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Fluid Mechanics

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Practical Report

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1. Measurement of Head Loss with Plant MP76

1.1 Experimental study of the singular head loss: severe section variations

1.1.1 Purpose of experiment:

In this study, we need to verify the existence of energy loss when the real fluid passes through the severe section variations.

1.1.2 Description of the apparatus

The nature of elements	Diameter(mm)	Number of pressure taps
Sharp enlargement	di=14-de=20 and di=20-de=34	9-10
Sudden contraction	di=20-de=34 and di=14-de=20	10-11

with: di is the internal diameter of the pipe and de is the external diameter of the pipe.

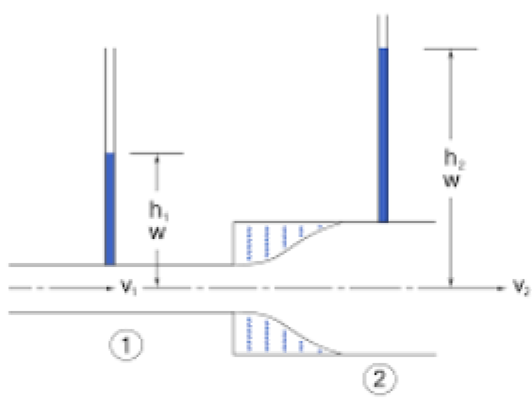


Figure 1. Sudden enlargement of a pipe

1.1.3 Experimental study and results

1) Perform the measurements of head loss at the abrupt change of each section with the different flow rate, then fill in the table as follows:

Q(L/h)	ΔP9−10 (mbar)	ΔP10−11 (mbar)
500	0.10	0.93
600	0.02	0.85
700	0.10	0.93
800	0.22	0.23
900	0.23	2.73
1000	0.23	3.60
1100	0.30	4.60
1200	0.42	5.83

Table 1: The data of experiment 1

2) According to Table 1, we have the graph evolution of the head loss of each pipe as a function of the flow rate ΔP = f (Q).

In theoretical model, we obtained results:

$$\Delta P = \zeta \frac{\rho V^2}{2g}$$

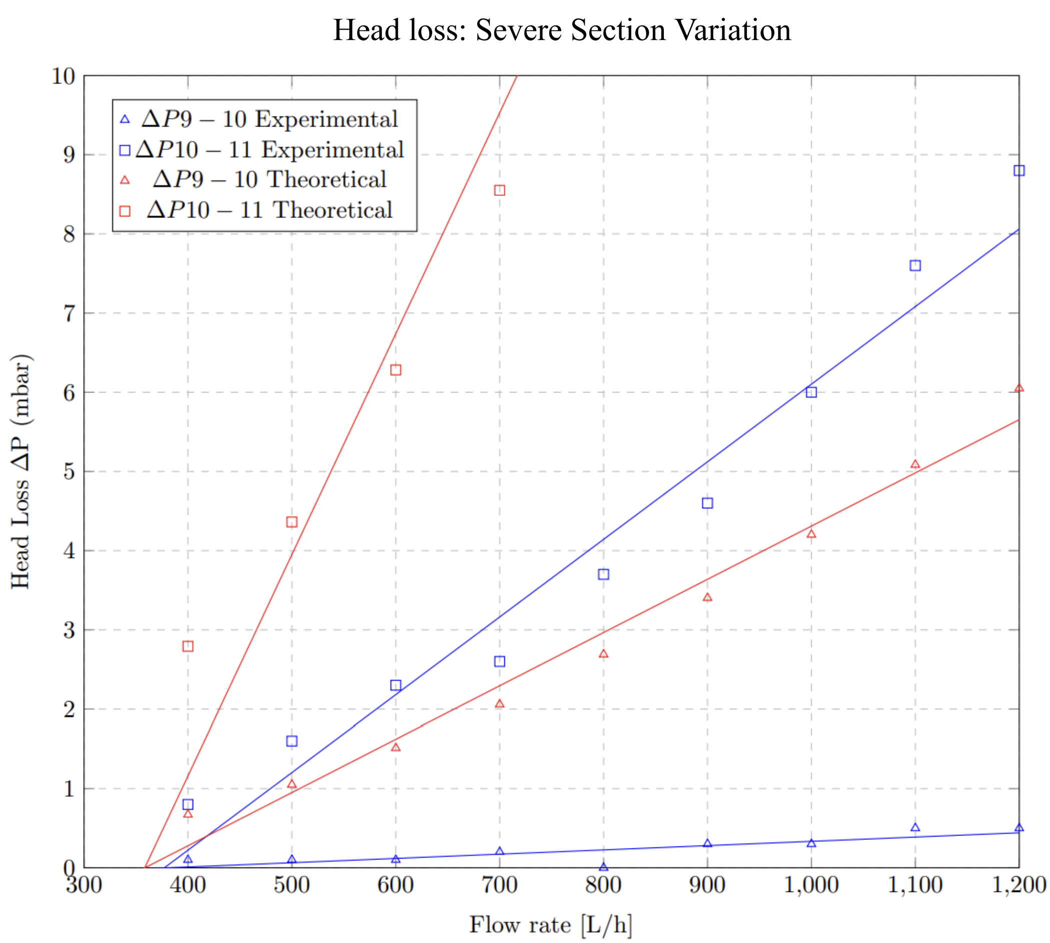
And the coefficient of the pressure drop:

$$\zeta = [1 - \frac{S_1}{S_2}]^2$$

Q(L/h)	ΔP9−10 (mbar)	ΔP10−11 (mbar)
500	1.05	4.36
600	1.51	6.28

700	2.06	8.54
800	2.69	11.16
900	3.40	14.12
1000	4.20	17.43
1100	5.08	21.09
1200	6.05	25.10

