University of Science and Technology of Hanoi
Department of Space and Application

Fluid Mechanics

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Practical Report

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Contents

List of Figures

List of Tables

1 Measurement of Headloss with Plant MP76

1.1 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	$d_i = 14 - d_e = 20$ and $d_i = 20 - d_e = 34$	9-10
Sudden contraction	$d_i = 20 - d_e = 34$ and $d_i = 14 - d_e = 20$	10-11

with: d_i is internal diameter of the pipe and d_e is external diameter of the pipe.

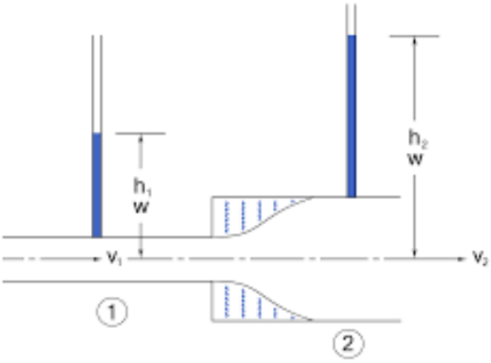


Figure 1: Sudden enlargement of a pipe

1.1.3 Experimental study and results

1) Measure the head loss at each section's sudden shift for each flow rate.

Q(L/h)	ΔP_{9-10} (mbar)	ΔP_{10-11} (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:

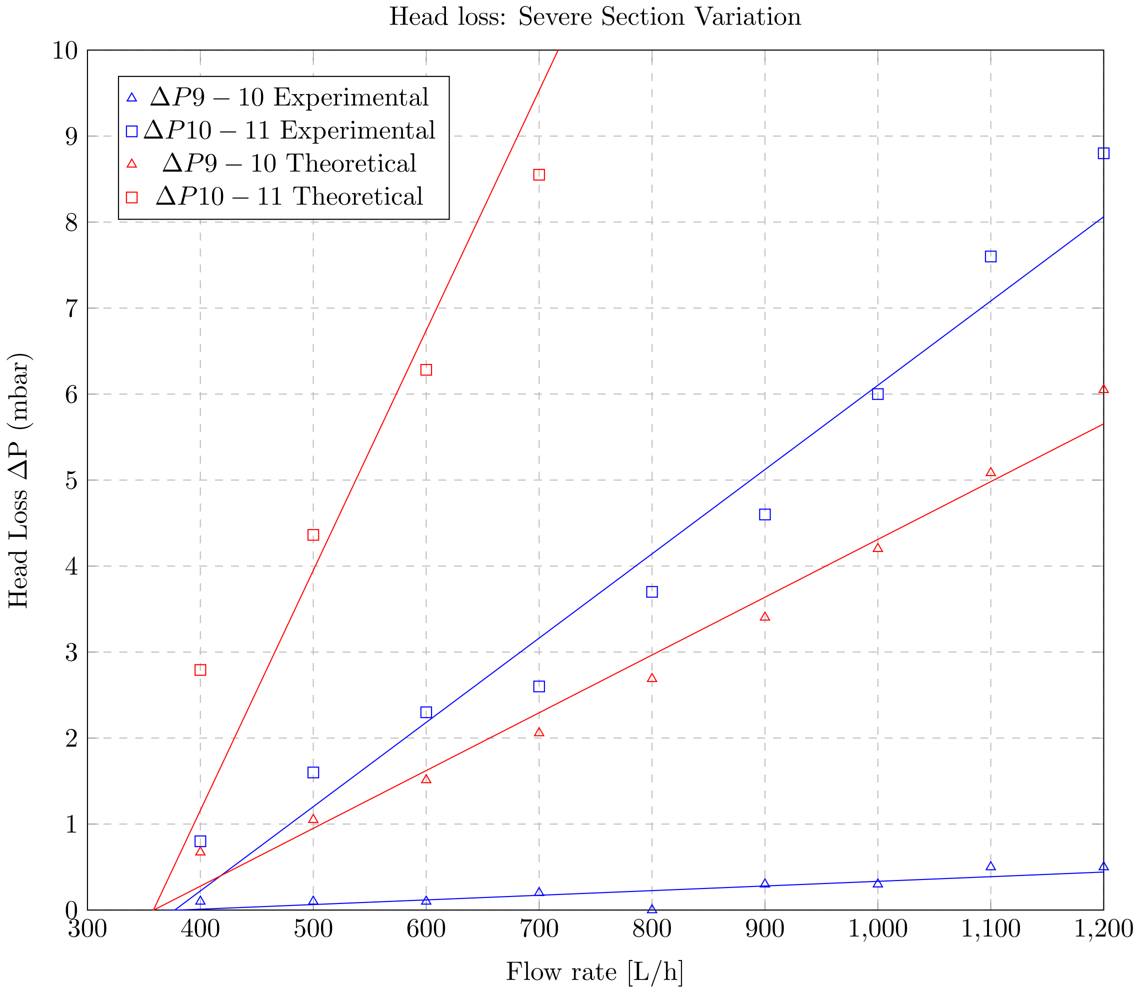
$$\Delta P = \zeta \frac{\rho V^2}{2g} \tag{1}$$

And the coefficient of the pressure drop:

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

Q(L/h)	ΔP_{9-10} (mbar)	ΔP_{10-11} (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


Head loss: Severe Section Variation
$\Delta P9 - 10$ Experimental
$\Delta P10 - 11$ Experimental
$\Delta P9 - 10$ Theoretical
$\Delta P10 - 11$ Theoretical
Head Loss ΔP (mbar)
Flow rate [L/h]
0
1
2
3
4
5
6
7
8
9
10
300
400
500
600
700
800
900
1,000
1,100
1,200

1.1.4 Conclusion and some comments on experiment:

From the data obtained above, it is clear that the head loss is increase proportional to the flow rate, but the change is much more rapidly in sudden contraction compared to that in sharp enlargement.

The results obtained from the theoretical model is higher than that of the experiment, for some reasons:

- The process of pumping the water into the pipes is not perfect, so the presence of air bubbles inside the pipes change the pressure drop.
- Part of kinetic energy is dissipated when the water flow through different sections of pipe system which is not involved in the experiments. And also, some energy loss for balancing the pressure in the manometer.
- The equipment used in this experiment is old, some of moss is growing inside causing a increase in the roughness and friction which somehow affect the result of experiment.

1.2 Singular Head Loss: Elbow

1.2.1 Purpose of experiment

In this study, we need to verify the existence of energy loss when the real fluid passes through the bends of pipes with different radii and angles. f

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)	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

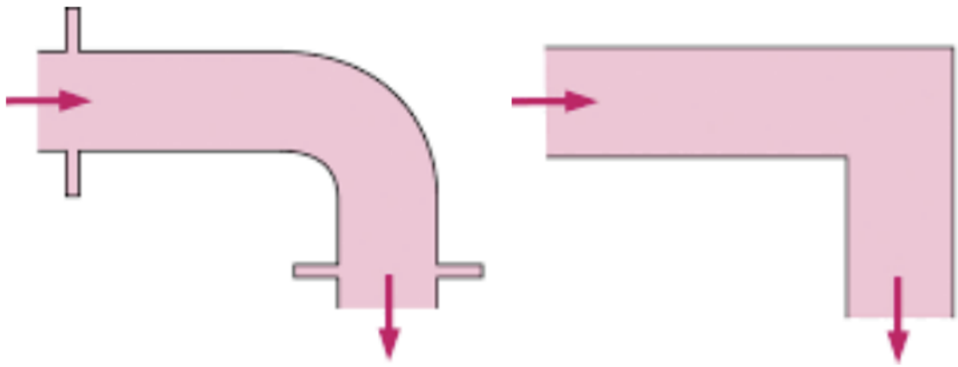


Figure 2: The shape of elbow-pipe

Each branch is equipped with an inlet valve and an outlet valve. At the main circuit's output, a diaphragm valve is used to increase load in the circuit.
Pressure taps are placed along the branches in order to measure, under the same condition, the linear head loss in pipes of different materials and diameters.

Notes: Measurement of piezometric heights: piezometric heights are measured by opening the small black valve connecting the manometric tubes with the pressure taps located 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 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
R_0 is the radius of the elbow
θ is the angle of the curvature

Using equation (3) to calculate the pressure drop coefficient as rounded angle at four levels and take the mean value:

- Pipe 13-14 has a large radius elbow with Radius R_0 = 40mm.
- Pipe 12-13 has a small radius elbow with Radius R_0 = 15mm.

Using equation (4) to calculate the pressure drop coefficient as sharp angle at four levels and take the mean value:

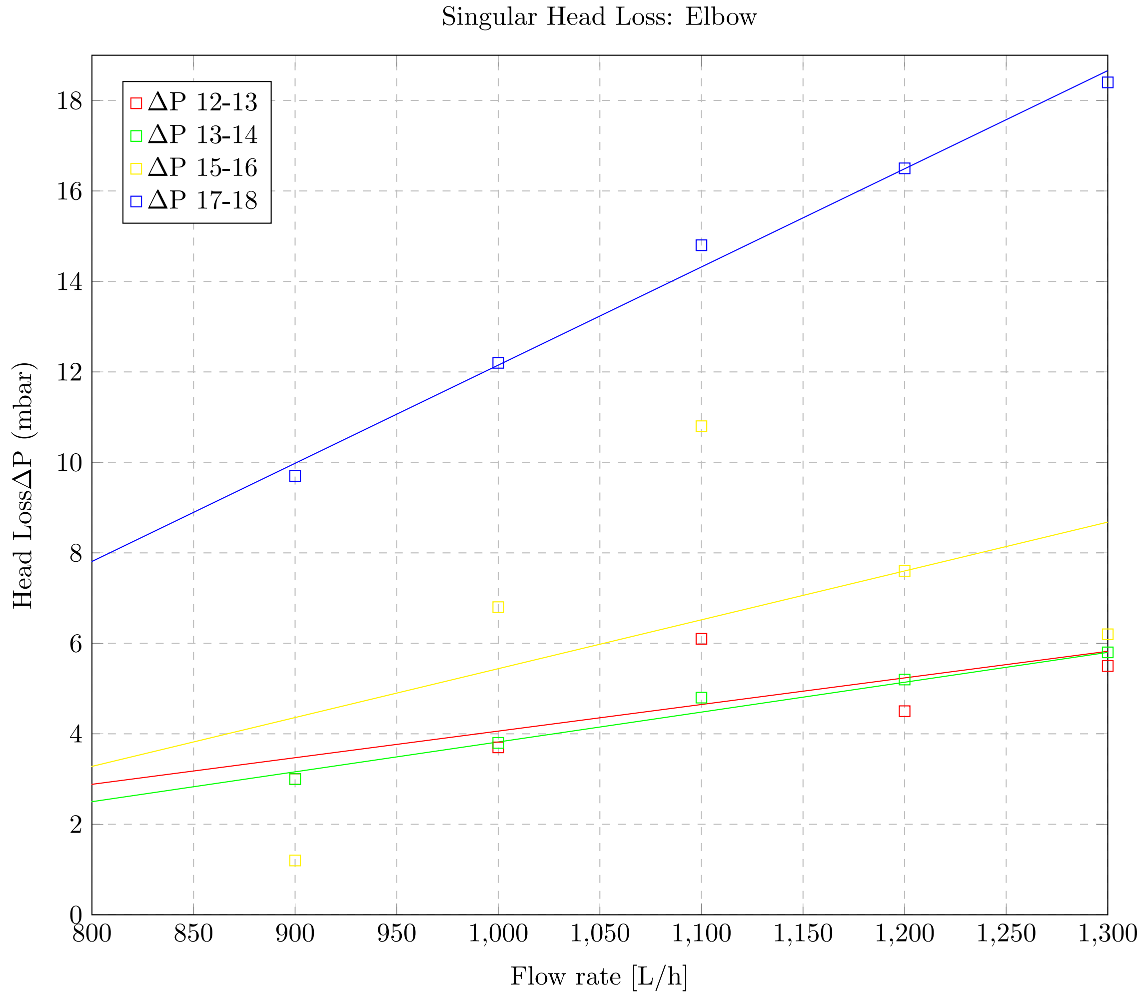
- Pipe 15-16 has two 135^o elbows.
- Pipe 17-18 has 45^o elbows.

