Faculty of Mechanical Engineering

Politechnika Krakowska

Analysis of Pressure Drops on a Straight Section of a Circular Pipe.

Final Project

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1. Introduction

Knowing how fluids move through pipes is crucial in fluid dynamics for designing effective pipeline systems. Friction between the pipe wall and fluid causes a decrease in pressure, which plays a crucial role in regulating fluid flow. The project is named "Analysis of Pressure Drops on a Straight Section of a Circular Pipe." and investigates the decrease in pressure in a straight circular pipe when fluid is flowing through it.

Comprehending pressure decreases is essential for a variety of engineering applications like constructing water supply networks, oil and gas pipelines, and HVAC systems. Precise monitoring and control of pressure losses are crucial for maintaining effective liquid transport, reducing energy usage, and avoiding operational problems.

2. Theoretical Part

The decrease in pressure as water flows through a water pipe is known as the pressure drop. The loss here is due to friction between the water and the inner walls of the pipe, by turbulence and other factors opposing flow.

2.1. Pressure Drop Influencing Parameters

Flow rate: The amount of water passing through the pipe in a given amount of time is one of the key factors affecting the pressure drop. This is because frictional forces are greater at larger flow rates and therefore pressure decreases are typically higher as well.

Pipe diameter: This is caused because the water has more room to flow and less friction per unit of length, larger diameter pipes produce smaller pressure drops.

Pipe length: The cause of this is that water experiences more friction over a longer distance in longer pipes, producing higher pressure decreases.

Pipe roughness: Friction is influenced by the inner surface texture of the pipe. More friction on rougher surfaces results in a greater pressure drop.

Density and viscosity of water: Greater viscosity fluids face higher resistance, which causes larger pressure drops. Viscosity and density of water can be influenced by temperature.

Flow regime: Pressure decreases are greatly influenced by the type of flow, whether laminar or turbulent. Compared to turbulent flow, which is defined by chaotic water movement, laminar flow, which is characterized by smooth, ordered water movement, producing therefore smaller pressure drops.

Figure 2.1. Pipes with different diameters.

2.2. How to Calculate Pressure Drop

Many theoretical and empirical equations can be used to compute the pressure drop.

Formulas that are most frequently used are:

1. Equation of Darcy-Weisbach [1]:
For computing pressure decreases in pipes, the Darcy-Weisbach equation is frequently utilized:

$$\Delta P = f \cdot \frac{L}{D} \cdot \frac{\rho \cdot V^2}{2} \qquad (2.1)$$

Where:

- ΔP = pressure drop (Pa)
- f= Darcy friction factor (dimensionless)
- L = length of the pipe (m)
- D = diameter of the pipe (m)
- ρ = density of the fluid (kg/m³)
- v = flow velocity (m/s)

The Darcy friction factor f depends on the flow regime (Reynolds number) and the relative roughness of the inner faces of the pipe.

2. Hazen-Williams Equation [2]: This empirical method is also frequently utilized for water flow in pipelines, particularly in applications related to civil engineering.

$$h = 10.674 \cdot \frac{Q^{1.852}}{C^{1.852} \cdot D^{4.871}} \cdot L \qquad (2.2)$$

Where:

- h = head loss (meters of water)
- L = length of the pipe (m)
- C = Hazen-Williams roughness coefficient (dimensionless)
- D = diameter of the pipe (m)
- Q = flow rate (m³/s)

2.3. Flow Regimes and Reynolds Number

The Reynolds number (Re) is a dimensionless value that helps predict flow regimes in pipes, it is calculated using the Reynolds number equation [3]:

$$Re = \frac{\rho V D}{\mu} \qquad (2.3)$$

Where:

- μ = dynamic viscosity of the fluid (Pa·s)

- Laminar Flow: Occurs at Re<2000. The flow is smooth and orderly. Pressure drop is directly proportional to the velocity.
- Turbulent Flow: Occurs at Re>4000. The flow is chaotic and mixed. Pressure drops increase roughly because it is related to the square of the velocity.
- Transitional Flow: Happens between $2000 < Re < 4000$. The flow regime is unstable and can change between both of the above.

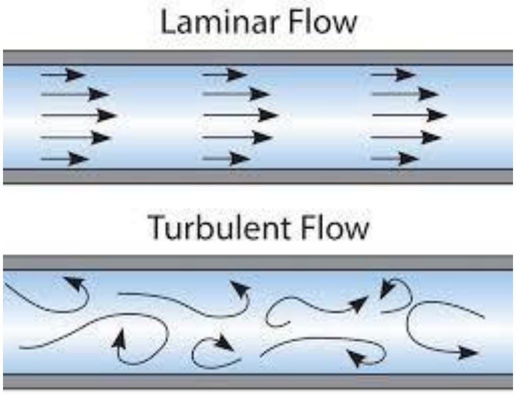


Figure 2.2. Laminar and turbulent flow.

2.4.Head loss in elbows

Figure 2.3. Pipe elbow

The term “head loss in elbows” makes reference to the decrease in a fluid’s total pressure as it flows through an elbow in a pipe system. This effect is caused by several factors, being the most important [4] [5]:

Flow Disturbance: A fluid must change direction when flowing through an elbow, typically by 45 or 90 degrees. When this change occurs, turbulence and flow separation happen, particularly on the outer side of the bend. If these effects are great enough it can lead to the formation of eddies and vortices which will increase the head loss as more energy will be lost in the form of heat and friction.

Frictional Losses: The roughness of the inner surfaces of the elbow adds to the frictional resistance faced by the fluid. The effective flow path when flowing through an obstacle such as an elbow is longer than that of a straight path of the same length, which will result in higher frictional losses.

Secondary Flows: When a fluid flows through the path of an elbow centrifugal forces appear to act on it, this results in a pressure difference between the inner and outer walls of the elbow. This pressure difference can end up in the creation of secondary flows.

The equation that is used to calculate the head loss in an elbow is:

$$\Delta P = K \cdot \frac{\rho \cdot v^2}{2} \qquad (2.4)$$

Where:

- K represents the resistance coefficient (friction factor) for the elbow
- ρ represents the density of the fluid flowing through the elbow (kg/m^3)
- v represents the velocity of the fluid (m/s)

The value of the coefficient K depends on factors as the angle of the elbow, common ones are 45 and 90 degrees, the radius of the bend (smoothly curved or sharp-edged) and the Reynolds number. Other factors that affect the value of this coefficient are the way in which it is connected to the network (flanged or threaded) and the existence of vanes.