Table 2: Theoretical model



1.1.4 Conclusion and some comments on experiment:

Based on the obtained data, it is evident that the head loss increases in proportion to the flow rate. Notably, the rate of change is significantly higher in sudden contractions than in sharp enlargements.

The theoretical model yields higher results compared to the experimental findings, for certain reasons.

- The process of pumping water into the pipes is not flawless, leading to the presence of air bubbles inside the pipes, which alters the pressure drop.
- A portion of the kinetic energy is dissipated as the water flows through various sections of the pipe system that were not included in the experiments. Additionally, there is energy loss associated with maintaining pressure balance in the manometer.
- The equipment utilized in this experiment is outdated, with the presence of moss growth inside leading to an increase in roughness and friction. This, in turn, has an impact on the experimental results.

1.2 Singular Head Loss: Elbow

1.2.1 Purpose of experiment

This study aims to confirm the presence of energy loss when real fluid flows through pipe bends with varying radius and angles.

The nature of elements	Diameter (mm)	Number of pressure taps
Large radius elbow (R0 = 40)	di=14-de=20	13-14
Small radius 90° elbow (R0 = 15) d	di=14-de=20	12-13
Small radius 90° elbow (R0 = 15)	di=14-de=20	14-15
Two 135° elbows	di=14-de=20	15-16
135° elbows	di=14-de=20	16-17
45° elbows	di=14-de=20	17-18

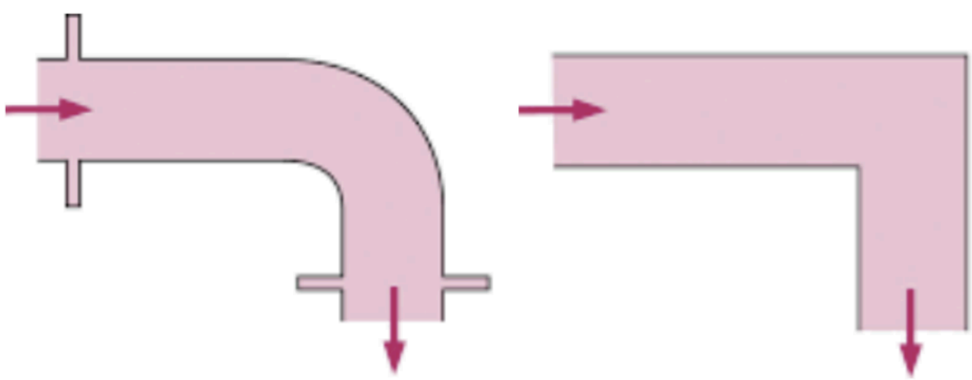


Figure 2: The shape of elbow-pipe

Each branch is fitted with an inlet valve and an outlet valve. The main circuit's output is equipped with a diaphragm valve to enhance the load in the circuit. Pressure taps are strategically positioned along the branches to measure the linear head loss in pipes of varying materials and diameters, under identical conditions.

The measurement of piezometric heights involves opening the small black valve that connects the manometric tubes with the pressure taps situated on the branches.

2) Plot in a same graph (by using Excel or an equivalent software) the evolution of the head loss of each pipe as a function of flow rate

$$\Delta P = f(Q)$$

3) Calculate the coefficients of pressure drop for the given flow of each elbow in the experimental values.

$$\Delta P = \zeta \frac{\rho V^2}{2} \rightarrow \zeta = \frac{\Delta P S^2}{\rho Q^2}$$

Compare the obtained results with the theoretical model. Comment and analyze the results. In theoretical model, the coefficient of the pressure drop for a rounded angle:

$$\zeta = [0.13 + 1.85(\frac{D}{2R_0})^{7/2}] \times \frac{\theta}{90} \tag{3}$$

The coefficient of the pressure drop for a sharp angle:

$$\zeta = sin^2\frac{\theta}{2} + sin^4\frac{\theta}{2} \tag{4}$$

where
D is the diameter of the pipe
Ro is the radius of the elbow
θ is the angle of the curvature

The pressure drop coefficient is calculated using equation (3) by rounding the angle at four levels, and then taking the mean value.

- Pipe 13-14 features a large radius elbow with a radius of R0 = 40mm.
- Pipe 12-13 is equipped with a small radius elbow with a radius of R0 = 15mm.