1.2.2 Experimental study and results

Flowrate Q	H_{12}	H_{13}	ΔP	H_{13}	H_{14}	ΔP	H_{15}	H_{16}	ΔP	H_{17}	H_{18}	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

- Notes: For some items, it is necessary to slightly close the outlet valve (the blue one) of the singular head loss line so as to obtain a readable value of the pressure drop across the two piezometric tubes. If the water level in the piezometric tube is too high, use the manual pump to bring the water column to a readable value.



1.2.3 Conclusion and comments:

In general, the head loss at each elbow have the tendency to increase proportional to the flow rate.

- In four types of elbow considered, the 45^o elbows have highest head loss, and also changes more dramatically than others.
- The head loss from pipe section 11 and section 12 is the lowest which is reasonable because this section has no elbow.
- The data obtained in the experiment of two 135^o elbows do not have the high precision may due to some of objective reasons such as the rusty pipes or the moss and air bubbles inside, or some of subjective reasons like the mistakes of observers.

The evolution of the coefficients of the pressure drops depends largely on the radius of elbows and bending angles.

- Rounded angles: The smaller radius of elbow lead to the higher coefficient which means more kinetic energy is dissipated.

- Shaped angles: The sharper bend leads to higher coefficient, suggested that the pressure loss is higher

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

Each branch is equipped with an inlet valve and an outlet valve.At the main circuit's output, a diaphragm valve is used to increase load in the circuit.
Pressure taps are placed along the branches in order to measure, under the same condition, the linear head loss in pipes of different materials and diameters.
Notes: Measurement of piezometric heights: piezometric heights are measured by opening the small black valve connecting the manometric tubes with the pressure taps located on the branches.

1.3.3 Theoretical part

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

$$\Delta P = \frac{128L}{\pi.D^4}.Q \tag{5}$$

Where: 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 (m^3/s)
µ is the fluid viscosity (10^{-3} Pa.s).

1.3.4 Experimental study and results

1) We will study the linear head loss in 6 straight pipes previously described in part 2. For at least 5 values of flow rate (800 L/h, 900 L/h, 1000 L/h, 1100 L/h, 1200 L/h), measure the difference of piezometric heights between the upstream and downstream of each pipe

Notes: For some items, it is necessary to slightly close the outlet valve (the blue one) of the singular head loss line so as to obtain a readable value of the pressure drop across the two piezometric tubes.

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 expreriment 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

If the water level in the piezometric tube is too high, use the manual pump to bring 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 $\Delta P = f(Q)$

3) In addition, plot the curve of the frictional coefficient λ as a function of Reynold number $\lambda =$ 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:

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

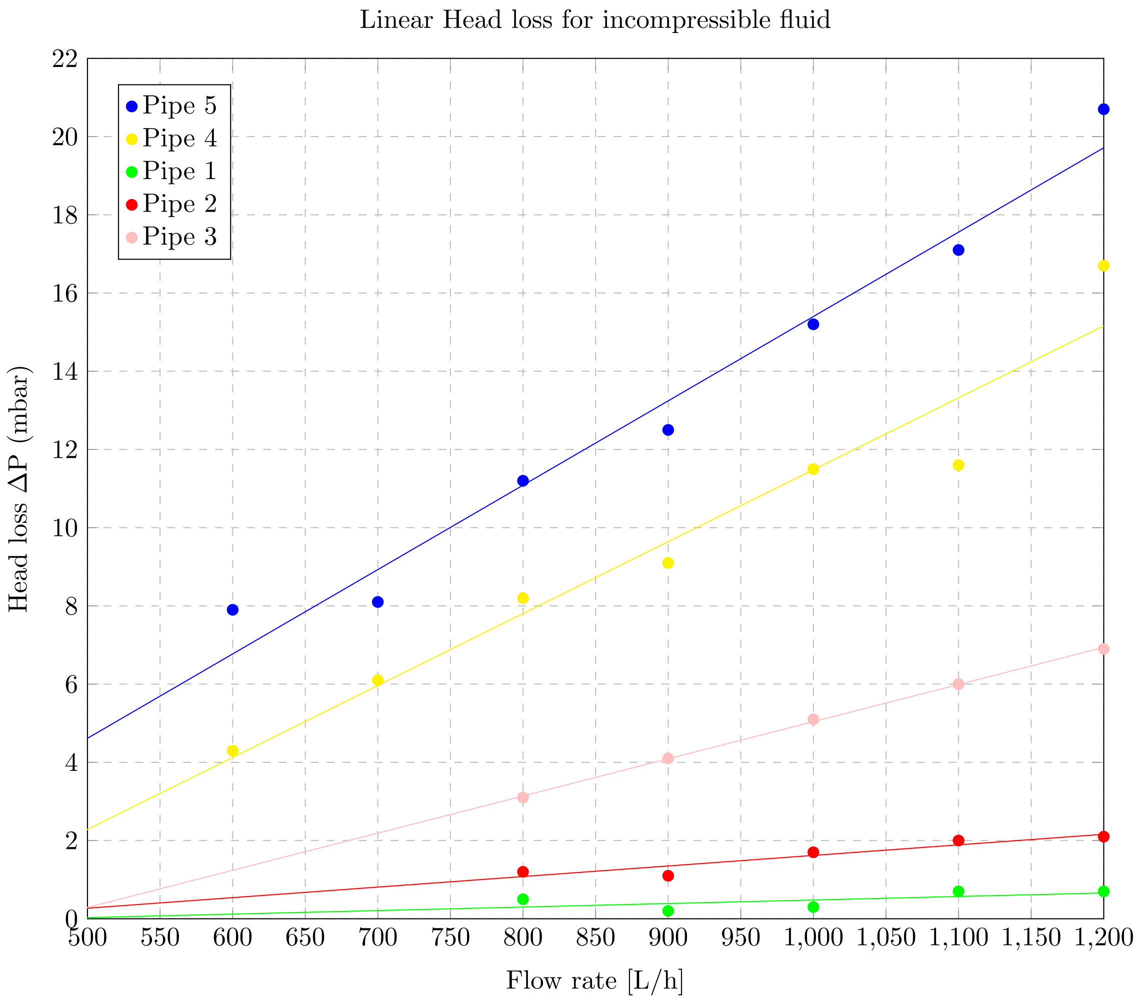
$$\lambda = \frac{256 \mu Q}{\rho \pi V^2 D^3} = \frac{64 \mu}{\rho V D}$$

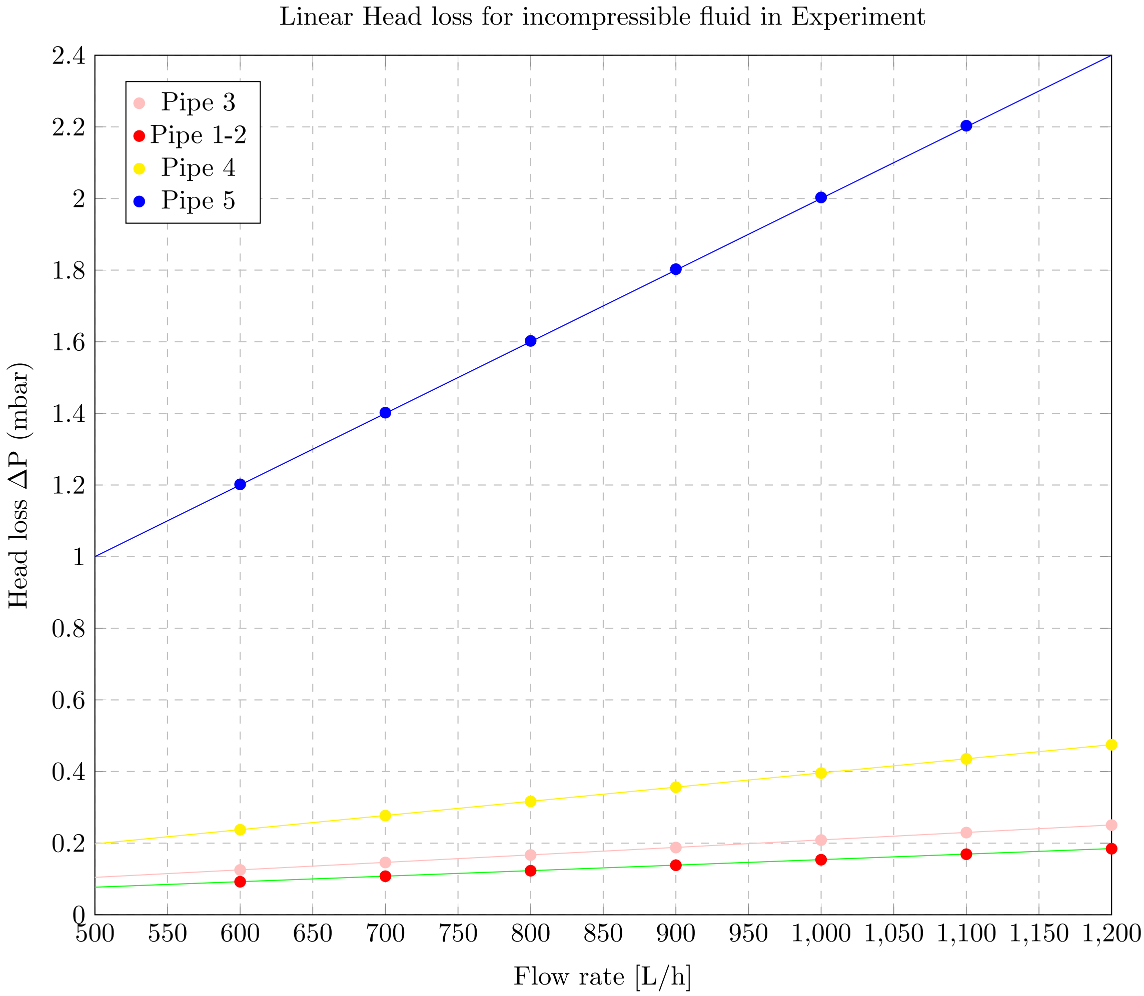
Hence:

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

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)).




Linear Head loss for incompressible fluid in Experiment
Pipe 3
Pipe 1-2
Pipe 4
Pipe 5
Head loss ΔP (mbar)
Flow rate [L/h]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
500
550
600
650
700
750
800
850
900
950
1,000
1,050
1,100
1,150
1,200

According to Poiseuille Law:

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

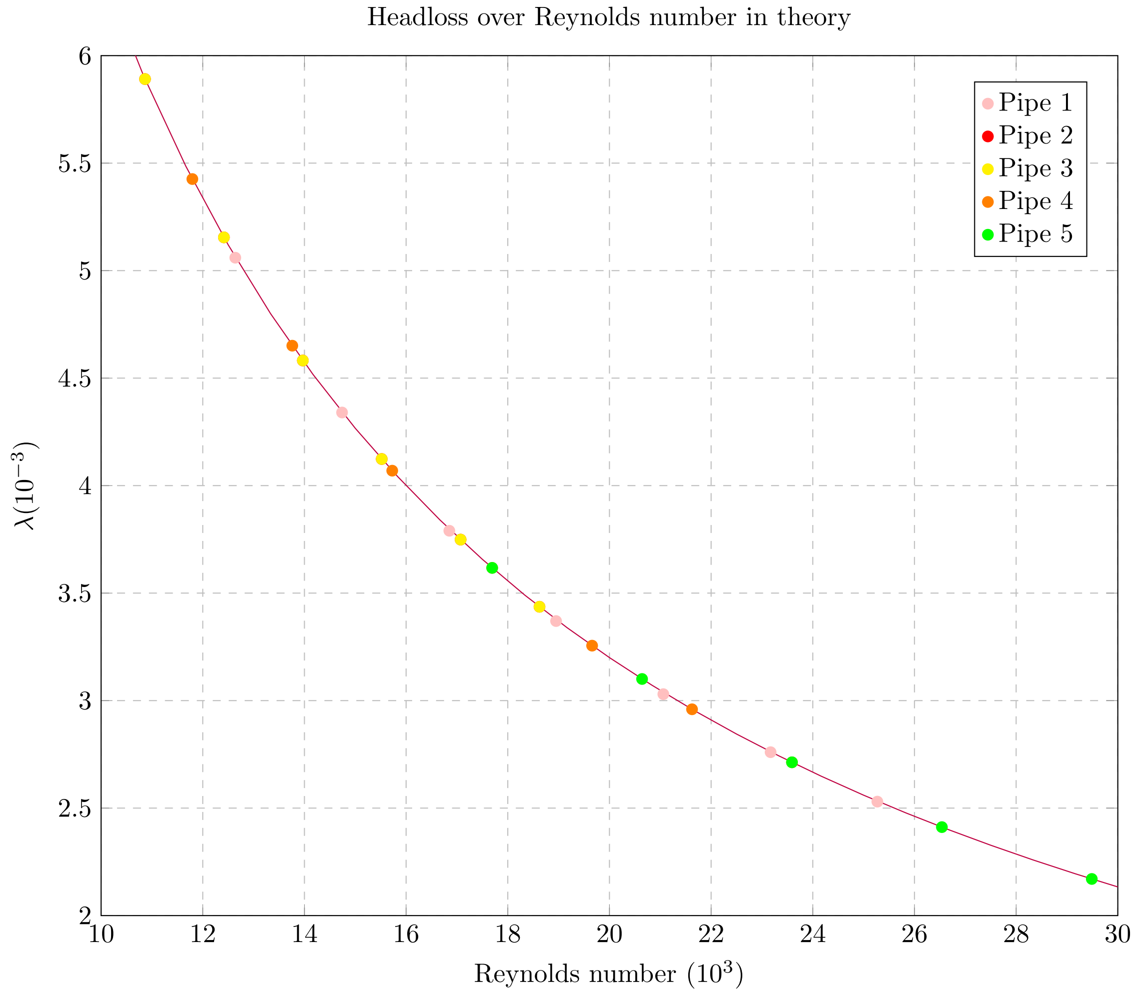
And equation relates the pressure loss with the Reynold number:

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

Thus, we can derive the expression for frictional coefficient λ

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

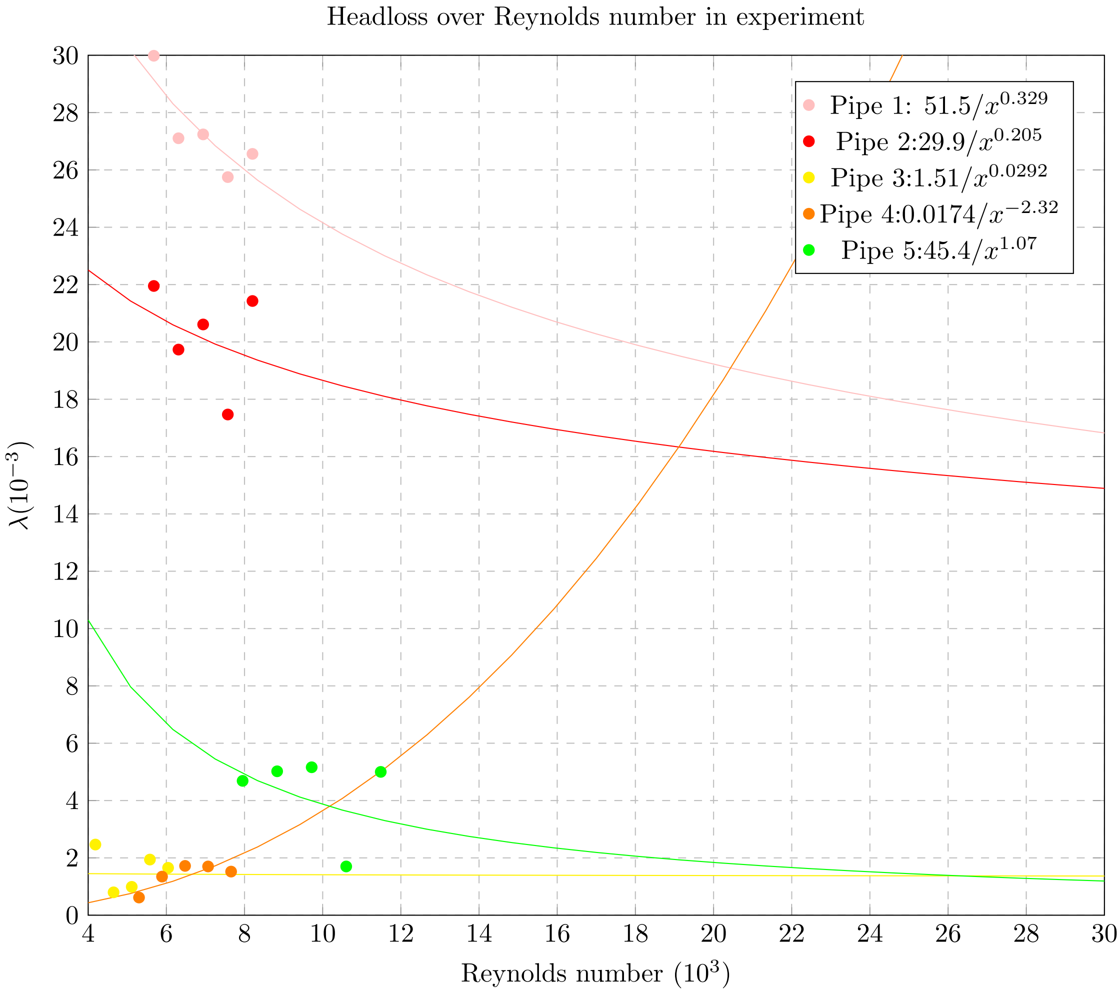
The frictional coefficient is only depend on the Reynolds numbers, in the theory;



From the equation:

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

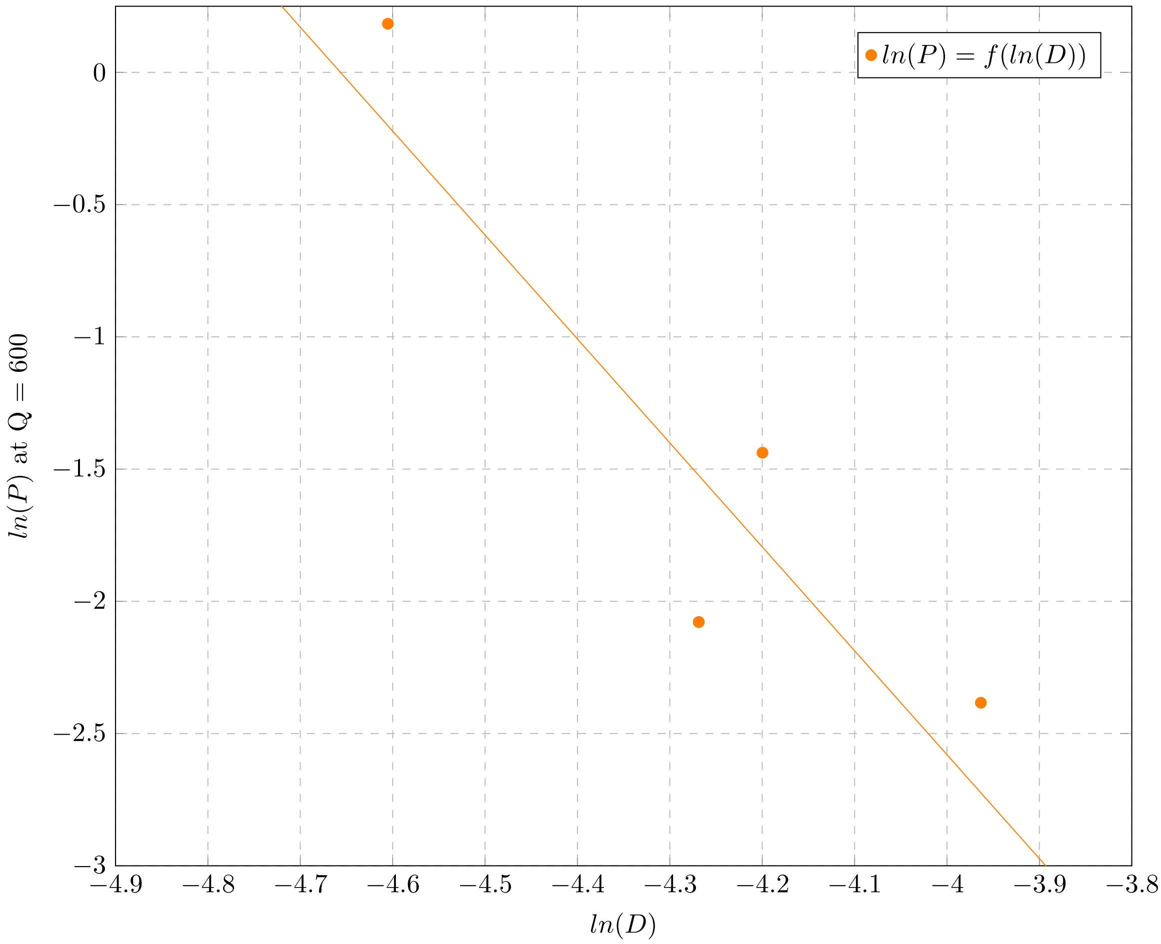
We have the plot of $\lambda = f(Re)$:



The data obtained from the practical experiment is not really correlate with the theoretical model when we try to fit the power series to each pipe,

- Pipe 1 and pipe 2 has too high coefficient compared with the theory, indicating that there are too much moss and other things inside the pipes.
- Pipe 3 is has low and consistent frictional coefficient over the pipe section compared with theory.
- Data from pipe 4 shows an opposite tendency with theoretical model, that may caused by errors by the equipment or in the process of recorded data by observers.
- Pipe 5 presents the most similar trend with the theoretical models (data is in fact slightly lower).

Linear Head loss for incompressible fluid in theory



The amount of data we acquired is quite low, however, the trendline obtained by the linear regression method show a tendency of decrease in logarithm of pressure loss in comparison with 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 in the experiment have the some similar and different behaviors with the theoretical model:

- The Head loss grows correlative to the increase in the flow rate.
- The head loss in two inclined tubes are higher than that of smooth PVC tubes in both experiment and theory.
- The head loss in the reality seems to be higher than that of theoretical model.
- While the head loss in two inclined PVC tubes in theory is the same, in reality the results acquired is slightly different which is possibly due to the kinetic energy dissipation when the fluids travel in different distances.

In the calculation of the frictional coefficient with the Reynolds Number, the data obtained is not really harmonize with the theoretical model. It's suggested that we should conduct another experiment with better set-up or we may consider a better theoretical model.

By using the linear regression method, the data show that the head loss decreases with the reduction in diameter which is reasonable because the less surface the fluid have to run over, the lower chance of friction.

2 Air Flow Experiments

2.1 Basic Principles

2.1.1 Measurement of the static pressure and the total pressure

The **static pressure** p_{stat} is the pressure that the air at rest exerts on an area. It is measured with a static tube.
The **total pressure** p_{total} is the sum of static pressure and dynamic pressure. It is measured with a Pitot tube.
The **dynamic pressure** p_{dyn} is generated by the flowing air and depends on the velocity of the air.
The dynamic pressure is determined as follows:

$$p_{dyn} = p_{total} - p_{stat} \tag{8}$$

p_{dyn}	Dynamic pressure
p_{total}	Total pressure
p_{stat}	Static pressure

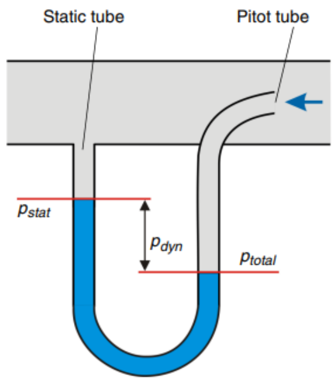


Figure 3: Pressure measurement with water tube manometers

2.1.2 Determining the dynamic pressure at measuring point 1

In the **HM 220 Air Flow Experimental Plant** the sucked-in air enters the pipe section through the inlet element. Due to the geometry of the inlet element, the difference between the reference pressure and the pressure at measuring point 1 is equal to the dynamic pressure at measuring point 1.