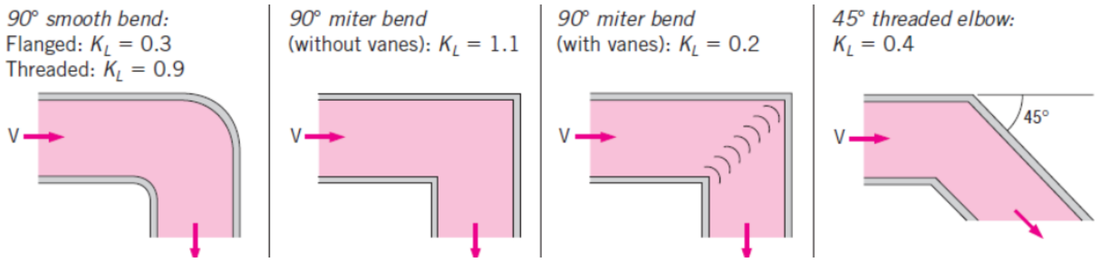


Figure 2.3. Values of K for different elbows.

2.5. Uses

It's essential to comprehend pressure drops for:

- designing water supply networks, industrial operations, and building pipe systems with efficiency in mind.
- ensuring that endpoints have sufficient water pressure.
- lowering energy usage through the improvement of pipe and pump parameters.
- avoiding low pressure-related problems including inadequate water supply and pump cavitation.

Figure 2.4. Part of a pump which has suffered cavitation.

3. Pressure Drop Calculations

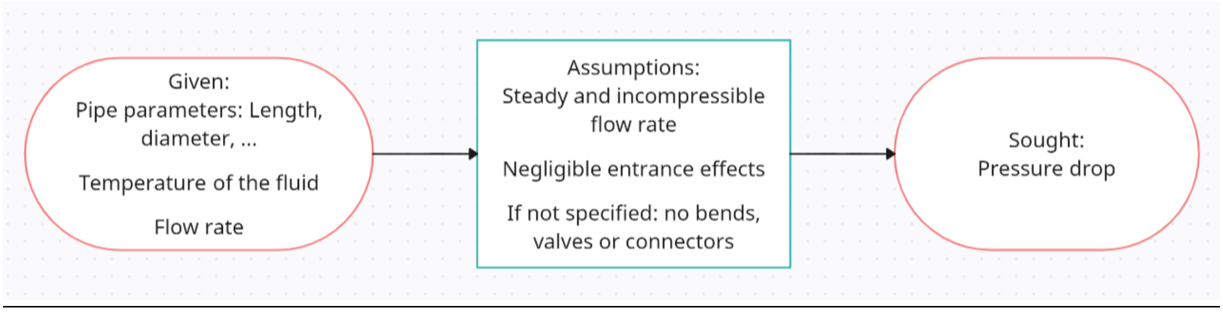
As said before, this final project aims to analyse the pressure drop experienced by a fluid (which will be water for this project) as it flows through a straight section of a circular pipe. To do this, we will be using both manual calculations and computer simulations using Simulink form the MATLAB software.

For this final project, the characteristics of the pipes through which the fluid is flowing are given beforehand. This means that we already know certain parameters such as the length and the diameter of these. Other parameters such as the temperature of the fluid are also given so that we can perform the calculations with greater precision due to the fact that we can know more accurate values for the fluid’s density and dynamic viscosity.

To carry out these calculations, several simplifying assumptions were made, these were:

- The flow rate is steady and incompressible.
- The entrance effects are negligible; therefore, the flow is fully developed.
- If not specified, the pipe involves no components such as bends, valves and connectors.

The following diagram illustrates what is given beforehand, what is sought in this final project and the assumptions made.



3.1. Manual Calculations

3.1.1. Determining the head loss in a water pipe

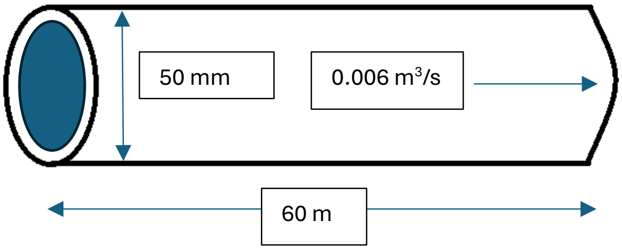


Fig. 3.1. Water flow in the pipe

The purpose of the analysis is to determine the required pressure difference to enable water flow in a pipe with a length of 60 m and a nominal (internal) diameter of 50 mm. The water has a constant temperature of 16 ºC and flows at a rate of 0.006 m^3/s. At this temperature the water flowing through the pipe has a density of 999.04 kg/m^3 and its dynamic viscosity is 0.001137 Pa*s. The calculations will be carried out assuming that water is incompressible and its flow is steady. Due to the much longer length of the pipe compared to its diameter the entrance effects are negligible and a fully developed flow is analysed. Equivalent roughness value for new commercial pipes made of stainless steel is 0.002 mm.

The pressure drop was calculated using equation (2.1):

$$\Delta P = f \cdot \frac{L}{D} \cdot \frac{\rho \cdot V^2}{2}$$

To calculate the pressure, drop manually the first step was to calculate the velocity of the fluid flowing through the pipe, this is done using the following equation:

$$V = \frac{\dot{V}}{A} = \frac{\dot{V}}{\pi \frac{D^2}{4}} = \frac{0.006\ \frac{m^3}{s}}{\pi \frac{(0.050\ m)^2}{4}} = 3.056\ \frac{m}{s}$$

After calculating the velocity of the fluid, we will use our value to calculate the Reynolds number and determine the flow regime through the pipe. As in the equation that we will need to use to calculate this both density and dynamic viscosity are involved we will need to enter the values of these two parameters at the temperature at which the fluid is flowing, in this case 16 ºC. To do the calculation we will use equation (2.3):

$$Re = \frac{\rho V D}{\mu} = \frac{(999.04\ \frac{kg}{m^3}) \cdot (3.056\ \frac{m}{s}) \cdot (0.050\ m)}{0.001137\ \mathrm{Pa} \cdot \mathrm{s}} = 134259.73$$

As the result for the Reynolds number is greater than 4000 this means that the flow of the liquid through the pipe is turbulent.

We know that the relative roughness for this pipe is determined by the equation:

$$\frac{\varepsilon}{D} = \frac{0.0000020\ m}{0.050\ m} = 0.00004$$

With both numbers (Reynolds number and relative roughness) we can determine the friction factor of the pipe. This can be done by different methods such as reading it from the Moody chart or using Colebrook's equation. To avoid any reading error that could happen when taking a reading from the Moody chart we will use Colebrook's equation to get a more precise answer.

$$\frac{1}{\sqrt{f}} = -2 \cdot \log_{10}\left(\frac{\varepsilon}{3.7 \cdot D} + \frac{2.51}{Re \cdot \sqrt{f}}\right) = -2 \cdot \log_{10}\left(\frac{0.00004}{3.7} + \frac{2.51}{134259.73 \cdot \sqrt{f}}\right)$$

When solving this equation, we get a result for the friction factor of f =0.01719 .