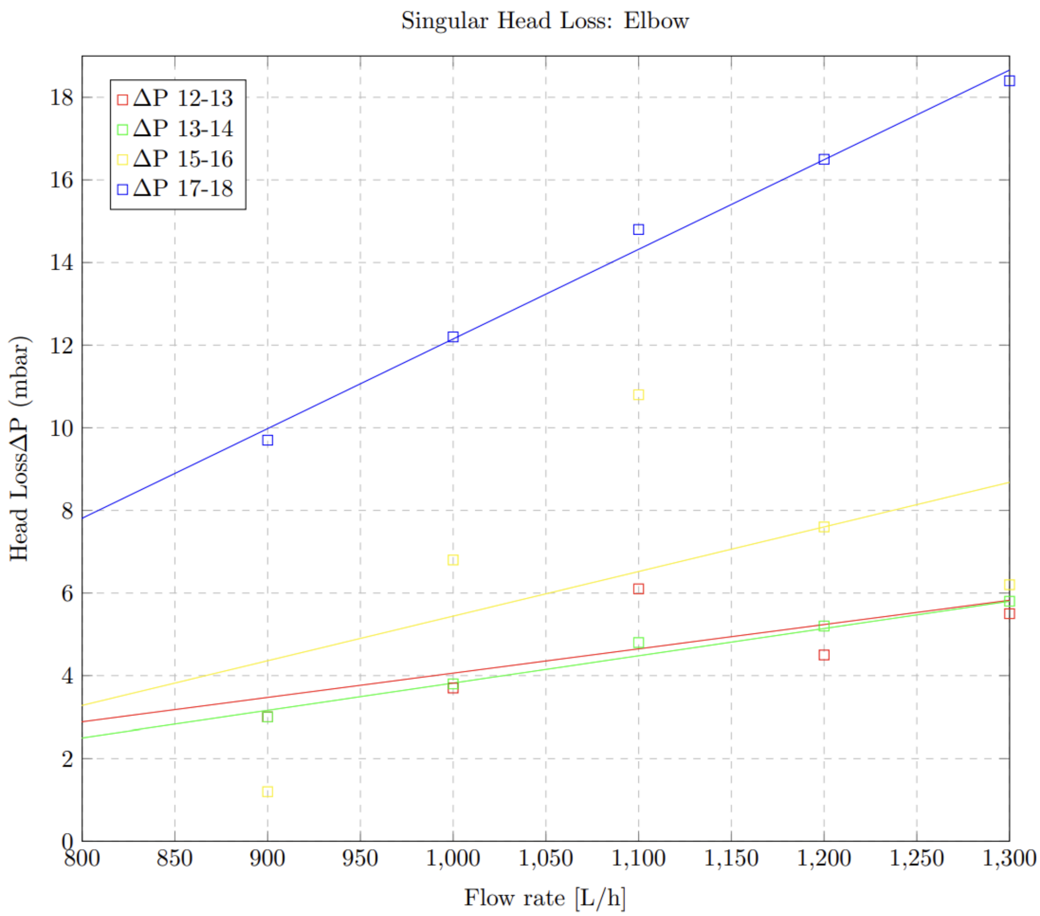
The pressure drop coefficient is calculated using equation (4) by considering the sharp angle at four levels, and then taking the mean value.

- Pipe 15-16 consists of two 135° elbows.
- Pipe 17-18 is equipped with 45° elbows.

1.2.2 Experimental study and results

Flow Rate Q	H12	H13	ΔP	H13	H14	ΔP	H15	H16	ΔP	H17	H18	ΔP
900	35.1	32.1	3	32.1	29.1	3	18.9	20.1	1.2	18	8.3	9.7
1000	47.1	43.4	3.7	43.4	39.6	3.8	23.1	29.9	6.8	26.4	14.2	12.2
1100	64	57.9	6.1	57.9	53.1	4.8	32.8	43.6	10.8	39.1	24.3	14.8
1200	76.5	72	4.5	72	66.8	5.2	45.8	53.4	7.6	48.3	31.8	16.5
1300	88	82.5	5.5	82.5	76.9	5.6	55.9	62.1	6.2	56.4	38	18.4

Table 3: The date of experiment 2



1.2.3 Conclusion and comments:

Generally, the head loss at each elbow exhibits a proportional increase with the flow rate

- Among the four types of elbows examined, the 45° elbows demonstrate the highest head loss, and their changes are also more pronounced compared to the other types.
- The head loss in pipe sections 11 and 12 is the lowest, which is expected as these sections do not contain any elbows.
- The data obtained from the experiment involving two 135° elbows may have lower precision due to various objective factors such as the presence of rusty pipes, moss, and air bubbles, as well as subjective factors like observer errors.

The coefficients of the pressure drops are significantly influenced by the radius of elbows and bending angles, leading to their evolution.

- In the case of rounded angles, a smaller radius of the elbow results in a higher coefficient, indicating a greater impact on the system.

- When considering shaped angles, a sharper bend leads to a higher coefficient, indicating an elevated pressure loss.

1.3 Linear Head Loss for incompressible fluid

1.3.1 Purpose of experiment

In this study, we wish to verify by measurements the existence of energy loss when real fluid passes through straight pipes of constant cross section but different materials and diameters. This energy loss is called linear head loss. The linear head loss represents energy losses due to friction of the fluid in a conduit of constant section.