The basis for this shall be explained in the sections below.

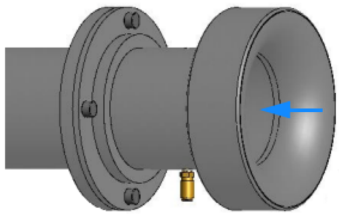


Figure 4: Inlet element with measuring point 1

The inlet element has a streamlined contour that prevents constriction of the air flow. Thus we can assume that the flow between inflow and measuring point 1 does not exhibit pressure losses. For the ambient air and the air at each flow cross section of the pipe section we can say:

$$p_{total} = p_{stat} + p_{dyn} \tag{9}$$

For the **ambient air** (index amb) we can state:

$$p_{amb,total} = p_{amb,stat} + p_{amb,dyn} \tag{10}$$

At a sufficient distance from the inlet element the ambient air is at rest and the dynamic pressure is 0.
It follows:

$$p_{amb,dyn} = 0 \tag{11}$$

and thus

$$p_{amb,total} = p_{amb,stat} \tag{12}$$

For the flow cross-section at measuring point 1 (index 1) the following applies:

$$p_{1,total} = p_{1,stat} + p_{1,dyn} \tag{13}$$

Since the flow between the inflow and measuring point 1 does not exhibit pressure losses, the total pressure of the ambient air and the total pressure at measuring point 1 are equal:

$$p_{amb,total} = p_{1,total} \tag{14}$$

If we substitute Formula (4.5) and Formula (4.6) into Formula (4.7) we get:

$$p_{amb,stat} = p_{1,stat} + p_{1,dyn} \tag{15}$$

After transforming the equation we get:

$$p_{1,dyn} = p_{amb,stat} - p_{1,stat} \tag{16}$$

Due to the position of measuring point 1, the air does not flow into this measuring nozzle but rather past it. Therefore, **at measuring point 1 the static pressure** $p_{1,stat}$ is measured:

$$p_1 = p_{1,stat} \tag{17}$$

The pressure of the ambient air acts on any manometer tube that is not connected to any measuring point. In accordance with Formula (4.5) it follows:

$$p_{amb} = p_{amb,stat} \tag{18}$$

The difference between the pressure of the ambient air and the pressure at measuring point 1 is therefore the difference between the static pressures:

$$p_{amb} - p1 = p_{amb,stat} - p_{1,stat} \tag{19}$$

According to Formula (4.9) **the difference between the pressure of the ambient air and the pressure at measuring point 1 is equal to the dynamic pressure at measuring point 1**:

$$p_{amb} - p1 = p_{1,dyn} \tag{20}$$

2.1.3 Calculating the velocity and the flow rate

The **velocity v** of the flow is calculated as follows:

$$v = \sqrt{\frac{2p_{dyn}}{\rho}} \tag{21}$$

v	Velocity
p_{dyn}	Dynamic pressure
ρ	Specific gravity (for air: 1,2kg/m^3)

The dynamic pressure measured in the centre of a pipe section is a measure of the maximum flow velocity in the pipe. The mean velocity can be assumed to be 80...88% of the maximum velocity. The **flow rate** V is calculated:

$$A = \pi.\frac{d^2}{4} \tag{22}$$

$$\dot{V} = 0.8A\sqrt{\frac{2p_{dyn}}{\rho}} \tag{23}$$

2.1.4 Calculating the flow rate with orifice plate or nozzle

Using the energy equation and continuity equation and with the help of some key figures, the flow rate is calculated as follows:

$$\dot{V} = \alpha.\epsilon.A.\sqrt{\frac{2.\Delta p}{\rho}} \tag{24}$$

$\dot{V}$	Flow rate
α	Flow coefficient Nozzle: Nozzle = 1,1377 Orifice plate: Orifice = 0,7588
ϵ	Expansion factor Nozzle: $\epsilon_{Nozzle} = 0,937$ Orifice plate: $\epsilon_{Orifice} = 0,9705$
A	A Cross-sectional area of the orifice plate or nozzle A = $1.964\mathrm{mm}^2$
Δp	Differential pressure between the measuring point upstream and downstream of the orifice plate or nozzle
ρ	Specific gravity (for air: 1,2kg/m^3)

The flow coefficient is a correction factor that takes into account the friction losses and geometric conditions.
The expansion factor corrects the density change of the fluid as a result of the pressure loss at the orifice plate or nozzle.
α and ϵ are determined empirically. The values used here are taken from DIN EN ISO 5167.

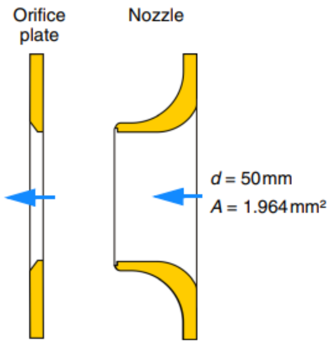


Figure 5: Cross-sectional Area

2.2 Experiment 1: Determining flow rate with the orifice plate or nozzle

2.2.1 Objective of the experiment

This experiment determines the flow rate by using an orifice plate or nozzle.

2.2.2 Preparation for the experiment

1. Set up the experimental plant and connect it.
2. Install the orifice plate
3. Remove the pinhole from the fan outlet
4. Adjust the manometer panel
5. Use hoses to connect measuring points 15 and 16 to the nozzles on the manometer panel. Ensure that there are no kinks in the hoses.

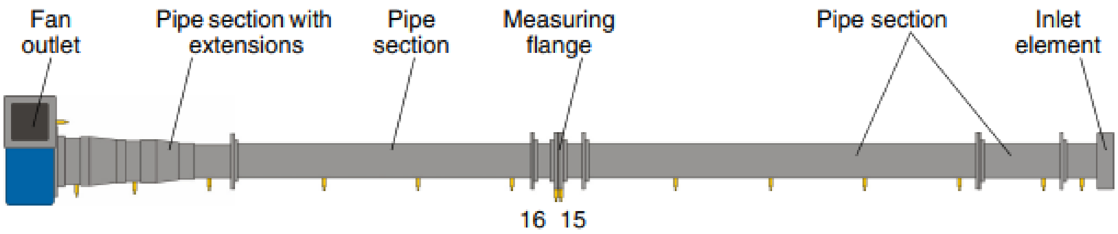


Figure 6: Experiment 1; Experiment set-up

Pipe section/Accessory	Measuring point	Measured pressure
Measuring flange	15	Static pressure upstream of the orifice plate or nozzle
	16	Static pressure down stream of the orifice plate or nozzle

Table 7: Experiment 1: Measuring points

2.2.3 Conducting the experiment

1. Turn the main switch on.
2. Turn the fan switch on.
3. Set the desired flow rate on the manometer tubes.
4. Repeat the experiment
   - With different flow rates that you set on the potentionmeter.
   - with the orifice plate or nozzle

2.2.4 Analysis of the experiment

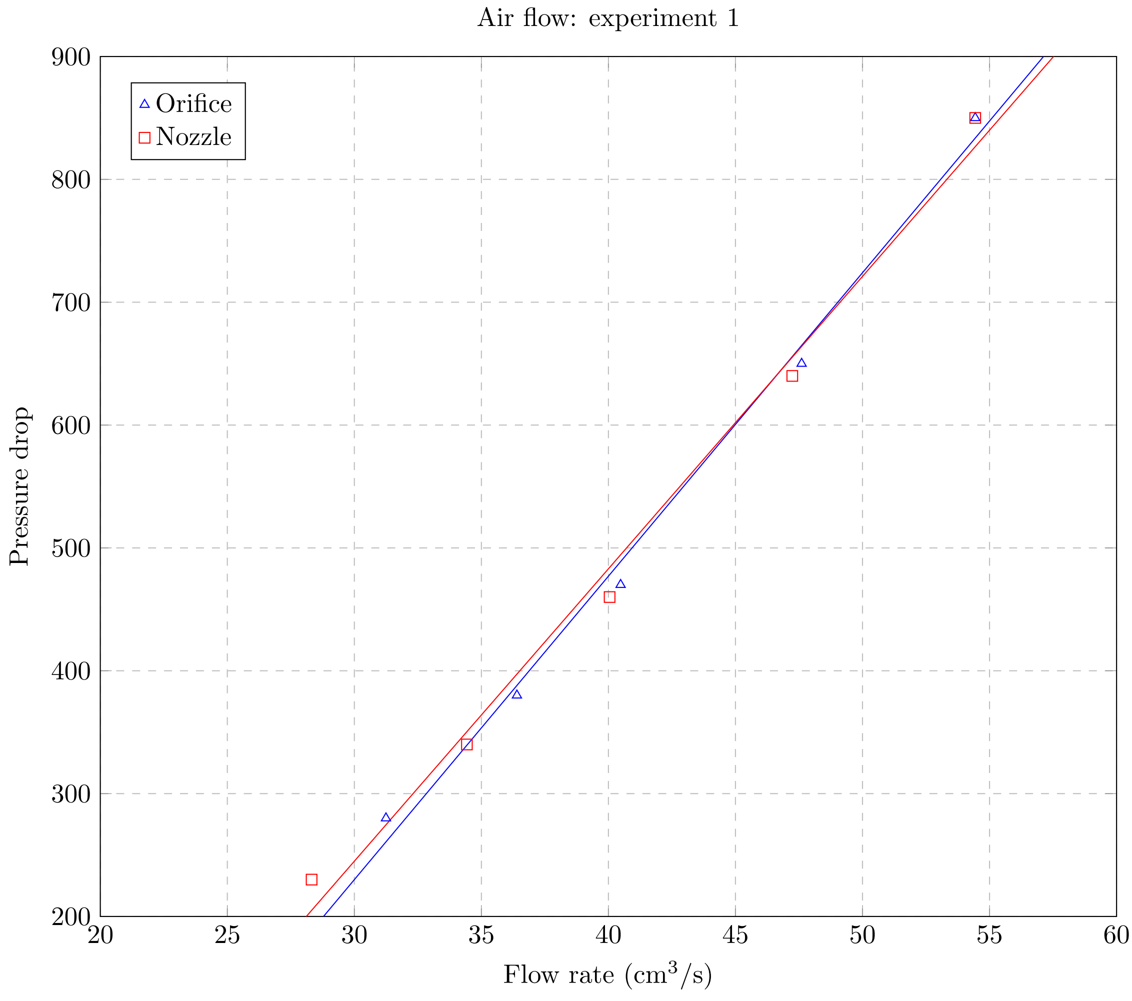
1. Calculate the pressure loss between measuring point 15 and 16.
2. Calculate the flow rate.

Potential meter position	Pressure loss (Pa)	Flow rate (m^3/s)
5	280	0.0000312
6	380	0.0000364
7	470	0.0000405
8	650	0.0000476
9	850	0.0000544

Table 8: The data of experiment 1 with orifice

Potential meter position	Pressure loss (Pa)	Flow rate (m^3/s)
5	230	0.0000283
6	340	0.0000344
7	460	0.0000400
8	640	0.0000472
9	850	0.0000544

Table 9: The data of experiment 1 with nozzle



Some comments:

- The flow rate measured with the orifice and nozzle is quite small compared with other set-up.
- In both nozzle and orifice, the pressure drops are proportional to the flow rate.
- Although the rate of pressure loss over flow rate of the flow rate of the orifice is slightly greater than that of nozzle, the difference between these two set-ups is modest.

2.3 Experiment 2: Determining flow rate with the iris diaphragm

2.3.1 Objective of the experiment

This experiment determines the flow rate by means of the iris diaphragm.

2.3.2 Preparation for the experiment

1. Set up the experimental plant and connect it.
2. Create the experiment setup according to Fig. 5.2. Tab. 5.2 lists the required measuring points.
3. Remove the pinhole from the fan outlet
4. Adjust the manometer panel
5. Use hoses to connect measuring points 17 and 18 to the nozzles on the manometer panel. Ensure that there are no kinks in the hoses.

