Changes in Area of Flow

i) Sudden Expansion: The head loss at a sudden expansion is given by the expression:

$$h_L = \frac{(v_1 - v_2)^2}{2g}$$



HEAD LOSSES

ii) Sudden Contraction: The head loss at a sudden contraction is given by the expression:

$$h_L = \frac{K_c v_2^2}{2g}$$

where K is a dimensionless coefficient which depends upon the area ratio as shown in Table. This table can be found in most good textbooks on fluid mechanics. .

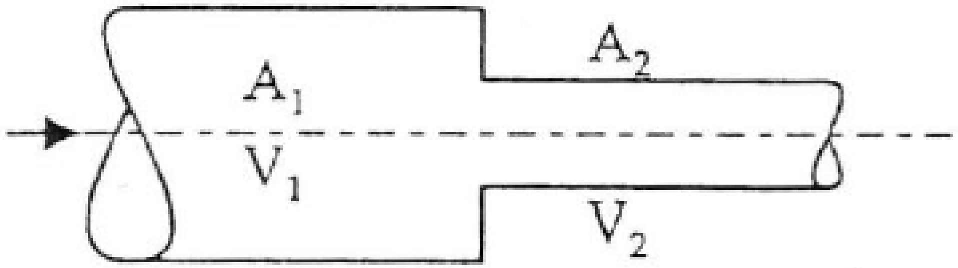


Table. Loss Coefficient For Sudden Contractions

A_2/A_1	0	0.1	0.2	0.3	0.4	0.6	0.8	1.0
K	0.50	0.46	0.41	0.36	0.30	0.18	0.06	0

iii) Head Loss Due To Bends:

$$h_B = \frac{K_B v^2}{2g}$$

where K is a dimensionless coefficient which depends upon the bend radius/pipe radius ratio and the angle of the bend

iv) Head Loss due to Valves:

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

where the value of K depends upon the type of valve and the degrees of opening.

A Straight Pipe 13.7mm Bore
B 90° Sharp Bend (Mitre)
C Proprietary 90° Elbow
D Gate Valve
E Sudden Enlargement - 13.7mm/26.4mm
F Sudden Contraction - 26.4mm/13.7mm
G Smooth 90° Bend 50.8 mm Radius
H Smooth 90° Bend 101.6 mm Radius
J Smooth 90° Bend l52.4 mm Radius
K Globe Valve
L Straight Pipe 26.4mm Bore