1.3.2 Description of the apparatus

The pipe network comprises 6 straight and inclined pipes of different diameters:

The nature of elements	Diameter (mm)	Length between 2 pressure taps (mm)	Number of pressure taps
Inclined smooth PVC tube	di=14-de=20	400	19-20
Inclined smooth PVC tube	di=14-de=20	400	21-22
Smooth PVC tube Ø25	di=19-de=25	1000	23-24
Smooth PVC tube Ø20	di=15-de=20	1000	25-26
Smooth PVC tube Ø15	di=10-de=15	1000	27-28
Smooth PVC tube Ø15 rough	di=10-de=15	1000	29-30

Table 4: The table of experiment 3

In each branch, there is an inlet valve and an outlet valve. Furthermore, a diaphragm valve is utilized at the output of the main circuit to enhance the load in the circuit. Pressure taps are placed along the branches to measure the linear head loss in pipes of different materials and diameters, all done under the same conditions.

For the measurement of piezometric heights, the small black valve connecting the manometric tubes with the pressure taps on the branches is opened.

1.3.3 Theoretical part

According to the law of Poiseuille, the linear head loss can be written in the following form:

$$\Delta P = \frac{128\mu L}{\pi . D^4} Q$$

ΔP is the linear head loss (Pa)
D is the diameter of the pipe (m)
L is the length of the pipe (m)
Q is the fluid's flow rate (m3/s)
μ is the fluid viscosity (10-3 Pa.s)

1.3.4 Experimental study and results

1) Our study aims to investigate the linear head loss in the previously mentioned 6 straight pipes from part 2. To achieve this, we will measure the difference in piezometric heights between the upstream and downstream of each pipe for at least 5 flow rate values (800 L/h, 900 L/h, 1000 L/h, 1100 L/h, 1200 L/h).

Q(L/h)	ΔP (Pipe 1 and 2)	ΔP (Pipe 3)	ΔP (Pipe 4)	ΔP (Pipe 5)
800	0.17	0.12	0.32	1.60
900	0.19	0.14	0.36	1.80
1000	0.21	0.15	0.40	2.00
1100	0.23	0.17	0.44	2.20
1200	0.25	0.18	0.47	2.40

Table 5: Theoretical model experiment 3

Flow rate Q	ΔP (Pipe 1)	ΔP (Pipe 2)	ΔP (Pipe 3)	ΔP (Pipe 4)	ΔP (Pipe 5)
800	11.2	8.2	0.5	1.2	3.1
900	12.5	9.1	0.2	1.1	4.1
1000	15.2	11.5	0.3	1.7	5.1
1100	17.1	11.6	0.7	2	2
1200	20.7	16.7	0.7	2.1	6.9

Table 6: The data of experiment 3

In the event that the water level in the piezometric tube becomes excessively high, utilize the manual pump to adjust the water column to a readable value.

2) In the same graph the evolution of the linear head loss of each pipe in the function of flow rate ΔP = f(Q)

3) Furthermore, generate a plot illustrating the relationship between the frictional coefficient λ and the Reynolds number λ = f(Re) for each pipe.

$$\Delta P = \lambda . \frac{\rho L V^2}{2D} \tag{6}$$

And the Reynolds number:

$$Re = \frac{\rho V D}{\mu} = \frac{\rho Q}{\mu \pi D} \tag{7}$$

In theory, we can derive the frictional coefficient, according to the Poiseuille law:

$$\Delta P = \frac{128 \mu L}{\pi D^4} Q$$

We have:

$$\frac{128 \mu L}{\pi D^4} Q = \lambda . \frac{\rho L V^2}{2D}$$

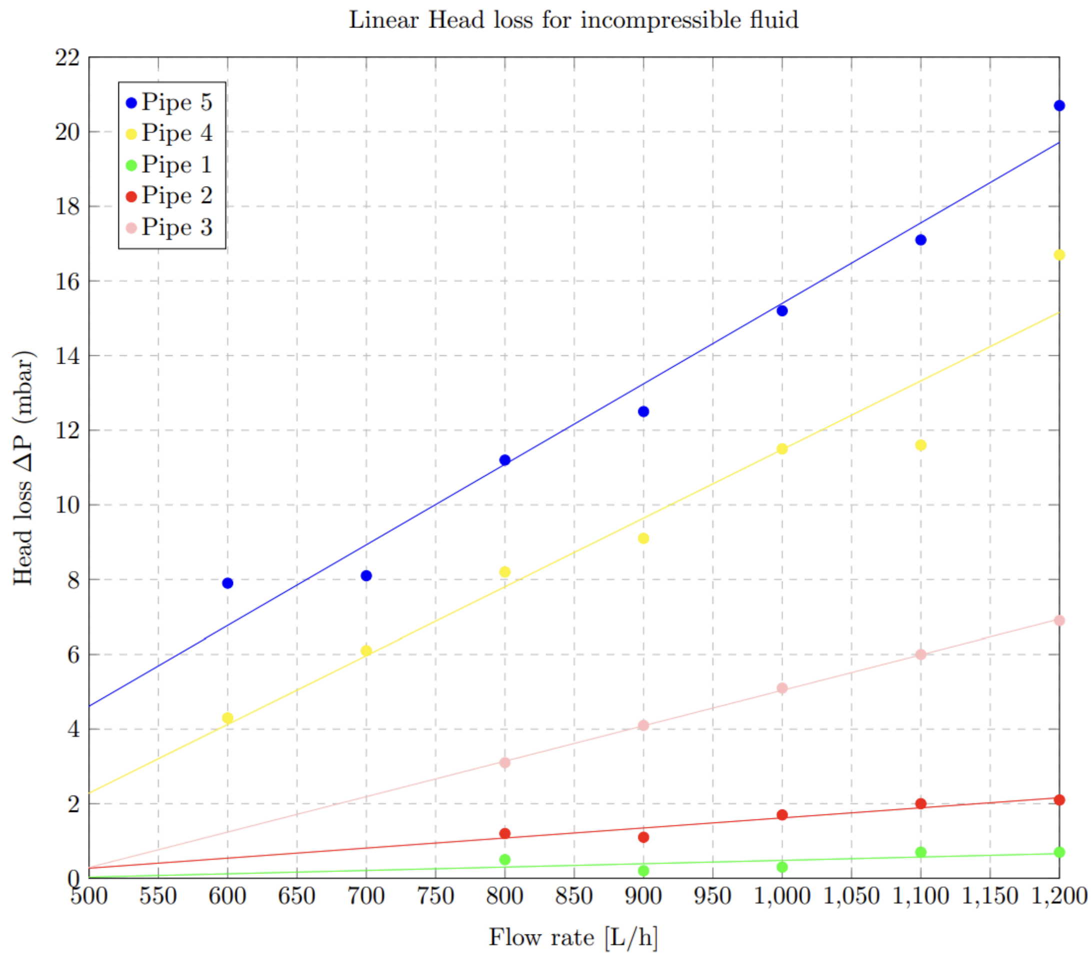
$$\lambda = \frac{256 \mu Q}{\rho \pi V^2 D^3} = \frac{64 \mu}{\rho V D}$$