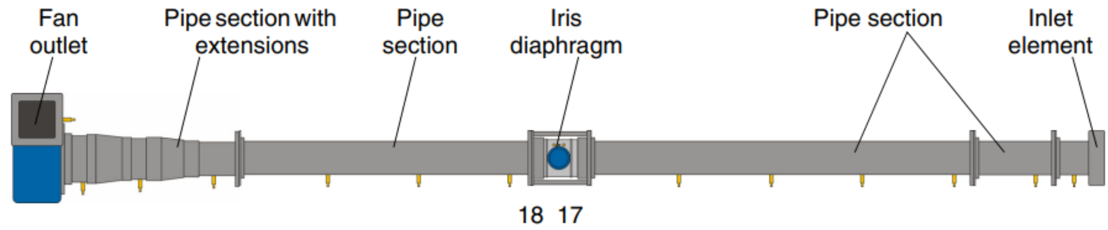


Figure 7: Experiment2: Experiment set-up

Pipe section/Accessory	Measuring point	Measured pressure
Iris diaphragm	17	Static pressure upstream of the iris diaphragm
	18	Static pressure downstream of the iris diaphragm

Table 10: Experiment 2: Measuring points

2.3.3 Conducting the experiment

1. Turn the main switch on
2. Turn the fan switch on
3. Set the desired flow rate on the potentiometer
4. Read off the pressures from the manometer tubes.
5. Repeat the experiment with different flowrates that you set on the potentiometer.

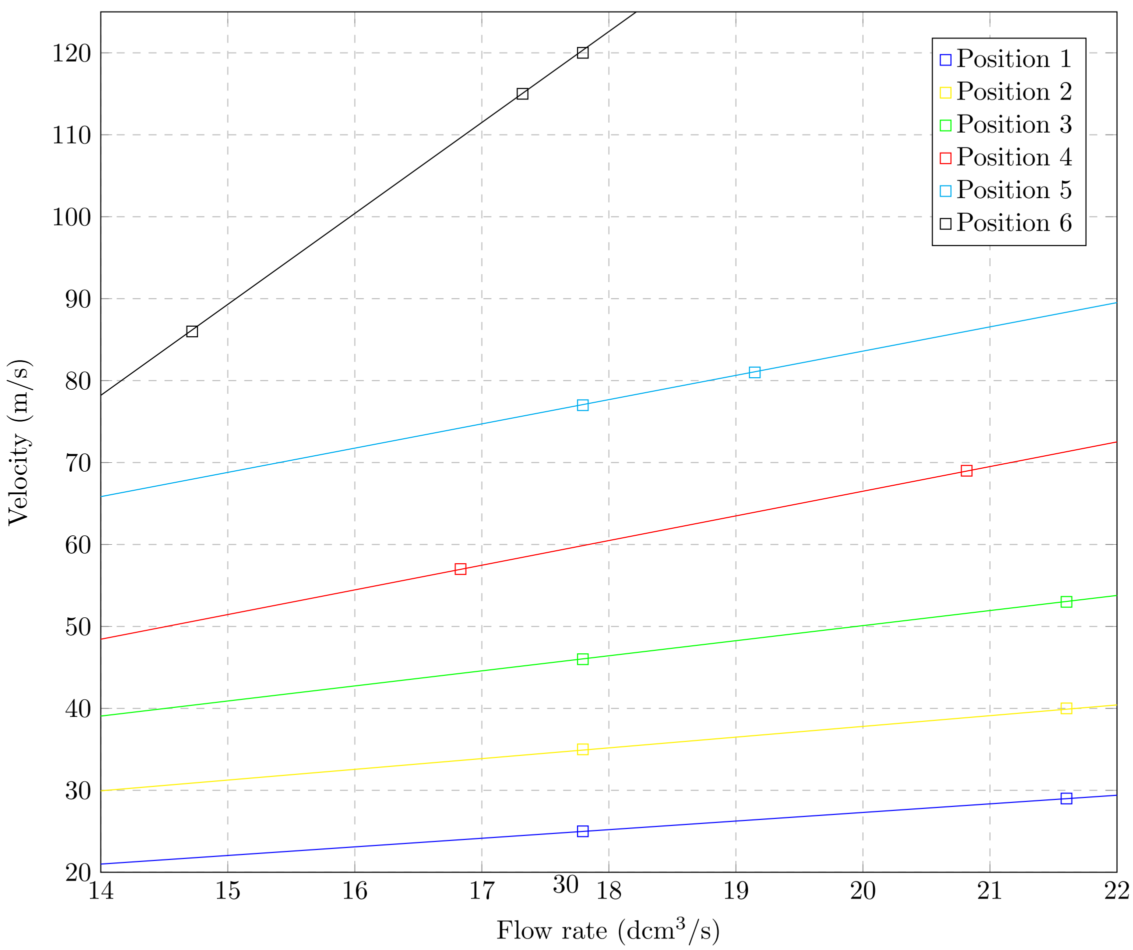
2.3.4 Analysis of the experiment

1. Calculate the pressure loss between measuring point 17 and 18.
2. Use the measurement chart for the iris diaphragm to calculate the velocity and the flowrate

Position of iris diaphragm	Pressure drop	Velocity (m/s)	Flow rate (dm^3/s)
1	190 280	17.795 21.602	25 29
2	190 280	17.795 21.602	35 40
3	170 260	17.795 21.602	46 53
4	170 260	16.833 20.817	57 69
5	170 220	17.795 19.194	77 81
6	180 130 190	17.321 14.720 17.795	115 86 120

Table 11: The data of experiment 2

Air flow: Experiment 2



Some comments:

- The Flow rate of the each position on iris diaphragm can be determined from the differential pressure by Figure 14 in Worksheet 2.
- As we analyse the results, some of the data our group had taken is unexpectedly out of the range provided. However, from the plot, the trend of velocity increase with the flow rate is clear.
- Also, the velocity trendlines over the flow rate rise from position 1 to position due to the decrease in diameters.

2.4 Experiment 3: Determining flow rate with the Pitot tube in the pipe section

2.4.1 Objective of the experiment

This experiment determines the flow rate by using a Pitot tube.

2.4.2 Preparation for the experiment

1. Set up the experimental plant and connect it
2. Create the experiment setup according to Fig. 5.3. Tab. 5.3 lists the required measuring points.
3. Remove the pinhole from the fan outlet
4. Adjust the manometer panel
5. Adjust the Pitot tube for the total pressure so that it is vertical in the centre of the pipe cross-section
6. Use hoses to connect measuring points 19 and 20 to the nozzles on the manometer panel. Ensure that there are no kinks in the hoses.

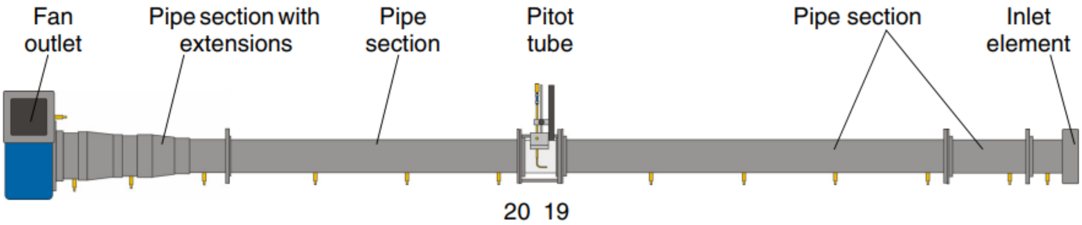


Figure 8: Experiment3: Experiment set-up

Pipe section/Accessory	Measuring point	Measured pressure
Iris diaphragm	19	total
	20	Static pressure

Table 12: Experiment 3: Measuring points

2.4.3 Conducting the experiment

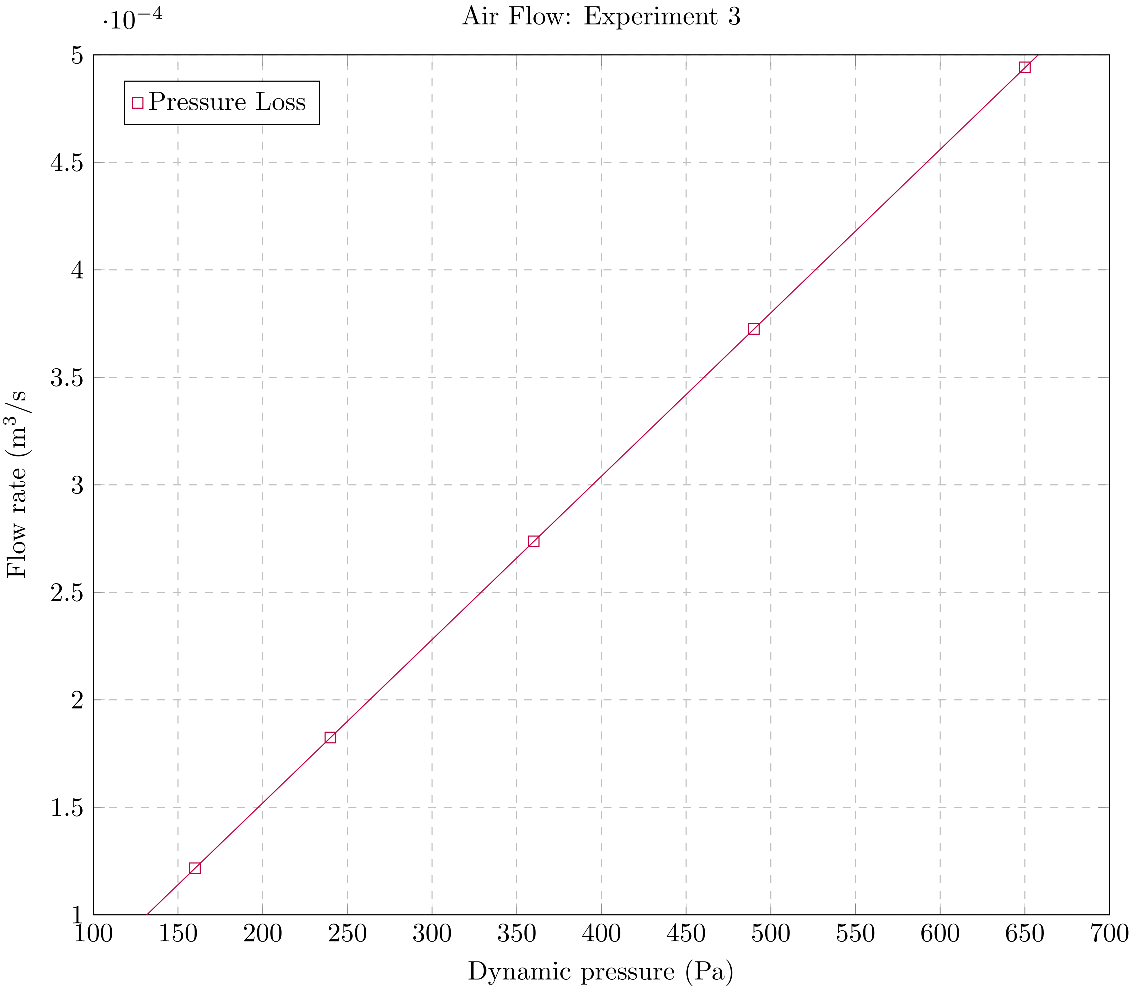
1. Turn the main switch on
2. Turn the fan switch on
3. Set the desired flow rate on the potentiometer.
4. Read off the pressures from the manometer tubes.
5. Repeat the experiment with different flowrates that you set on the potentiometer.

2.4.4 Analysis of the experiment

1. Calculate the differential pressure between measuring point 19 and 20. This represents the dynamic pressure.
2. Calculate the flow rate.

Potential meter position	Dynamic pressure	Flow rate
5	160	0.00012
6	240	0.00018
7	360	0.00027
8	490	0.00037
9	650	0.00049

Table 13: The data of experiment 3



Some comments:
Using the pitot tube, we can obtain the dynamic pressure from the calculation. It is clear that the flow rate is increase linearly with the dynamic pressure.

2.5 Experiment 4: Pressure losses in pipe sections

2.5.1 Objective of the experiment

This experiment determines the pressure loss across a pipe section without fixtures.