Dark Blue Circuit

1. Gate valve
2. Standard elbow
3. 90° joint
4. straight pipe

Light Blue Circuit

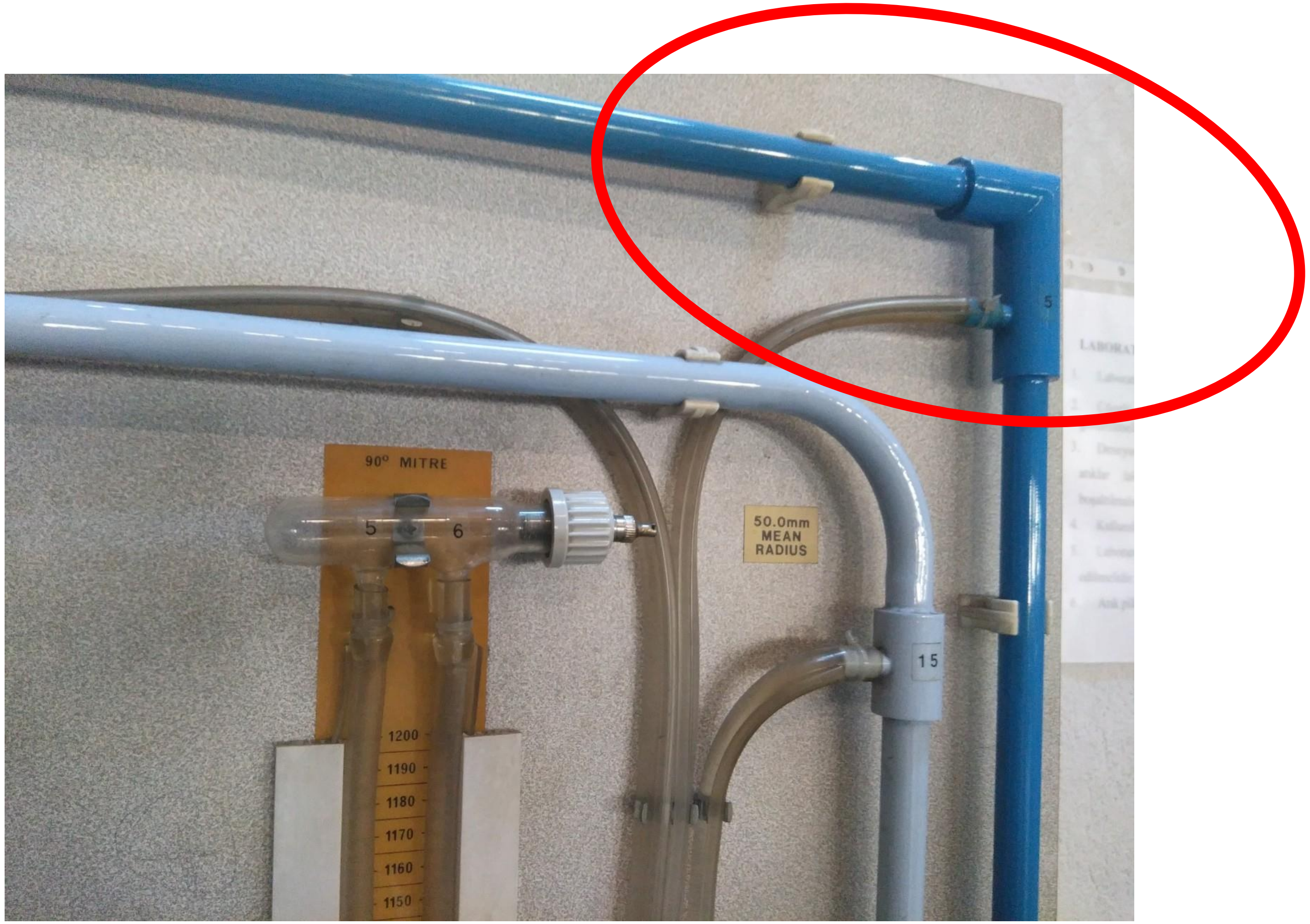
5. Globe valve
6. Sudden expansion
7. Sudden contraction
8. 90° elbow with a radius of 152.4 mm
9. 90° elbow with a radius of 101.6 mm
10. 90° elbow with 50.8 mm radius