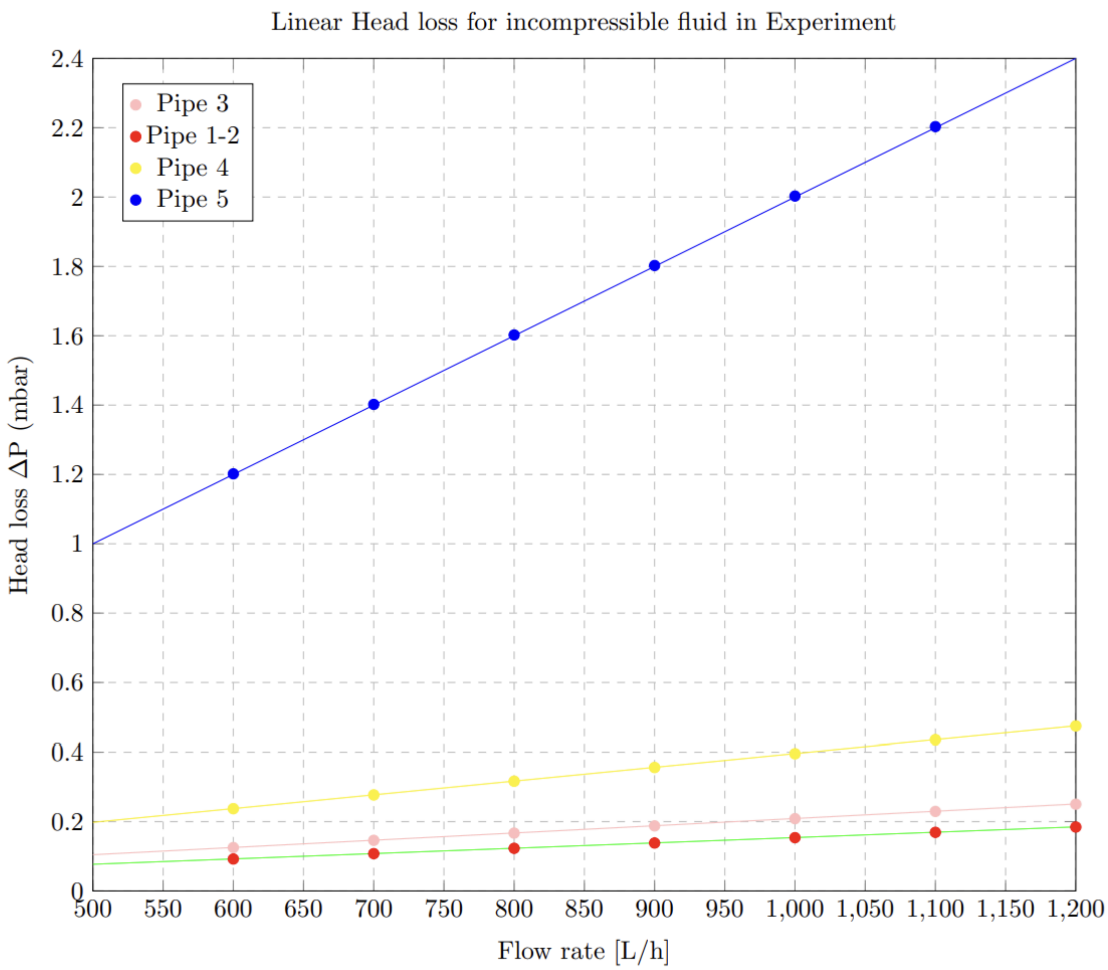
Hence:

$$\lambda = \frac{64}{Re}$$

Analyze the results, then compare the experimental results with the theoretical values of the pressure losses.