2.5.2 Preparation for the experiment

1. Set up the experimental plant and connect it.
2. Create the experiment setup shown in Figure 9. Table 14 lists the necessary measuring points.
3. Remove the pinhole from the fan outlet.
4. Adjust the manometer panel.
5. Use hoses to connect the measuring points to the nozzles on the manometer panel. Ensure that there are no kinks in the hoses.

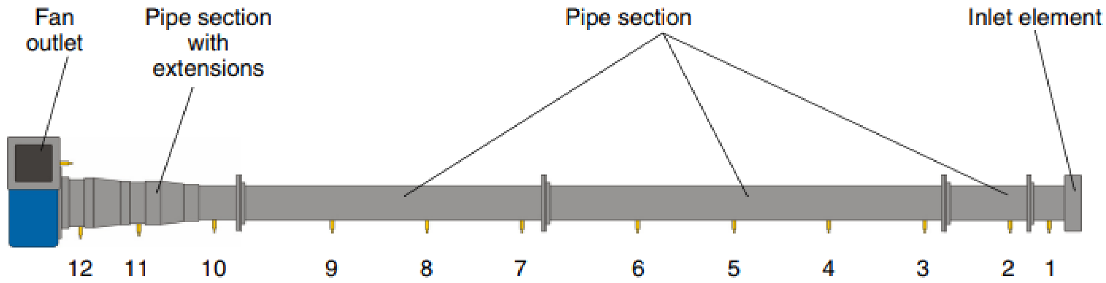


Figure 9: Experiment 4 set-up

Pipe section/Accessory	Measuring point	Measured pressure
-	-	Reference pressure
Inlet element	1	Static pressure
Pipe section	2 to 12	Static pressure

Table 14: Experiment 4 - Measuring points

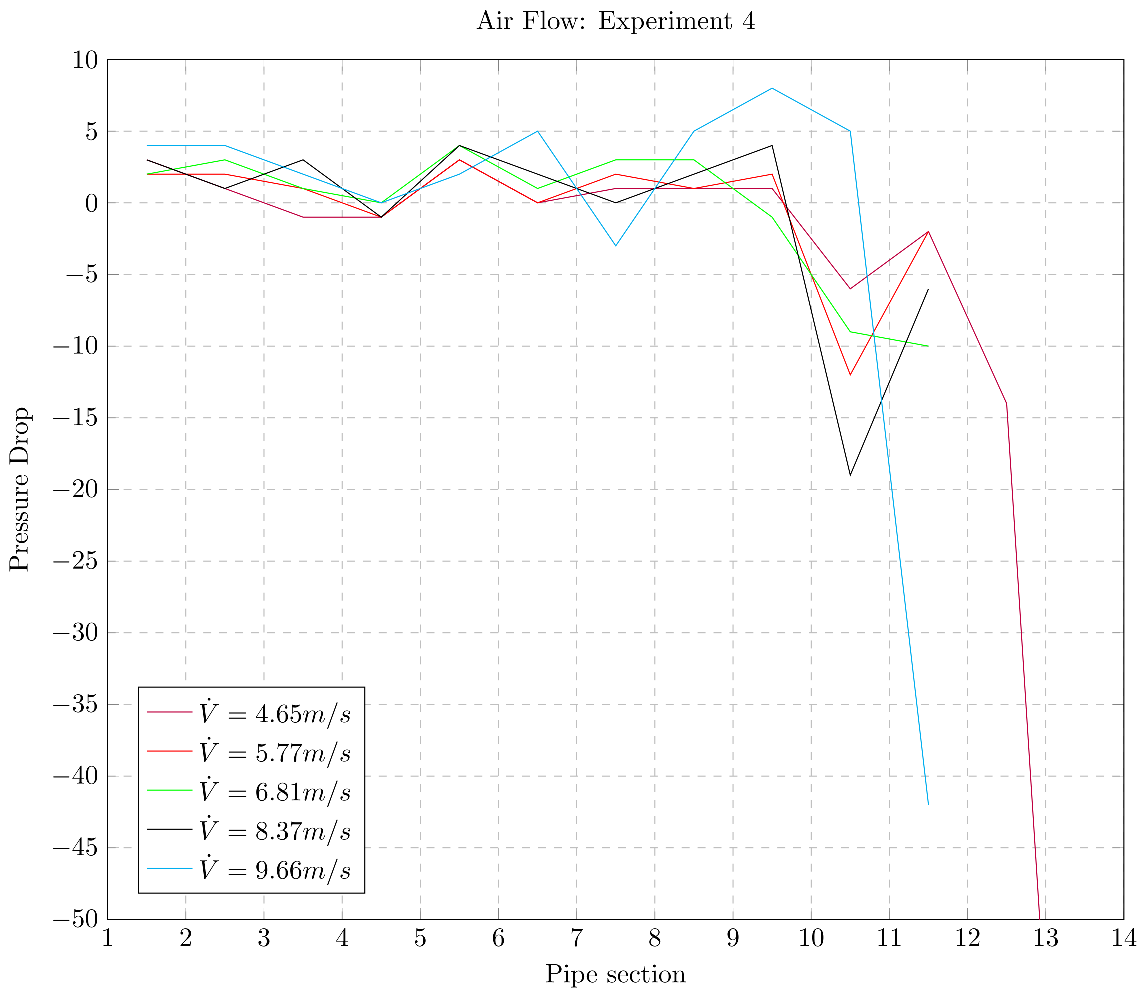
2.5.3 Conducting the experiment

1. Turn the main switch on.
2. Turn the fan switch on.
3. Set the desired flow rate on the potentiometer.
4. Read off the pressures from the manometer tubes.
5. Repeat the experiment with different flow rates that you set on the potentiometer.

2.5.4 Analysis of the experiment

1. Calculate the differential pressure between the reference pressure and measuring point 1. This is the dynamic pressure at measure point 1.

2. From this, calculate the flow rate at the inlet of the pipe section, see Chapter 2.1.3.
3. Calculate the pressure loss between the separate measuring points (measuring point 2 to 12).
4. Plot the pressure loss over the flow rate in a chart.



Some comments:

- From the figure, it can be seen that the pressure drops over the pipe section from 1 to 10 fluctuate in the vicinity around 0-5. The higher the flow rate, the higher the fluctuate.
- In the pipe section 11-12, the pressure loss between the section is significant (minus sign indicate the loss), which is quite reasonable because of the expansion of the cross sectional areas of pipe section 11-12.

2.6 Experiment 5: Pressure losses in fittings

2.6.1 Objective of the experiment

This experiment measures the pressure loss at various fittings.

2.6.2 Preparation for the experiment

1. Set up the experimental plant and connect it.
2. Create the experiment setup according to Figure 10. Use one of the three fittings. Table 15 lists the required measuring points.
3. Remove the pinhole from the fan outlet.
4. Adjust the manometer panel.
5. Use hoses to connect measuring points 1, 2 and 3 to the nozzles on the manometer panel. Ensure that there are no kinks in the hoses.

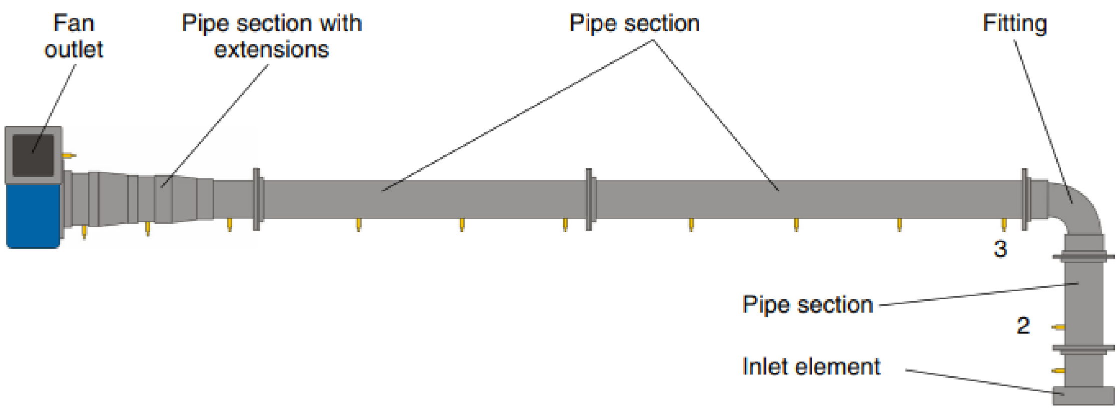


Figure 10: Experiment 5 set-up

Pipe section/Accessory	Measuring point	Measured pressure
-	-	Reference pressure
Inlet element	1	Static pressure
Pipe section	2	Static pressure
Pipe section	3	Static pressure

Table 15: Experiment 5 - Measuring points

2.6.3 Conducting the experiment

1. Turn the main switch on.
2. Turn the fan switch on.
3. Set the desired flow rate on the potentiometer.
4. Read off the pressures from the manometer tubes.

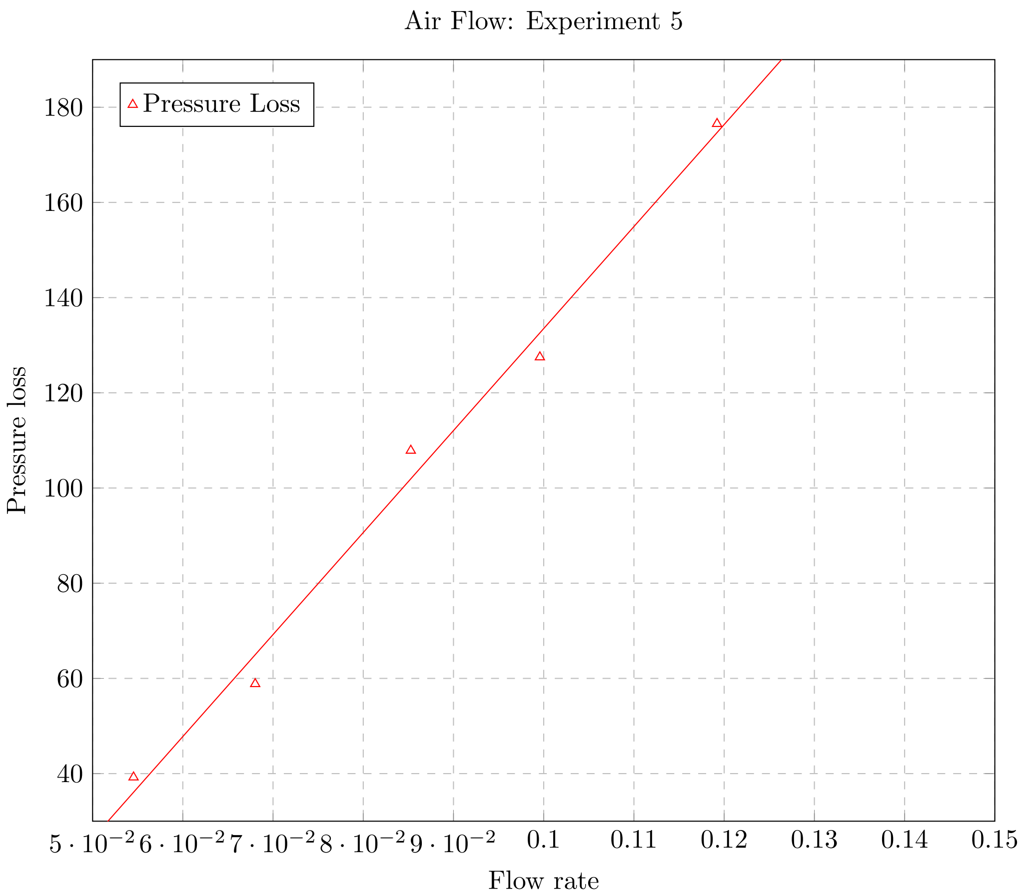
5. Repeat the experiment with different flow rates that you set on the potentiometer.

2.6.4 Analysis of the experiment

1. Calculate the differential pressure between the reference pressure and measuring point 1. This is the dynamic pressure at measuring point 1.
2. From this, calculate the flow rate at the inlet of the pipe section, see Chapter 2.1.3.
3. Calculate the pressure loss between measuring points 2 and 3.
4. Plot the pressure loss over the flow rate in a chart

Potential meter position	Pressure loss	Flow rate
5	39.23	0.0545
6	58.84	0.0680
7	107.87	0.0853
8	127.49	0.0996
9	176.52	0.1192

Table 16: The data of experiment 5



Some comments:
With the Pipe-bend fitting set-up, the pressure loss increases in proportion with the flow rate.