The last step is to calculate the pressure drop by using equation (2.1):

$$\Delta P = f \cdot \frac{L}{D} \cdot \frac{\rho \cdot V^2}{2} = 0.01719 \cdot \frac{60m}{0.050m} \cdot \frac{999.04 \frac{kg}{m^3} \cdot \left(3.056 \frac{m}{s}\right)^2}{2} = 96231.38 \frac{kg}{m \cdot s^2}$$

The result obtained in the units above is equal to the result expressed in SI units which in this case would be pascals, this means that the pressure drop in the pipe is 96231.38 Pa.

3.1.2. Determining head loss in a water pipe and an elbow

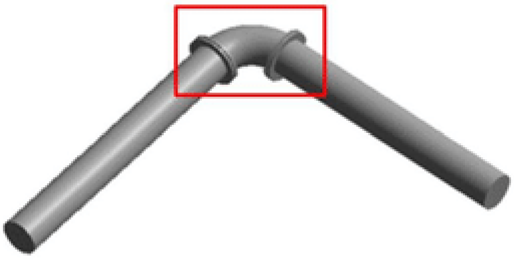


Fig 3.2. Elbow attached to pipe

The purpose of the analysis is to determine the required pressure difference to enable water flow in a pipe with an elbow attached to it. In this second case that was analysed, the installation consisted of adding an elbow to the same pipe that was analysed before and calculate the pressure drop for this modified installation. These characteristics of this elbow are that it is smoothly curved, has the same 50 mm diameter as the pipe to which it is attached and does a 90º turn. The critical Reynolds number for this elbow is 150. The calculations will be carried out assuming that water is incompressible and its flow is steady. Due to the much longer length of the pipe compared to its diameter the entrance effects are negligible and a fully developed flow is analysed. Equivalent roughness value for new commercial pipes made of stainless steel is 0.002 mm.

To calculate the pressure drop in the elbow we need to use formula (2.4):

$$\Delta P = K \cdot \frac{\rho \cdot v^2}{2}$$

As we have chosen an elbow which is smoothly curved, we can assume a value for K=0.3 if we assume that it is flanged, substituting values into formula (2.4) we get:

$$\Delta P = 0.3 \cdot \frac{999.04 \frac{kg}{m^3} \cdot \left(3.056 \frac{m}{s}\right)^2}{2} = 1399.53 \frac{kg}{m \cdot s^2}$$

As explained above the result we obtained above is equivalent to 1399.53 Pa. To calculate the total pressure drop in the system we now have to add the result of 1399.53 Pa to the one obtained in point 3.1.1. of the project.

$$\Delta P_T = \Delta P_{pipe} + \Delta P_{elbow} = 96231.38 + 1399.53 = 97630.91\ Pa$$

3.1.3. Determining head loss in a water installation

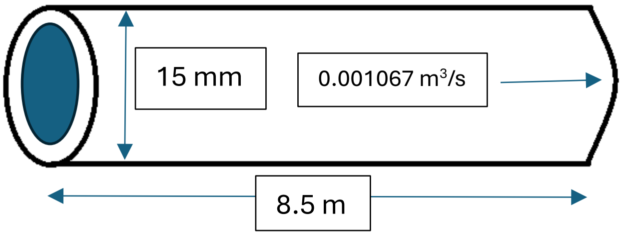


Fig 3.3. Water flow in first pipe of installation

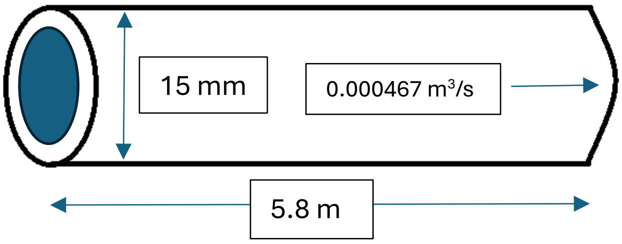


Fig 3.4. Water flow in second pipe of installation

The purpose of the analysis is to determine the required pressure difference to enable water flow in a water installation for a common household. To analyse this installation, it was decided to calculate the maximum pressure drop that could happen in this network. The installation for which the maximum pressure drop was going to occur consisted of a pipe with a diameter of 15mm that had a length of 14.3 m. For the first 8.5m of the pipe the elements which could need water flow were 2 showers, 2 bathroom sink taps, 1 kitchen sink tap and 2 toilets. For the rest of the installation which are 5.8m the water flow could only end in 1 shower, 1 bathroom sink tap and 1 toilet. The calculations will be carried out assuming that water is incompressible and its flow is steady. Due to the much longer length of the pipe compared to its diameter the entrance effects are negligible and a fully developed flow is analysed. Equivalent roughness value for new commercial pipes made of stainless steel is 0.002 mm.

As the pressure drop through the installation was going to be maximum when the flow rate was at its maximum this meant that there was going to be a different amount of flow in different parts of the installation as not all the flow was demanded from the same point. For this reason, I analysed the installation as two independent pipes and then adding the pressure drop in each of them to obtain the total pressure drop.

To calculate the head loss we will use equation (2.1):

$$\Delta P = f \cdot \frac{L}{D} \cdot \frac{\rho \cdot V^2}{2}$$

The first thing that I calculated was the maximum flow rate that could be demanded by the installation producing the maximum pressure drop. To do this I used the following values for the different appliances:

- **Shower:**

  For each minute that it is working it consumes approximately 12 litres.

- **Bathroom sink tap:**

  For each minute that a person spends using the sink tap completely open it consumes approximately 6 litres.

- **Kitchen sink tap:**

  This appliance consumes approximately 8 litres per minute that it spends fully opened.

- **Toilet:**

  Each time that the toilet button is pressed the whole tank is emptied, the amount of water depends on the model of the toilet, for this exercise we will say that the toilet can store up to 10 litres of water. For this exercise we will also consider that the toilet's tank will take one minute to fill up completely after a discharge.