Gate valve

Globe valve

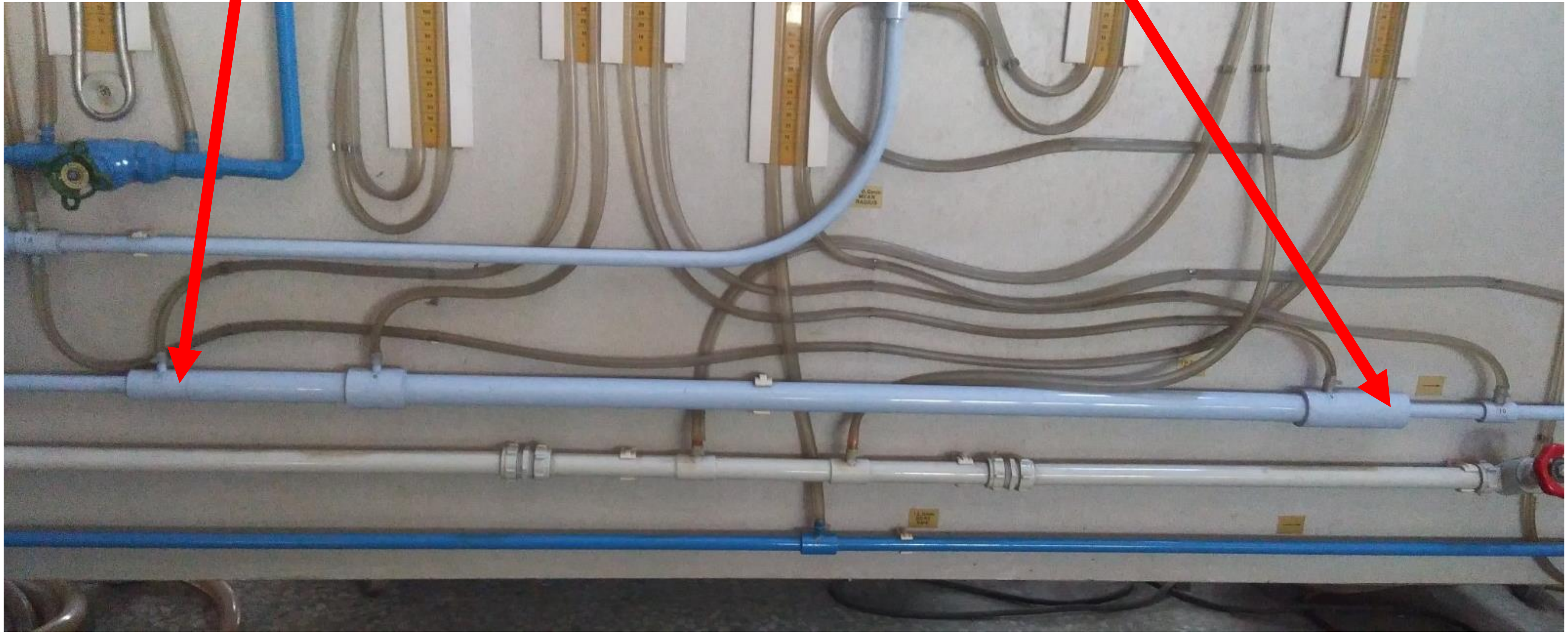
Standart elbow

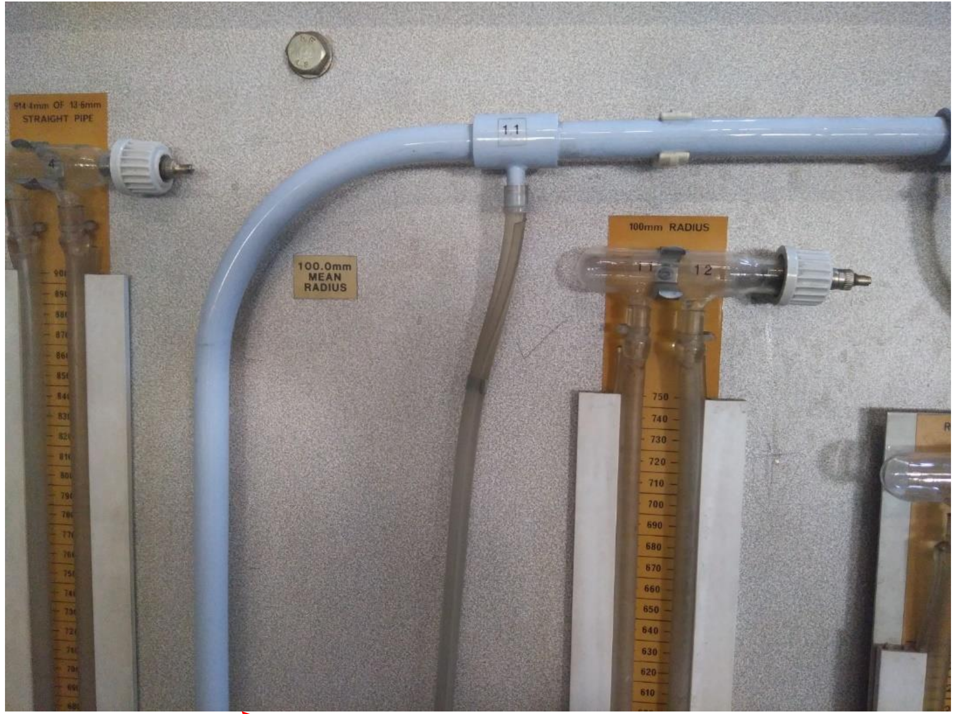
90º sharp bend (mitre)