2.7 Experiment 6: Velocity profile in the pipe cross-section

2.7.1 Objective of the experiment

This experiment determines the velocity profile in the pipe cross-section.

2.7.2 Preparation for the experiment

1. Set up the experimental plant and connect it.
2. Create the experiment setup according to Figure 11. Use one of the three fittings. Table 17 lists the required measuring points.
3. Remove the pinhole from the fan outlet.
4. Adjust the Pitot tube (measuring point 19) so that it almost touches the pipe wall and read off the height.
5. Use hoses to connect measuring points 1, 19 and 20 to the nozzles on the manometer panel. Ensure that there are no kinks in the hoses.

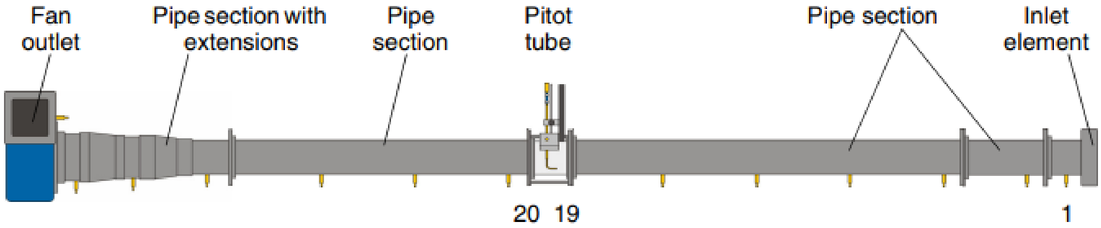


Figure 11: Experiment 6 set-up

Pipe section/Accessory	Measuring point	Measured pressure
-	-	Reference pressure
Inlet element	1	Static pressure
Pitot tube in the pipe section	19	Total pressure
	20	Static pressure

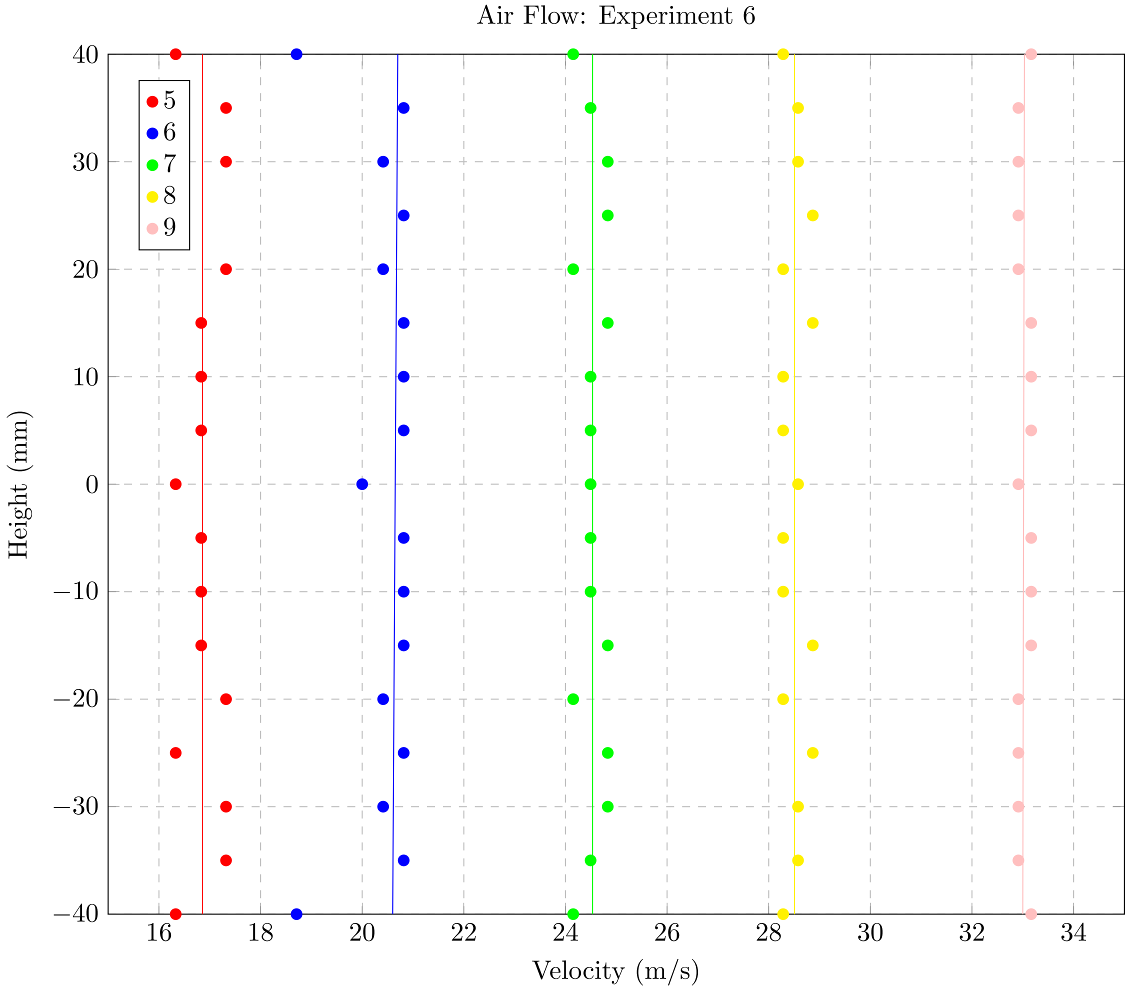
Table 17: Experiment 6 - Measuring points

2.7.3 Conducting the experiment

1. Turn the main switch on.
2. Turn the fan switch on.
3. Set the desired flow rate on the potentiometer.
4. Read off the pressures from the manometer tubes.
5. Change the height of the Pitot tube (measuring point 19) and repeat the measurement

2.7.4 Analysis of the experiment

1. Calculate the differential pressure between the reference pressure and measuring point 1. This is the dynamic pressure at measuring point 1.
2. From this, calculate the flow rate at the inlet of the pipe section, see Chapter 2.1.3.
3. Calculate the differential pressure between measuring point 19 and 20. This represents the dynamic pressure in this pipe section.
4. From this, calculate the velocity in this pipe section, see Chapter 2.1.3.
5. Plot the velocity over the height of the Pitot tube in a chart.



Some comments:
Using Reynold's equation $Re = \frac{\rho D v}{\mu}$, the Reynold number of the airflow inside the pipe can be calculated at around 100000-200000, we can deduce that the airflow inside the pipe section is turbulent flow.

Using the entrance length number for turbulent flow: $\frac{l_e}{D} = 4.4Re^(1/6)$, we can obtained l_e at around 2.5m.

As the Pitot tube is not placed far enough from the inlet, so the flow is not fully developed. The result is that the velocity profile corresponds to each flow rates appeared to be flatten over the height. So the experiment agrees with the theory.

2.8 Experiment 7: Velocity profile in the free jet

2.8.1 Objective of the experiment

This experiment determines the velocity profile in the free jet.

2.8.2 Preparation for the experiment

1. Set up the experimental plant and connect it, see Chapter 3.4, Page 19.
2. Create the experiment setup according to Fig. 5.7. Tab. 5.7 lists the required measuring points.
3. Attach the pinhole in the fan outlet, see Chapter 3.2.2, Page 7.
4. Adjust the manometer panel, see Chapter 3.2.4, Page 8.
5. Adjust the Pitot tube (measuring point 14) so that it is horizontally and vertically in the centre of the pinhole, see Chapter 3.3.3, Page 14. Read off the position in all three directions (x-, y- and z-axis).
6. Use hoses to connect measuring points 1 and 14 to the nozzles on the manometer panel. Ensure that there are no kinks in the hoses.

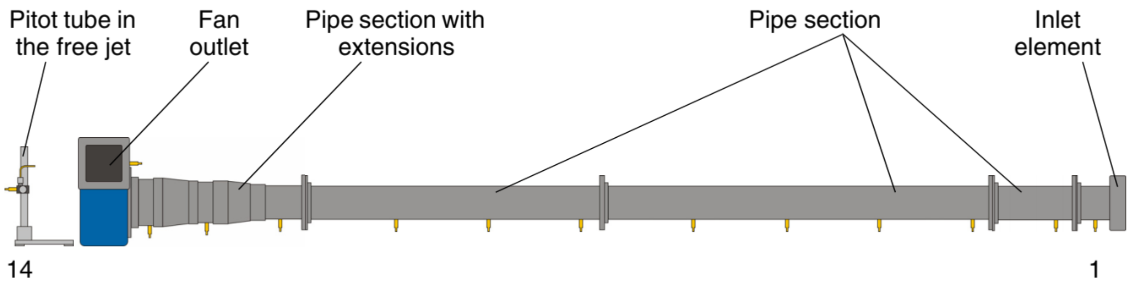


Figure 12: Experiment 7 set-up

2.8.3 Conducting the experiment

1. Turn the main switch on.
2. Turn the fan switch on.
3. Set the desired flow rate on the potentiometer.
4. Read off the pressures from the manometer tubes.
5. Change the position of the Pitot tube in the longitudinal direction (x-axis) and transverse direction (z-axis) and repeat the measurement.

2.8.4 Analysis of the experiment

1. Calculate the differential pressure between the reference pressure and measuring point 1. This is the dynamic pressure at measuring point 1.
2. From this, calculate the flow rate at the inlet of the pipe section, see Chapter 4.3, Page 26.

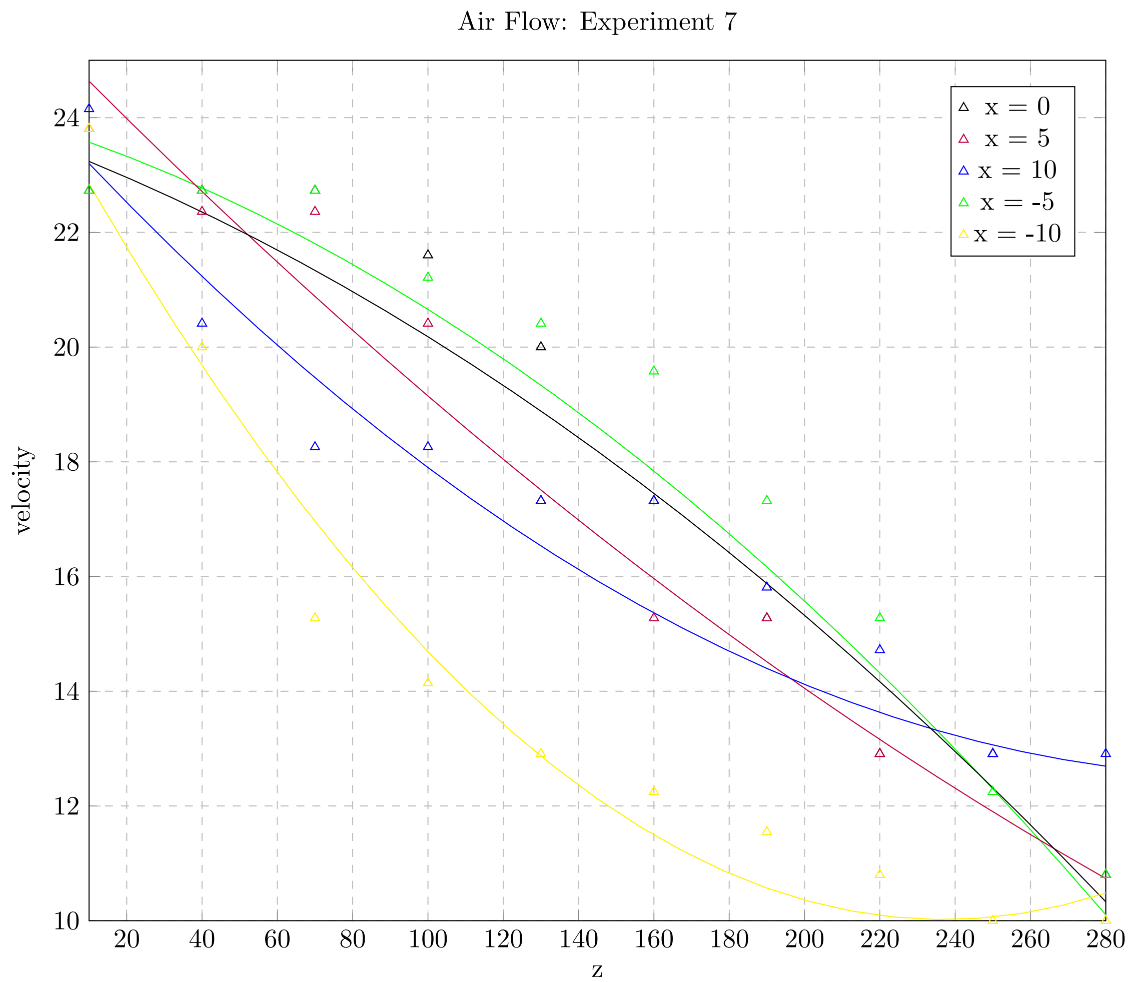
3. Calculate the differential pressure between the reference pressure and measuring point 14. This is the dynamic pressure at measuring point 14.
4. From this, calculate the velocity in the pipe section, see Chapter 4.3, Page 26.
5. Plot the velocity over the position of the Pitot tube in the longitudinal direction (x-axis) and transverse direction (z-axis) in a chart.