The maximum flow rate demanded by the installation will be the sum of all the flow rates demanded by each appliance. This will also be the flow rate demanded by the first section of the installation.

$$\dot{V}_1 = \frac{2 \cdot 12\, l}{60\, s} + \frac{2 \cdot 6\, l}{60\, s} + \frac{2 \cdot 10\, l}{60\, s} + \frac{8\, l}{60\, s} = 1.067\ \frac{l}{s} = 0.001067\ \frac{m^3}{s}$$

The flow rate in the second section of the installation can be calculated either in the same way as the flow rate above or by subtracting the flow rates of the appliances that are not placed at the end of the longest line of the installation from the total flow rate. I will calculate it using the first option.

$$\dot{V}_2 = \frac{12\, l}{60\, s} + \frac{6\, l}{60\, s} + \frac{10\, l}{60\, s} = 0.467\ \frac{l}{s} = 0.000467\ \frac{m^3}{s}$$

Now I will proceed to calculate the pressure drop in the first section of the installation as done in the calculations in the first part of the project.

$$V = \frac{\dot{V}}{A} = \frac{0.001067\ \frac{m^3}{s}}{\pi \cdot \frac{(0.015\ m)^2}{4}} = 6.038\ \frac{m}{s}$$

For this part of the project, we will consider that the temperature at which the liquid flows through the installation is 13 degrees Celsius. This means that the density of the water will be 999.4 kg/m3 and the dynamic viscosity will be 0.00122 Pa s.

$$Re = \frac{\rho V D}{\mu} = \frac{999.4\ \frac{kg}{m^3} \cdot 6.038\ \frac{m}{s} \cdot 0.015\ m}{0.00122\ Pa \cdot s} = 74193.16$$

As the Reynolds number calculated above is greater than 4000 this means that the flow in this section of the network is turbulent.

$$\frac{\varepsilon}{D} = \frac{0.000015\ m}{0.015\ m} = 0.001$$

$$\frac{1}{\sqrt{f}} = -2 \cdot \log_{10}\left(\frac{\varepsilon}{3.7 \cdot D} + \frac{2.51}{Re \cdot \sqrt{f}}\right) = -2 \cdot \log_{10}\left(\frac{0.001}{3.7} + \frac{2.51}{74193.16 \cdot \sqrt{f}}\right)$$

When solving this equation, the answer we get is f = 0.02287.

$$\Delta P_1 = f \cdot \frac{L}{D} \cdot \frac{\rho \cdot V^2}{2} = 0.02287 \cdot \frac{8.5\ m}{0.015\ m} \cdot \frac{999.4\ \frac{kg}{m^3} \cdot \left(6.038\ \frac{m}{s}\right)^2}{2}$$
$$= 236096.42\ \frac{kg}{m \cdot s^2}$$

Now we will calculate the pressure drop for the second and last part of the installation:

$$V = \frac{\dot{V}}{A} = \frac{0.000467\ \frac{m^3}{s}}{\pi \cdot \frac{(0.015\ m)^2}{4}} = 2.643\ \frac{m}{s}$$

We will continue the calculation of this section of the network considering that the fluid flows through the pipes at a temperature of 13 degrees Celsius as said before as there is no reason for it to change its temperature.

$$Re = \frac{\rho V D}{\mu} = \frac{999.4\ \frac{kg}{m^3} \cdot 2.643 \frac{m}{s} \cdot 0.015\ m}{0.00122\ Pa \cdot s} = 32476.404$$

As the Reynolds number calculated for this section of the network is still greater than 4000, we can say that the fluid flows with a turbulent behaviour through this part of the installation.

$$\frac{\varepsilon}{D} = \frac{0.000015\ m}{0.015\ m} = 0.001$$

$$\frac{1}{\sqrt{f}} = -2\cdot\log_{10}\left(\frac{\varepsilon}{3.7\cdot D}+\frac{2.51}{Re\cdot\sqrt{f}}\right) = -2\cdot\log_{10}\left(\frac{0.001}{3.7}+\frac{2.51}{32476.404\cdot\sqrt{f}}\right)$$

When solving the equation above we get a result of f = 0.02563.

$$\Delta P_2 = f\cdot\frac{L}{D}\cdot\frac{\rho\cdot V^2}{2} = 0.02563\cdot\frac{5.8\,m}{0.015\,m}\cdot\frac{999.4\,\frac{kg}{m^3}\cdot\left(2.643\,\frac{m}{s}\right)^2}{2}$$
$$= 34593.06\,\frac{kg}{m\cdot s^2}$$

The last step to obtain the total pressure drop is to add the two results we calculated for each section of the installation.

$$\Delta P = \Delta P_1 + \Delta P_2 = 236096.42 + 34593.06 = 270689.48\,\frac{kg}{m\cdot s^2}$$

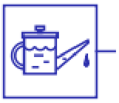
As said in the first part of the project the result in the units above is equivalent to the result in pascals so we can say that the total pressure drop in the installation is 270689.48 Pa.

3.2. Computational Simulations

3.2.1. Elements used in the Simulations

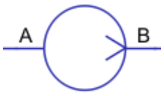
To carry out the computational simulations to verify the manual calculations for each of the cases described in point 3.2.1., 3.2.2. and 3.2.3 in MATLAB Simulink the following elements were used:

-Isothermal Liquid Predefined Properties (IL)



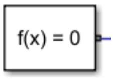
This element provides isothermal liquid properties to the isothermal liquid network to which it is connected. This means that when you connect this block to the liquid network a fluid is selected and its temperature are introduced, this block introduces the fluid with the characteristics (density, dynamic viscosity…) corresponding to the introduced temperature to the network.

-Flow Rate Source (IL)



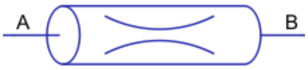
This element of the network represents an ideal mechanical energy source in an isothermal liquid network that can maintain a constant or variable mas or volumetric flow rate independent of the pressure differential. This element does not generate any losses due to friction.

-Solver Configuration



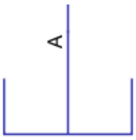
This element of the network defines solver settings to use for simulation. As we can see in the image to the left in this simulation this element did not have any settings modified as the equation that appears in it is just zero.

-Pipe (IL)



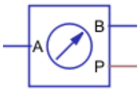
This element is one of the most important ones in our network as we will simulate the pressure drop of the fluid flowing through it. This block models pipe flow dynamics in an isothermal liquid network due to viscous friction losses. There is the option in this block to include the effects of dynamic compressibility or fluid inertia.

-Reservoir (IL)



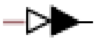
This block of the network can be set a constant or controlled boundary condition in an isothermal liquid network. The volume inside this reservoir is considered to be infinite and therefore the flow is assumed to be quasi-steady. The liquid enters and leaves at the reservoir pressure which can be modified if needed.

-Pressure Sensor (IL)



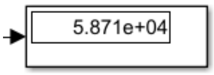
This element of the network is the one responsible to measure the pressure in an isothermal liquid network. There is no mass flow through the sensor. In this simulation the pressure sensor measures the difference of pressure between the points of the network to which ports A and B are connected. Port P is the one responsible of reporting this pressure difference.

-PS-Simulink Converter



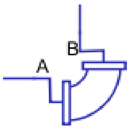
This element of the network converts the input Physical Signal to a Simulink output signal. This means that it is the responsible for transforming the signal sent by the pressure sensor to a signal that is capable of being displayed by the block display.

-Display



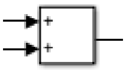
This element displays the signal sent to it by the PS-Simulink Converter. In the image to the left we can see the example of the block displaying the answer to a simulation.

- Elbow (IL)



This element models an elbow in an isothermal liquid network, it only considers the losses due to the curvature. The bend radius to diameter radius is small enough to assume that the viscous friction losses are neglectable.