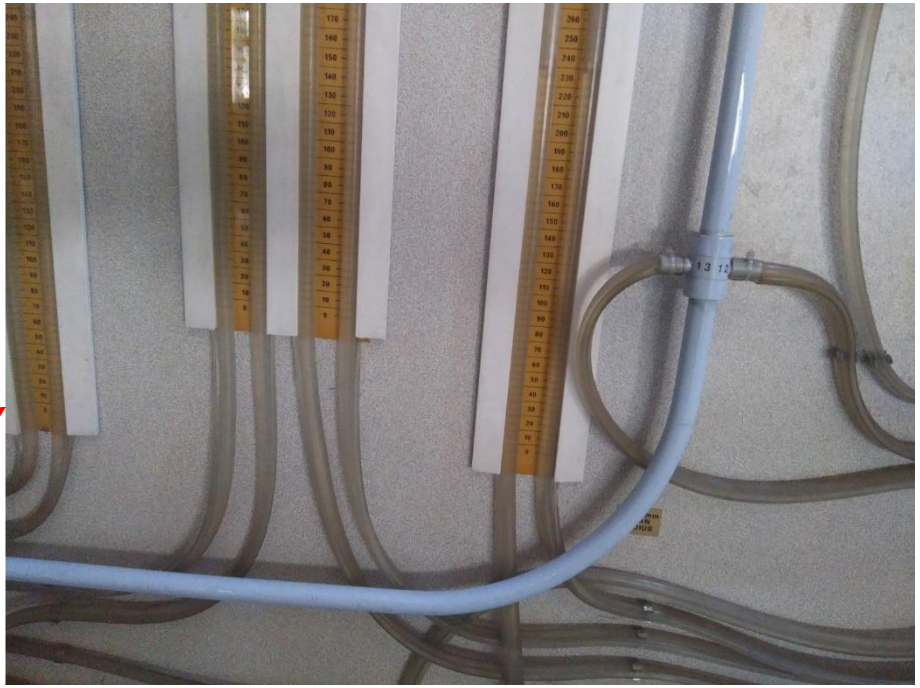


Sudden Enlargement - 13.7mm/26.4mm

Sudden Contraction - 26.4mm/13.7mm



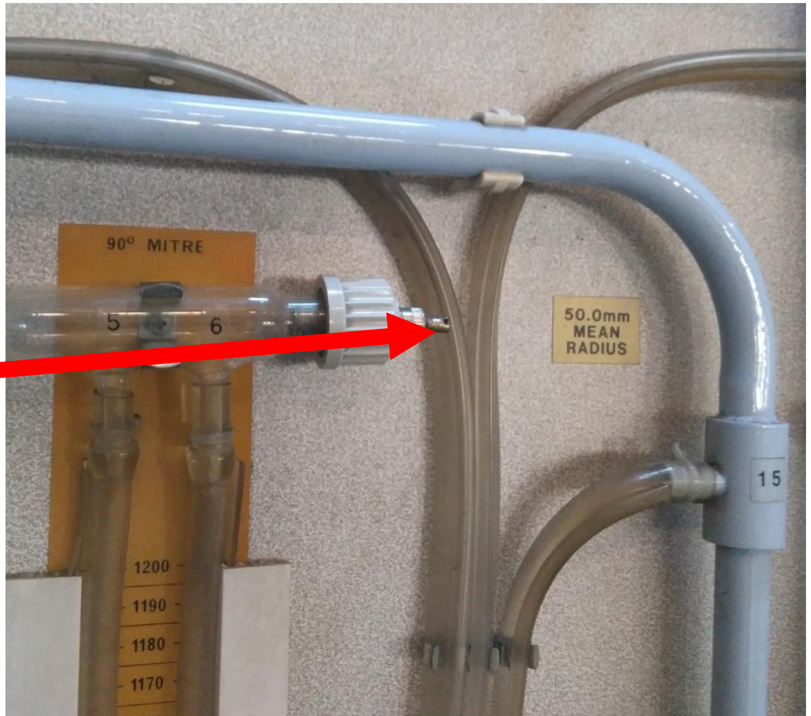




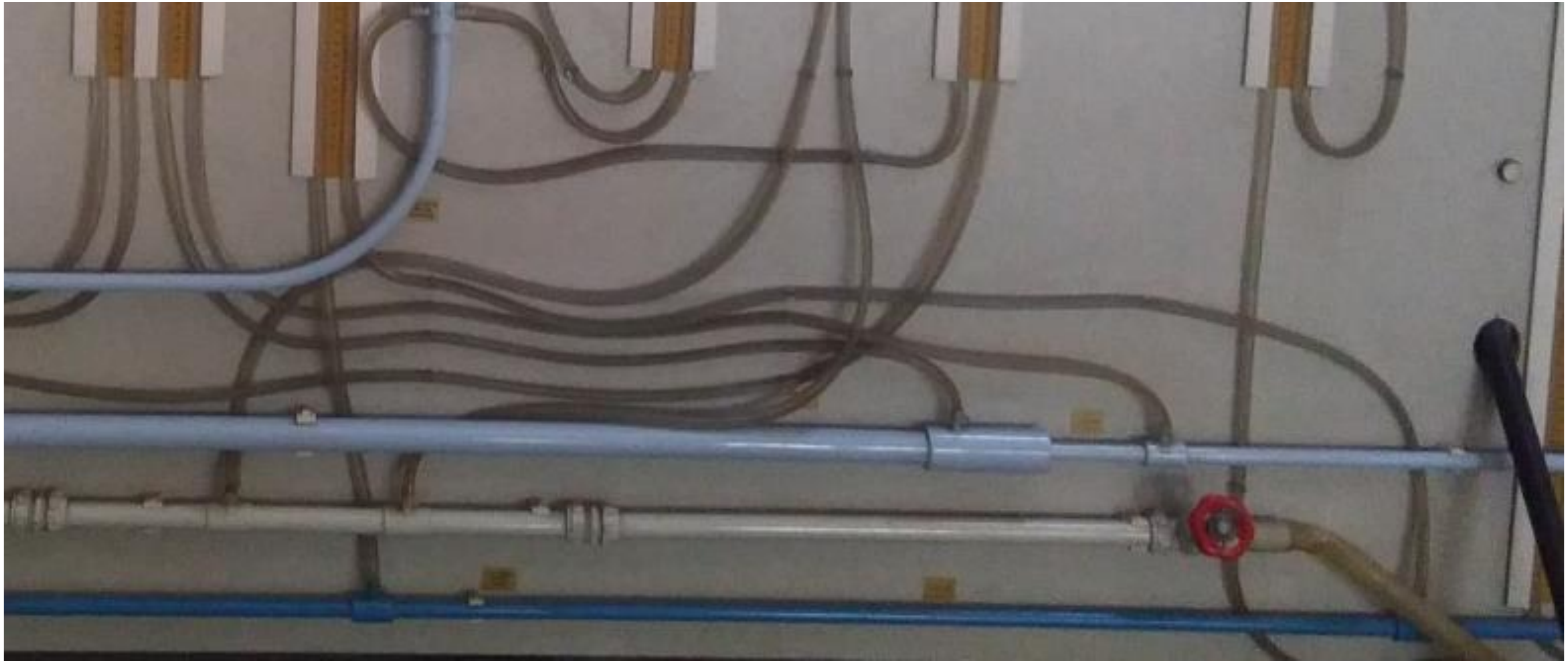
90º bend 152,4 mm radius

90º bend 101,6 mm radius

90º bend 50,8 mm radius



Straight Pipe 13.7mm Bore



DETERMINATION OF FRICTION LOSSES

• **Friction losses from the flow (A dark blue line)**

To determine the friction losses due to the flow, carry out the following experimental work at different flow rates.