Pipe section/Accessory	**Measuring point**	**Measured pressure**
-	-	Reference pressure
Inlet element	1	Static pressure
Pitot tube in the free jet	14	Total pressure

Table 18: Experiment 7 - Measuring points

z	Velocity				
	x = -10	x = -5	x = 0	x = 5	x = 10
10	22.73	23.80	24.15	22.73	23.80
40	22.73	22.36	20.41	22.73	20.00
70	22.73	22.36	18.25	21.21	15.28
100	21.60	20.41	18.25	20.41	14.14
130	20.00	17.32	17.32	19.57	12.91
160	17.32	15.27	15.8	17.32	12.25
190	15.28	12.90	14.71	15.27	11.55
220	12.91	12.90	12.90	13.54	10.80
250	12.91	12.90	12.90	12.24	10.00
280	10.80	10.8	12.90	10.8	10.00

Table 19: Experiment 7: Measurement Data



Some comments:
The velocity of the free jet measured decreases with the increase of the transverse dimension (Go further away from the outlet).

2.9 Experiment 8: System characteristic

2.9.1 Objective of the experiment

This experiment records a system characteristic.

2.9.2 Preparation for the experiment

1. Set up the experimental plant and connect it, see Chapter 3.4, Page 19.
2. Create the experiment setup according to Fig. 5.8. Tab. 5.8 lists the required measuring points.
3. Remove the pinhole from the fan outlet, see Chapter 3.2.2, Page 7.
4. Adjust the manometer panel, see Chapter 3.2.4, Page 8.
5. Use hoses to connect measuring points 1 and 13 to the nozzles on the manometer panel. Ensure that there are no kinks in the hoses.

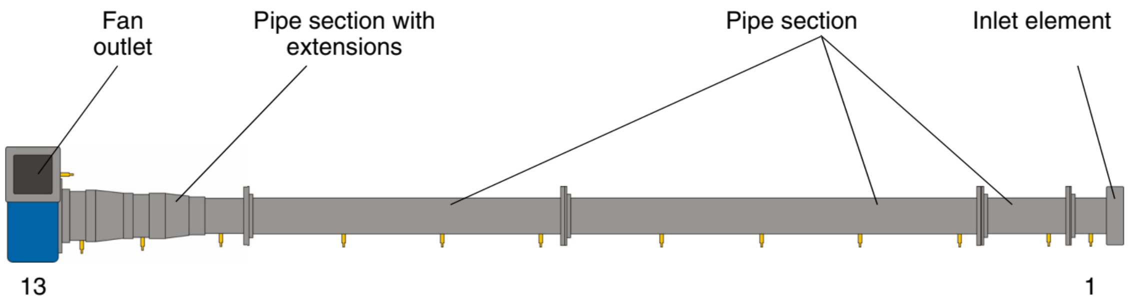


Figure 13: Experiment 8 set-up

Pipe section/Accessory	Measuring point	Measured pressure
-	-	Reference pressure
Inlet element	1	Static pressure
Fan outlet	13	Static pressure

Table 20: Experiment 8 - Measuring points

2.9.3 Conducting the experiment

1. Turn the main switch on.
2. Turn the fan switch on.
3. Set the desired flow rate on the potentiometer.
4. Read off the pressures from the manometer tubes.
5. Repeat the experiment with different flow rates that you set on the potentiometer

2.9.4 Analysis of the experiment

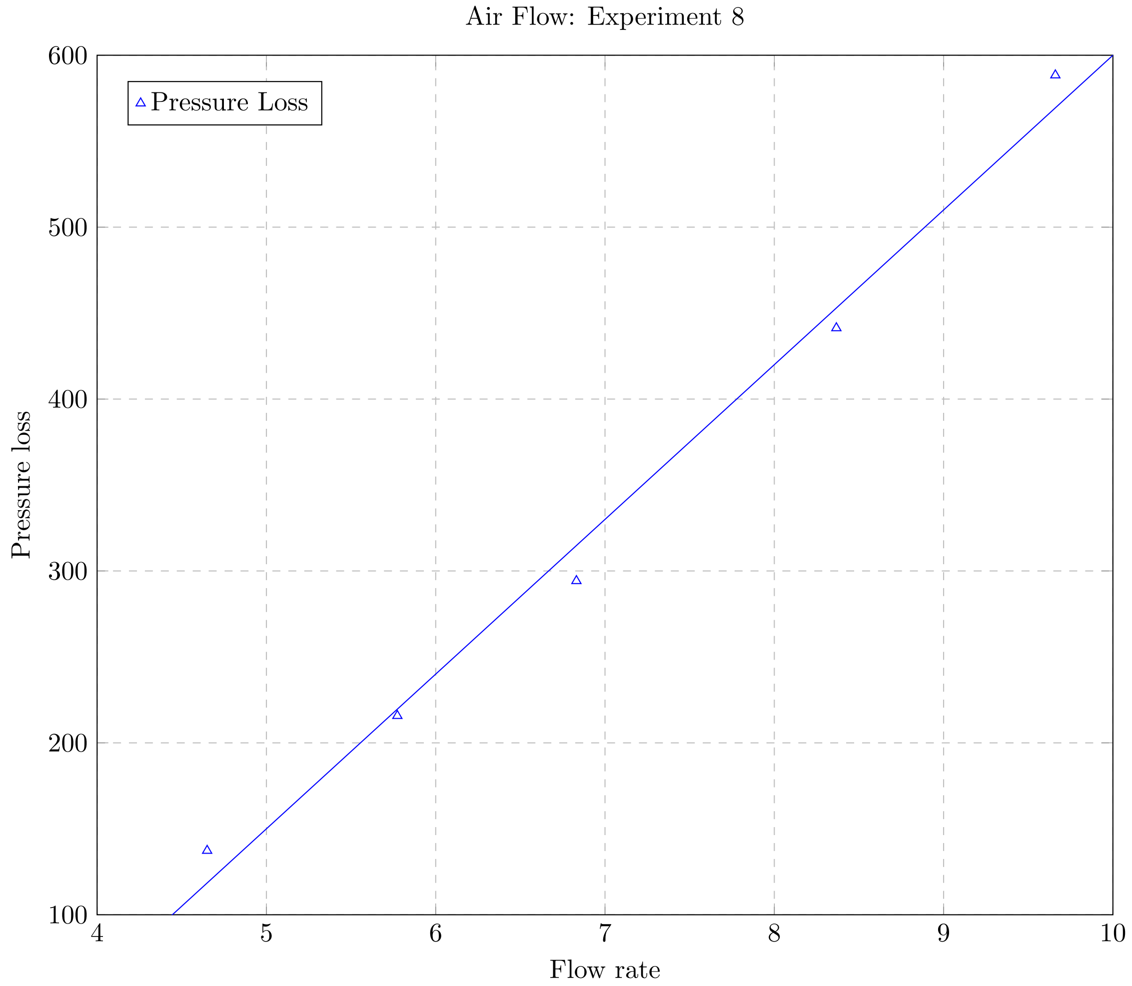
1. Calculate the differential pressure between the reference pressure and measuring point 1. This is the dynamic pressure at measuring point 1.
2. From this, calculate the flow rate at the inlet of the pipe section, see Chapter 4.3, Page 26.
3. Calculate the pressure loss between measuring point 1 and measuring point 13.
4. Plot the pressure loss over the flow rate in a chart (system characteristic).

Measuring point	Reference pressure	Inlet element	Fan outlet
Connected to manometer tube		D	P
Potentiometer position	Pressure in mm WC		
5	100	113	99
6	100	120	98
7	100	128	98
8	100	142	97
9	100	156	96

Table 21: Experiment 8: Measurement data

Dynamic pressure	Pressure loss 1-13	Flow rate at inlet
13	14	4,655
20	22	5,774
28	30	6,831
42	45	8,367
56	60	9,661

Table 22: Experiment 8: Measurement data



Some comments:
The Pressure loss between the inlet and outlet of the pipe increase proportionally with the flow rate

2.10 AIR FLOW EXPERIMENTAL PLANT

2.10.1 Worksheet 1: Flow rates and pressure losses

Measuring point	Reference pressure	Inlet element	Fan outlet
Connected to manometer tube		D	P
Potentiometer position	Pressure in mm WC		
5	100	113	99
6	100	120	98
7	100	128	98
8	100	142	97
9	100	156	96

Table 23: The data of experiment 8

2.10.2 Worksheet 2: Measurement diagram for iris diaphragm PRA-100

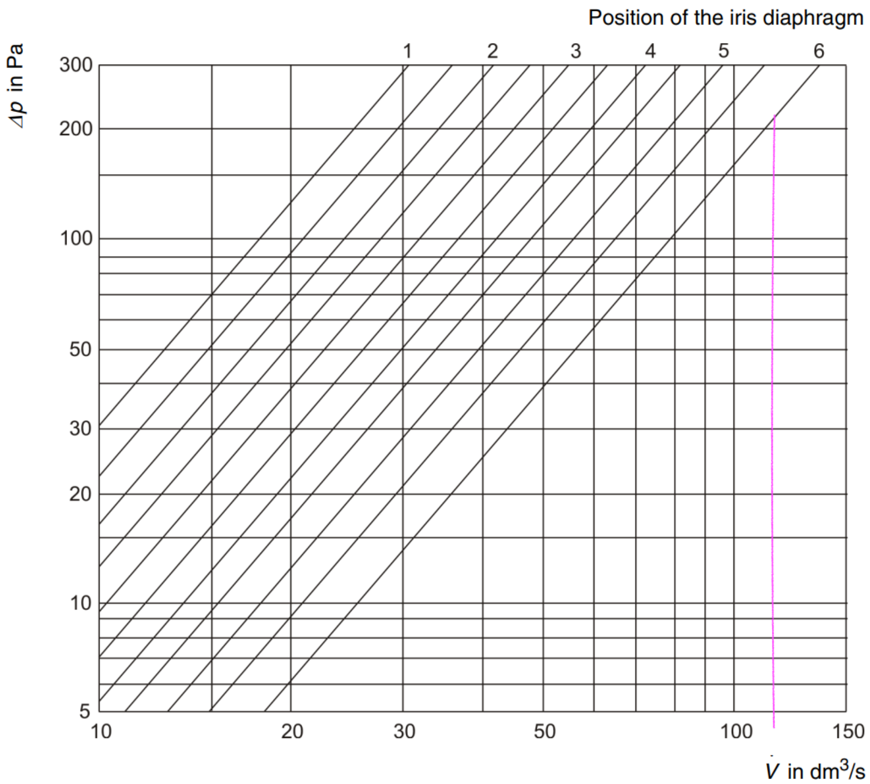


Figure 14: Iris diaphragm