-Add



The function of this block is to add the two input signals that it receives from the PS- Simulink Converters and add them up so that the display block displays the result for the total pressure drop in the installation.

3.2.2 Simulating the head loss in a water pipe

To carry out the simulation for determining the head loss in a water pipe, the following installation had to be introduced into the program:

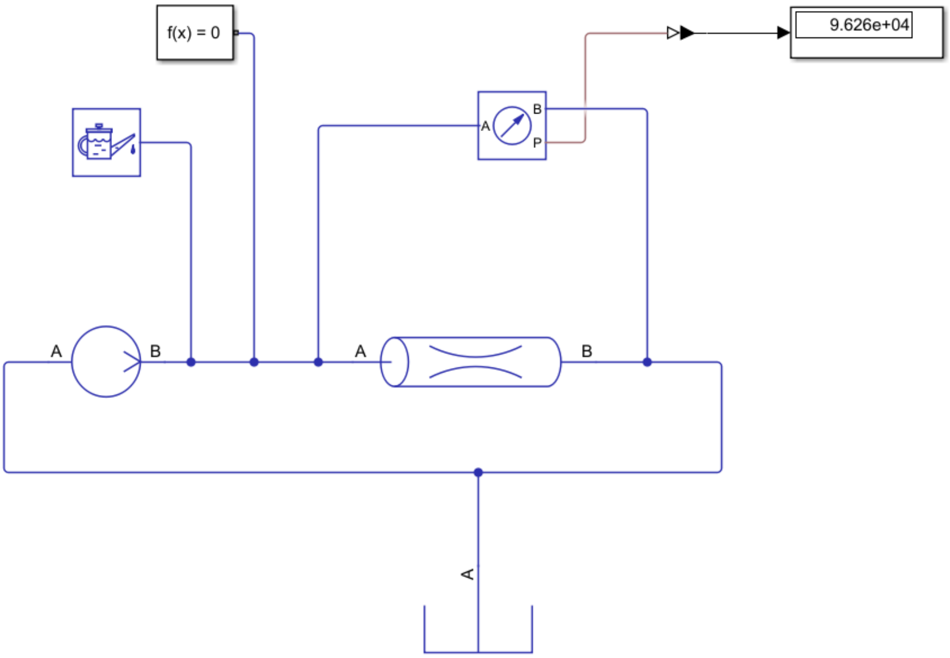
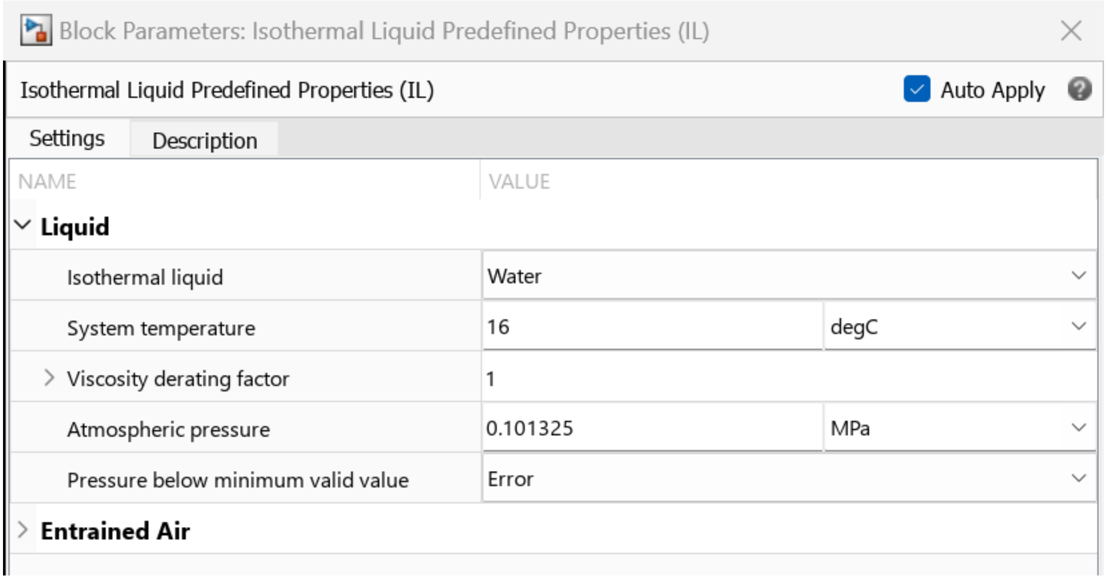


Figure 3.1. Installation to simulate head loss in a straight pipe

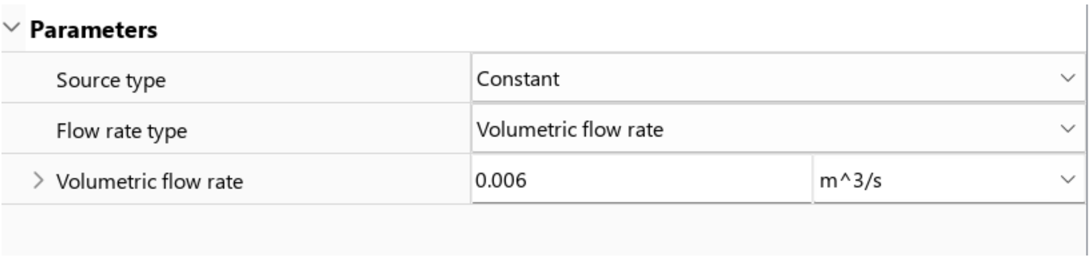
To match the simulation to the example that was analysed in point 3.1.1. it was needed to change parameters in different elements of the network and the initial data that was given was needed to be introduced.

The following screenshots show where the parameters were introduced:



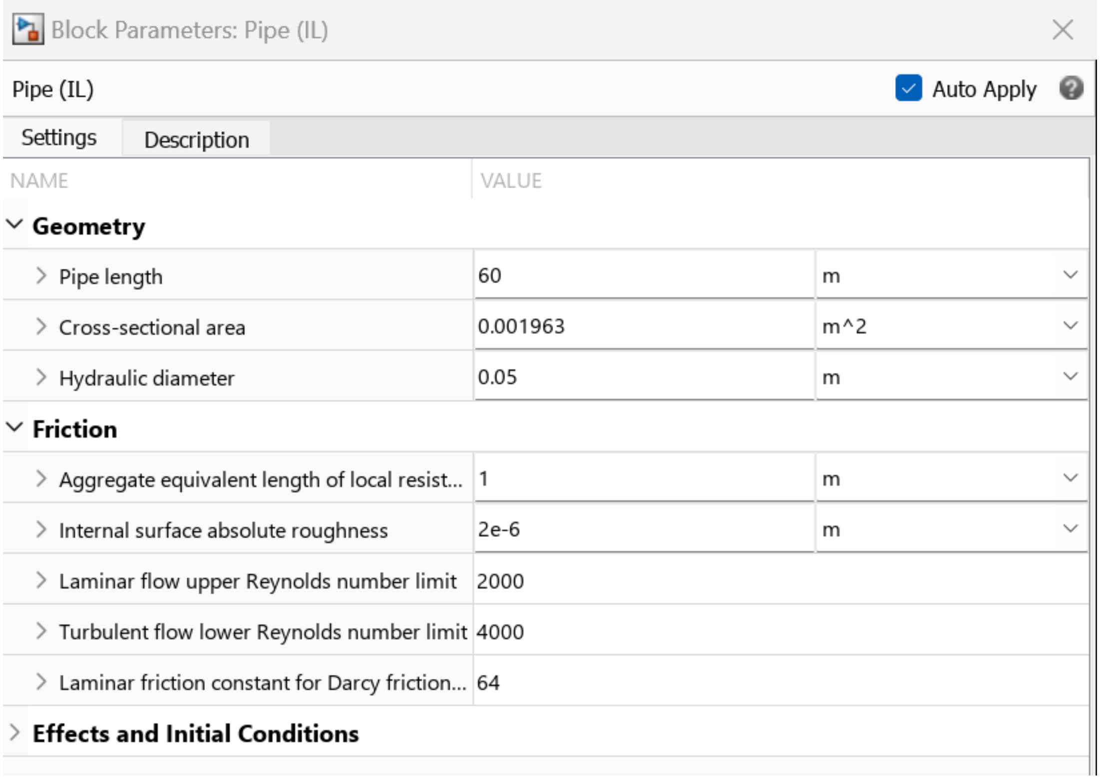
NAME	VALUE	
Liquid		
Isothermal liquid	Water	
System temperature	16	degC
Viscosity derating factor	1	
Atmospheric pressure	0.101325	MPa
Pressure below minimum valid value	Error	
Entrained Air		

Figure 3.2. Screenshot of parameters introduced in an element of the simulation



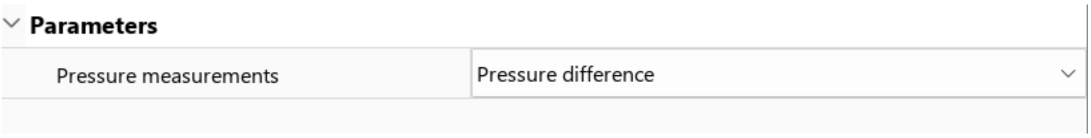
Parameters		
Source type	Constant	
Flow rate type	Volumetric flow rate	
Volumetric flow rate	0.006	m^3/s

Figure 3.3. Screenshot of parameters introduced in an element of the simulation



NAME	VALUE	
Geometry		
Pipe length	60	m
Cross-sectional area	0.001963	m^2
Hydraulic diameter	0.05	m
Friction		
Aggregate equivalent length of local resist...	1	m
Internal surface absolute roughness	2e-6	m
Laminar flow upper Reynolds number limit	2000	
Turbulent flow lower Reynolds number limit	4000	
Laminar friction constant for Darcy friction...	64	
Effects and Initial Conditions		

Figure 3.4. Screenshot of parameters introduced in an element of the simulation



Parameters	
Pressure measurements	Pressure difference

Figure 3.5. Screenshot of parameters introduced in an element of the simulation

As we can see in the display block in Figure 3.1 shows the final results of the first simulation. As you can see the result of the pressure drop for this simulation was 9.626e+04 Pa which is the same as saying 96260 Pa.

3.2.3. Simulating head loss in a water pipe and an elbow

The network that had to be drawn to carry out the simulation for determining the head loss of an installation consisting of an elbow attached to a pipe is shown in the next screenshot:

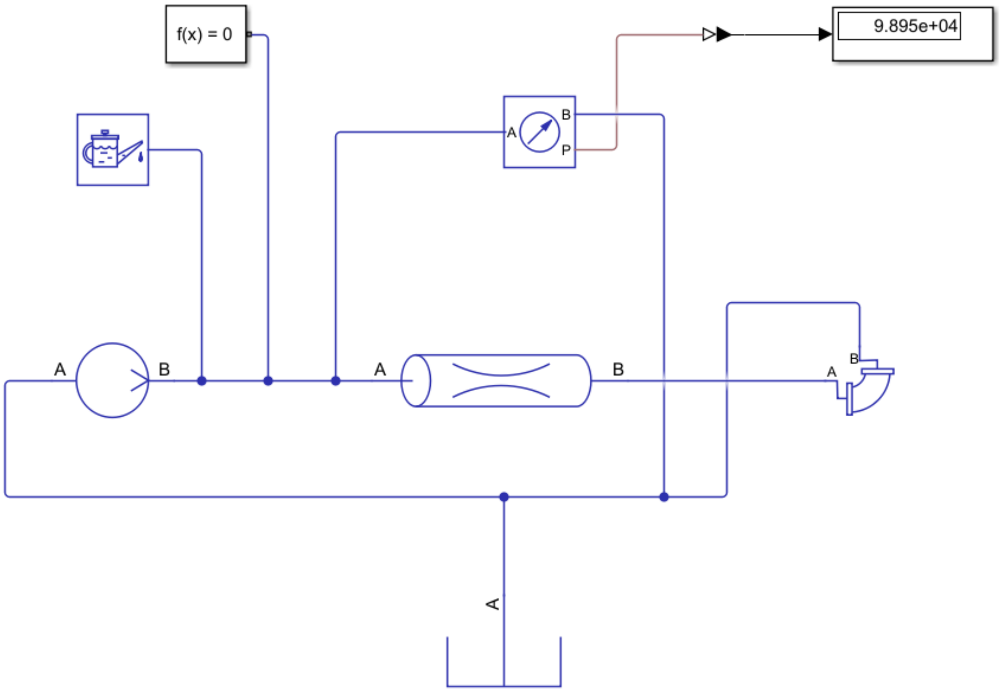
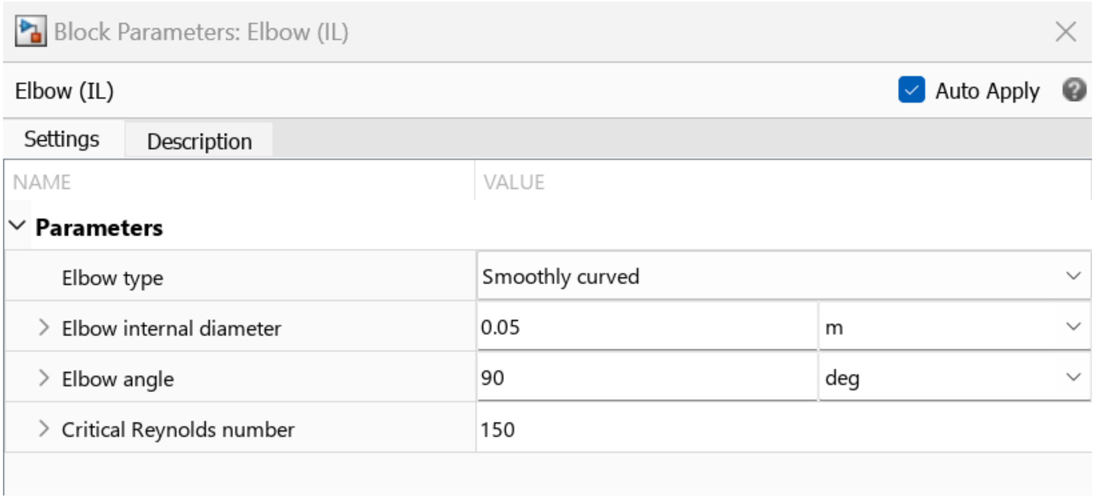