- The water control valve on the hydraulic tank is fully opened.
- The globe valve is closed and the gate valve is brought to the fully open position.
- Allow two to three minutes of water flow.
- The volumetric flow rate is determined in the steady state.
- The values read in the U-tube and piezometer tubes along this line are recorded.
- The same readings are recorded at different flow rates obtained by slowly closing the gate valve.

DETERMINATION OF FRICTION LOSSES

Table A. Data recorded in dark blue line

Ex. No	Time needed to fill the tank (s)	Piezometer Readings (mm H_2O)			U-tube (mm-Hg) Gate valve
		1 - 2	3 - 4	5 - 6	
1					
2					
3					
4					
5					
6					

- **<u>Friction losses due to connection elements (B light blue line)</u>**

Carry out the following experimental work at different flow rates to determine the friction losses due to the connection elements in the pipeline.

- After the measurements in the dark blue line are finished, the gate valve is closed and the globe valve is brought to the fully open position.
- The similar procedure is repeated for the light blue line.After the experiment is finished, the gate and globe valves are closed first, then operation of the pump is stopped.

Table B. Data recorded in light blue line

Ex. No	Time needed to fill the tank (s)	Piezometer Readings (mm H_2O)					U-tube (mm-H_2O) Globe valve
		7 – 8	9 – 10	11 – 12	13 – 14	15 – 16	
7							
8							
9							
10							
11							
12							

DETERMINATION OF FRICTION LOSSES

a) **Prepare the table below using the data in Table A.**

Table I. f values at different flow rates

Ex. No	Time needed to fill the tank (s)	h_L,experimental ($m\ H_2O$) Δ_{3-4}	Q (m^3/s)	V (m / s)	Re	f experimental	f theoretical
1							
2							
3							
4							
5							
6							

Plot the following graphs using the prepared Table I.

Find the relationship that gives the change of surface friction loss with flow rate:

$\log h_L - \log Q$. (Since $h_L \alpha Q^n$ calculate the value of n in this relationship)

- ✓ Compare your relationship with that given in the literature.
- ✓ Find the variation of the friction coefficient with the Reynolds number (f-Re) (Find the f-Re values given for smooth pipes in the literature and compare them with your own results)

b) Calculate hL at different flow rates using Equation (2) given for sudden expansions and prepare the table below.

Plot Experimental h_L - calculated h_L graph

Table II. Friction losses due to the sudden expansion

Ex. No	V_7	V_8	h,experimental (m H_2O) $\Delta_{7\text{-}8}$	h,calculated (m H_2O)
7				
8				
9				
10				
11				
12				

c) Calculate h_L at different flow rates using Equation (3) given for sudden contractions and prepare the table below.
Plot Experimental h_L - calculated h_L graph

Table III. Friction losses due to the sudden contraction

Test No	V_9	V_{10}	h,deneysel (m H_2O) $\Delta_{9\text{-}10}$	h,hesaplanan (m H_2O)
7				
8				
9				
10				
11				
12				

d) Calculate the experimental K_B values using the Equation (4) given for the bends. Plot K_B – (r/d) graph (r/d= bending diameter/pipe diameter)

Table IV. Friction loses for bending

Ex. No	V	h (r=52mm)	h (r=104mm)	h (r=152mm)	K_B (r=52mm)	K_B (r=104mm)	K_B (r=152mm)
7							
8							
9							
10							
11							
12							

e) Find the relationship between the loss coefficient - volumetric flow rate (Q) for both valves in the system and plot them.

Ex. No	V (m/s) Dark Blue	V (m/s) Light Blue	h_{gate} (mH_2O)	H_{globe} (mH_2O)	K gate	K globe