4)For Q= 500 L/h, plot the curves ln (ΔP)= f(ln(D)).





According to Poiseuille's Law:

$$\Delta P = \frac{128L}{\pi.D^4}.Q$$

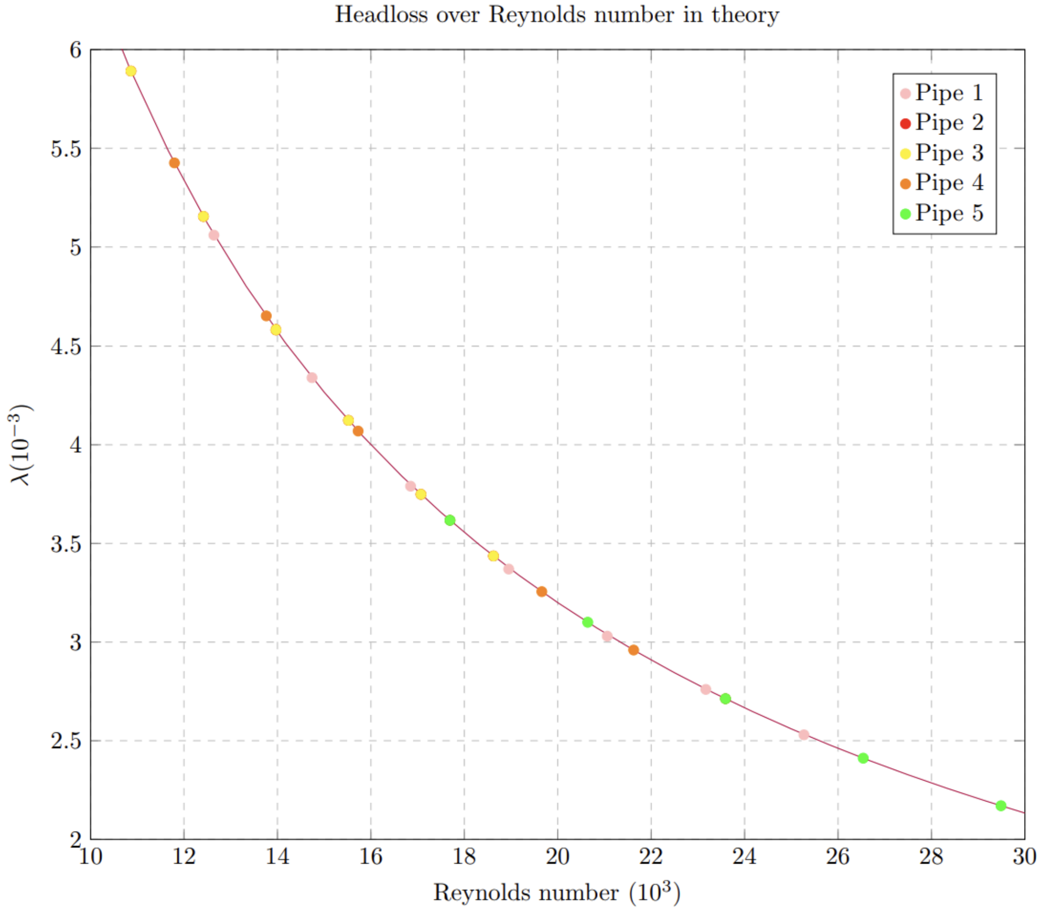
And equation relates the pressure loss with the Reynold number:

$$\Delta P = \lambda.\frac{\rho L V^2}{2D}$$

Thus, we can derive the expression for frictional coefficient λ

$$\lambda = \frac{64}{Re}$$

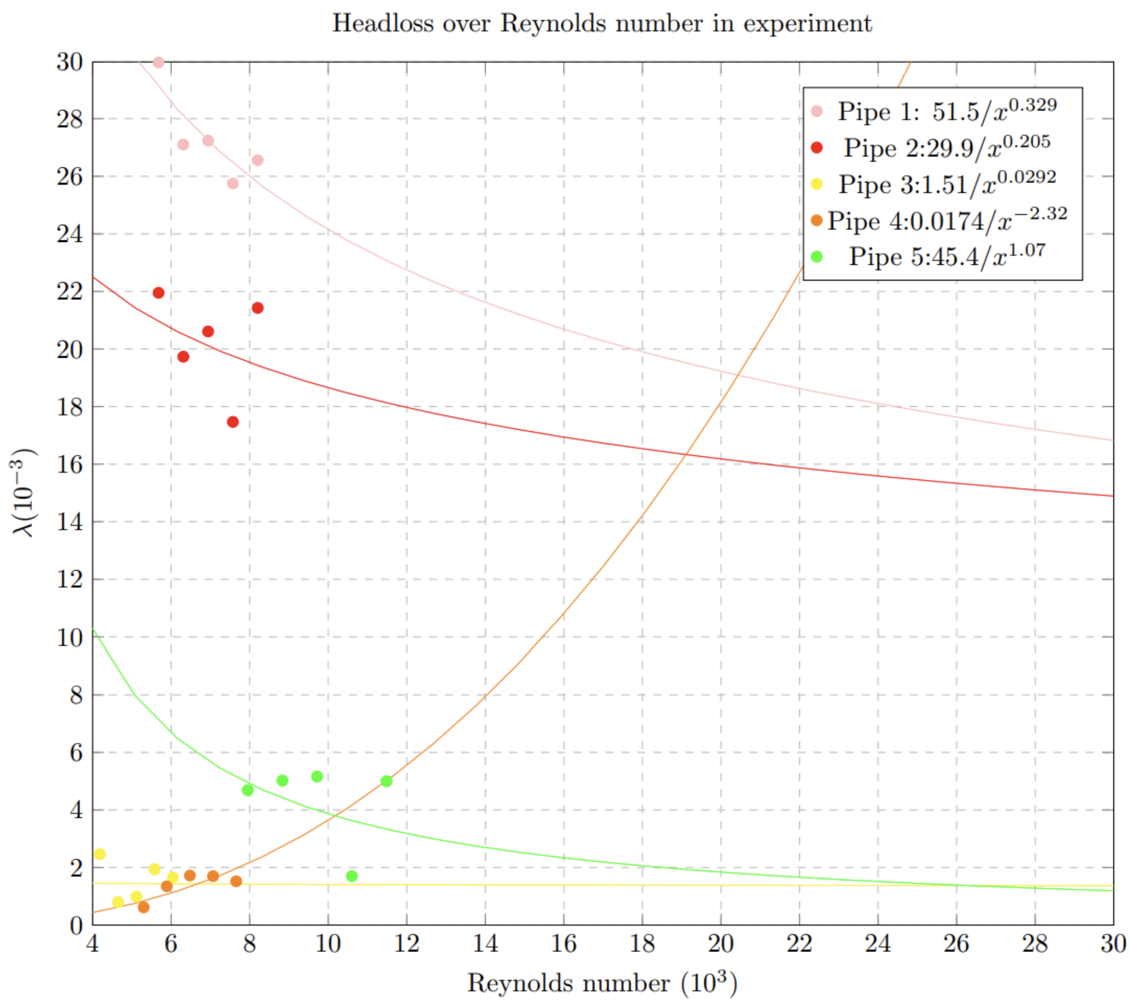
The frictional coefficient is only depend on the Reynolds numbers, in the theory



From the equation:

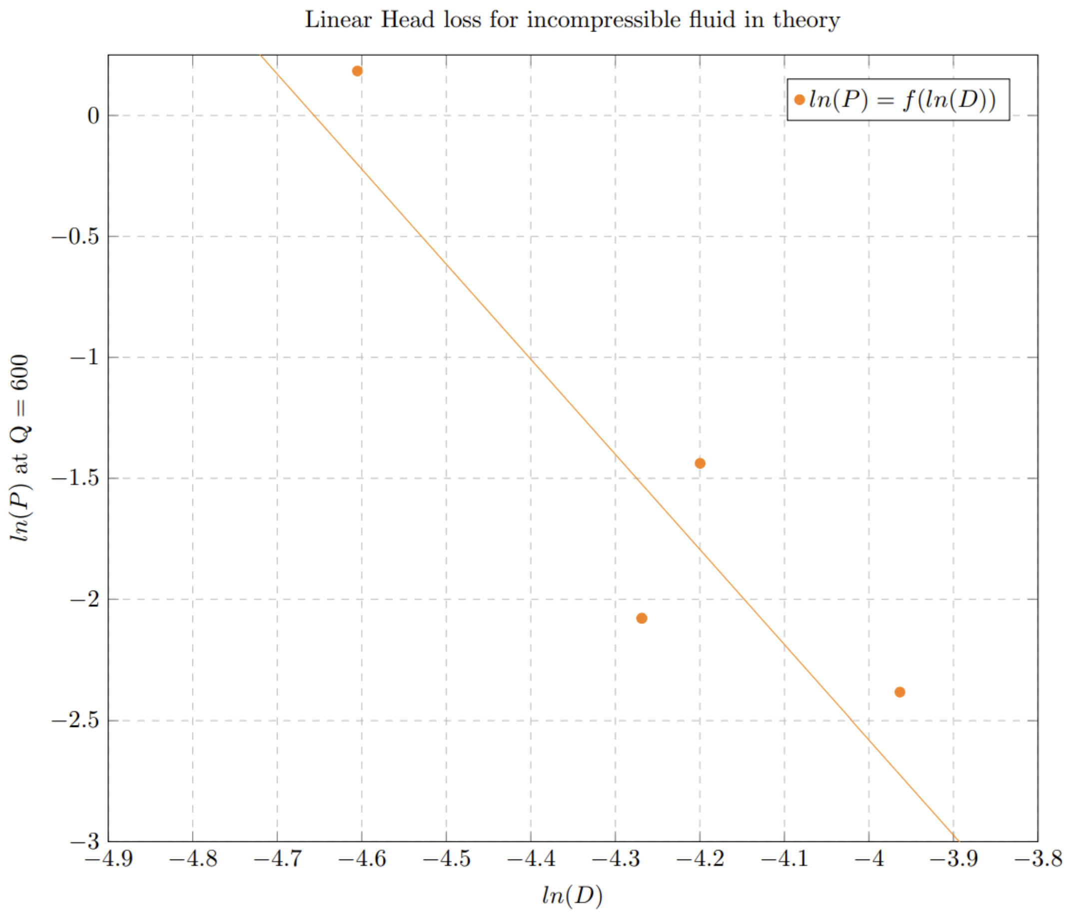
$$\Delta P = \lambda . \frac{\rho L V^2}{2D}$$

We have the plot of λ = f(Re):



The data obtained from the practical experiment does not exhibit a strong correlation with the theoretical model when attempting to fit the power series to each pipe.