Figure 3.6. Installation to simulate head loss in a straight pipe and elbow

The only parameters that had to be introduced to carry out this simulation was the ones corresponding to the elbow as the other were introduced when carrying out the first simulation. As the elements were the same than the ones in the first case there was no need to modify them. The following screenshot shows the parameters introduced into the elbow matching the ones given in the definition of the problem.


Block Parameters: Elbow (IL)

Elbow (IL)

☑ Auto Apply

Parameters

NAME	VALUE	
Elbow type	Smoothly curved	
Elbow internal diameter	0.05	m
Elbow angle	90	deg
Critical Reynolds number	150	

Figure 3.7. Screenshot of parameters introduced in an element of the simulation

As we can see Figure 3.6 the result after the simulation which is shown in the display block was 9.895e+04 Pa (which is the same as saying 98950 Pa) for the total pressure drop of the network.

3.2.4. Simulating head loss in a water installation

As explained before in point 3.1.3. the installation was divided into two separate parts to be analysed independently; the resulting network drawn in MATLAB Simulink is the one shown in the next screenshot:

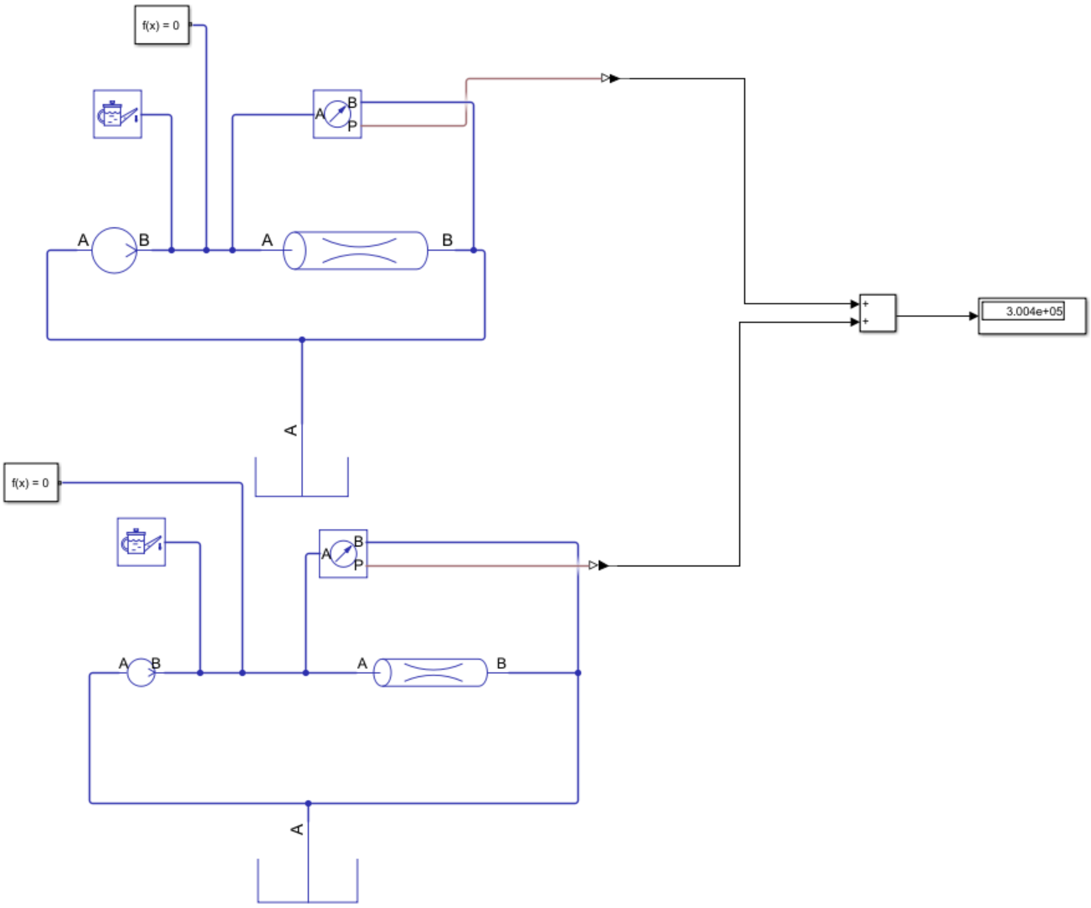
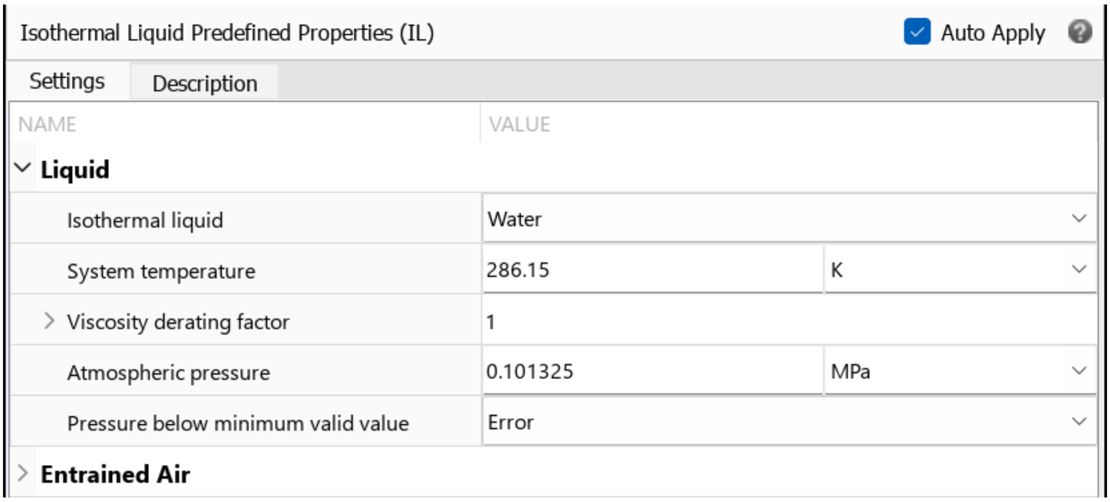