- Pipe 1 and pipe 2 exhibit higher coefficients compared to the theoretical values, suggesting the presence of excessive moss and other substances inside the pipes.
- Pipe 3 demonstrates a low and consistent frictional coefficient throughout the pipe section, deviating from the theoretical expectations.
- The data obtained from pipe 4 exhibits a contradictory pattern compared to the theoretical model, indicating the possibility of errors in the equipment or inaccuracies in the data recorded by the observers.
- Pipe 5 demonstrates the highest degree of similarity to the theoretical models, albeit with slightly lower data values.



Despite the limited amount of acquired data, the trendline generated through the linear regression method reveals a consistent decrease in the logarithm of pressure loss as compared to the logarithm of diameter.

1.3.5 Conclusion and comments

In this experiment, we close one of the outlet valve on experiment of two inclined smooth PVC tube to obtain the readable data.

The data collected during the experiment display both similarities and differences in behavior as compared to the theoretical model.

• There is a correlation between the increase in flow rate and the growth of head loss.
• The head loss in the two inclined tubes is higher compared to that of smooth PVC tubes, both in the experimental and theoretical settings.
• In reality, the head loss appears to be higher than predicted by the theoretical model.
• Despite the theoretical expectation of equal head loss in the two inclined PVC tubes, the actual results exhibit slight variations, likely attributable to the dissipation of kinetic energy during fluid flow over different distances.

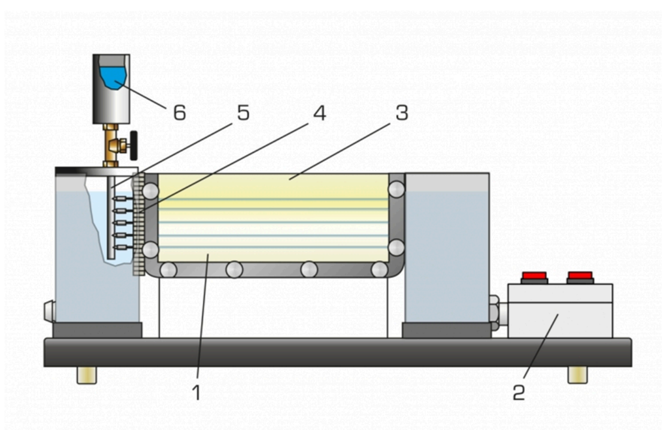
The data obtained in the calculation of the frictional coefficient using the Reynolds Number does not exhibit strong agreement with the theoretical model. It is advisable to conduct a further experiment with an enhanced setup or explore an alternative theoretical model for better accuracy.

Through the utilization of the linear regression method, the data demonstrates a clear pattern of decreasing head loss as the diameter is reduced. This observation is consistent with the logical premise that a smaller surface area for fluid flow corresponds to a reduced probability of friction.

2. HM 153 Visualization of Different Flows

2.1 Equipment

1. Flow section
2. Control unit for pump and illumination
3. Transparent front panel
4. Nozzles
5. Distributor for ink
6. Ink reservoir



2.2 Experiment

2.2.1 Cylinder cross section

- The ink flows around the shape of the circle and at the end it combines and creates a triangle shape right behind the circle.
- The velocity at the top of the circle is equal to the bottom since the circle shape is balanced; there aren't any differences between the top and bottom, and so are the density of the two ink flows.

https://drive.google.com/file/d/1cyLFTTlSHEBj-h-5267GcscgW7oZEie2/view?usp=sharing

2.2.2 Trapezoidal rectangle

- The density of the ink flow at the top is lower than that at the bottom because of the trapeze rectangle shape. It makes the ink flow disbalance; the top has more contact area than the bottom. And at the end of the obstacle the ink flow combines and creates a straight line.

- The velocity at the top is larger than the bottom because the density at the top is lower than the bottom.

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2.2.3 Symmetrical aerofoil

- The density and velocity of the air flow at the top is equal to the bottom because of its symmetry. However, due to the contact area of the experiment 3 shape is smaller than experiment 1 so the velocity of experiment 3 is larger than experiment 1.
- At the end the ink flow combines and creates a straight line like experiment 2 and this experiment doesn't create any lift.

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2.2.4 Asymmetrical aerofoil

- The velocity of the ink flow at the top is greater than the velocity at the bottom and the density of the ink flow at the top is lower than the density at the bottom because the contact area at the top is larger than at the bottom.

- The two-ink flows combine and create a teardrop shape and this experiment creates lift due to the shape of the aerofoil.

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