Figure 3.8. Network to simulate the head loss in a water installation of a home

For this last case about determining the head loss in a water installation all the parameters had to be introduced as this network had nothing to do with the ones analysed in the previous simulations. The following screenshots show where these parameters were introduced:



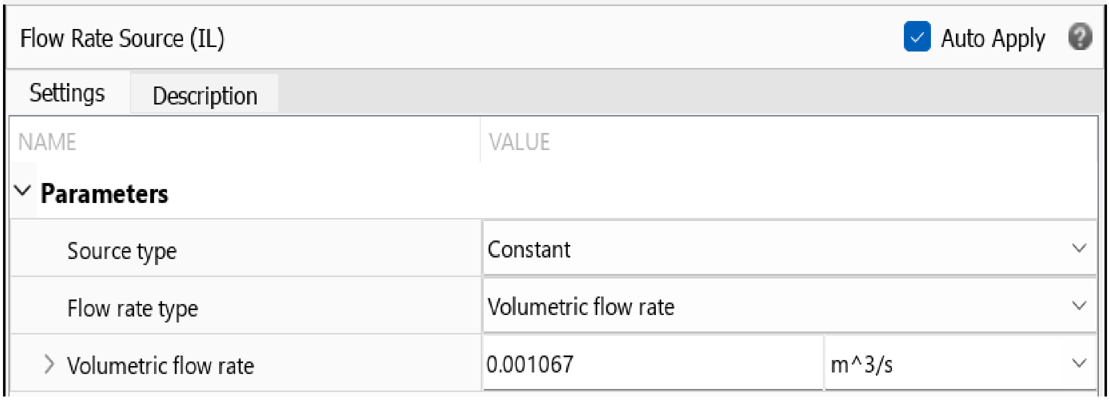
Liquid

Isothermal liquid	Water	
System temperature	286.15	K
Viscosity derating factor	1	
Atmospheric pressure	0.101325	MPa
Pressure below minimum valid value	Error	

Entrained Air

Figure 3.9. Screenshot of parameters introduced in an element of the simulation

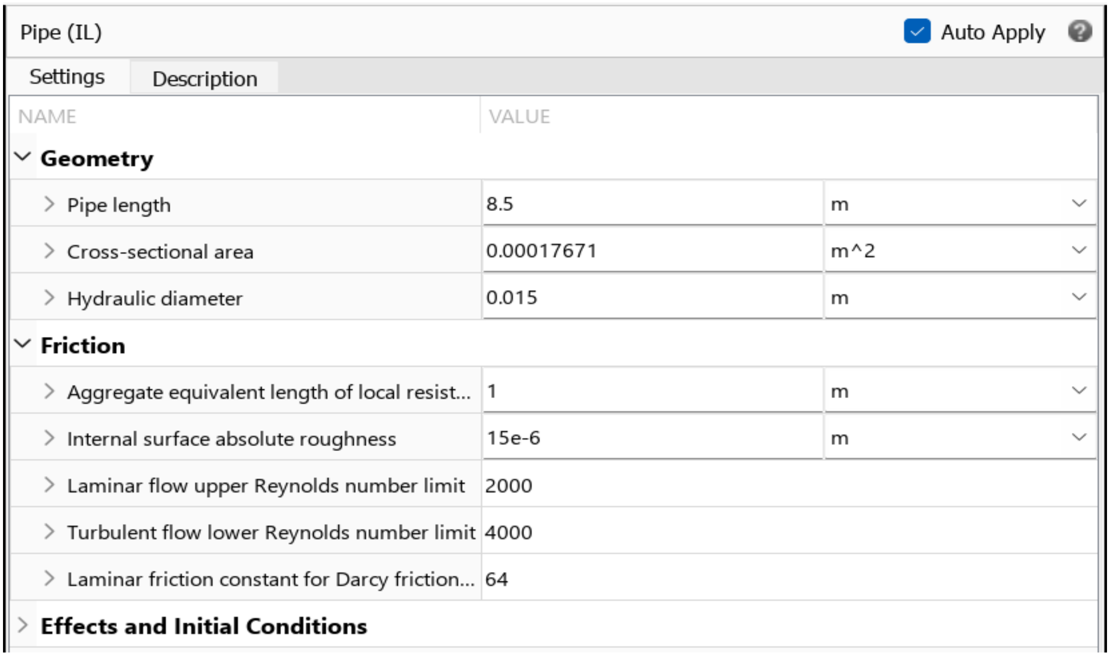
Both Isothermal Liquid Predefined Properties blocks had the same parameters introduced in them.



Parameters

Source type	Constant	
Flow rate type	Volumetric flow rate	
Volumetric flow rate	0.001067	m^3/s

Figure 3.10. Screenshot of parameters introduced in an element of the simulation

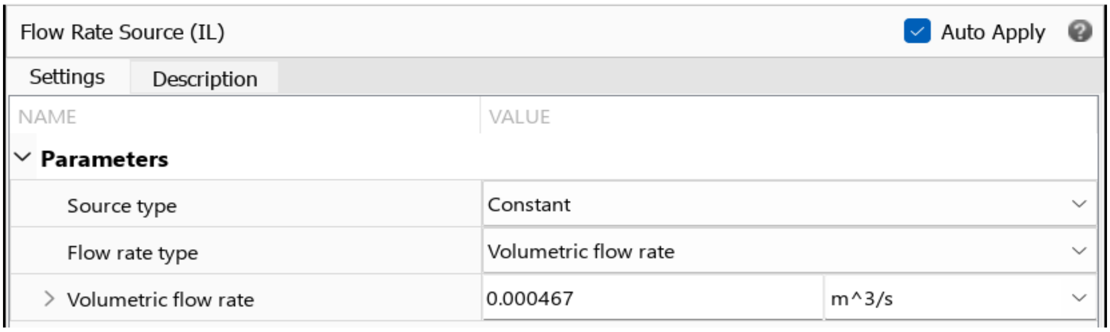


NAME	VALUE	
Geometry		
Pipe length	8.5	m
Cross-sectional area	0.00017671	m^2
Hydraulic diameter	0.015	m
Friction		
Aggregate equivalent length of local resist...	1	m
Internal surface absolute roughness	15e-6	m
Laminar flow upper Reynolds number limit	2000	
Turbulent flow lower Reynolds number limit	4000	
Laminar friction constant for Darcy friction...	64	
Effects and Initial Conditions		

Figure 3.11. Screenshot of parameters introduced in an element of the simulation

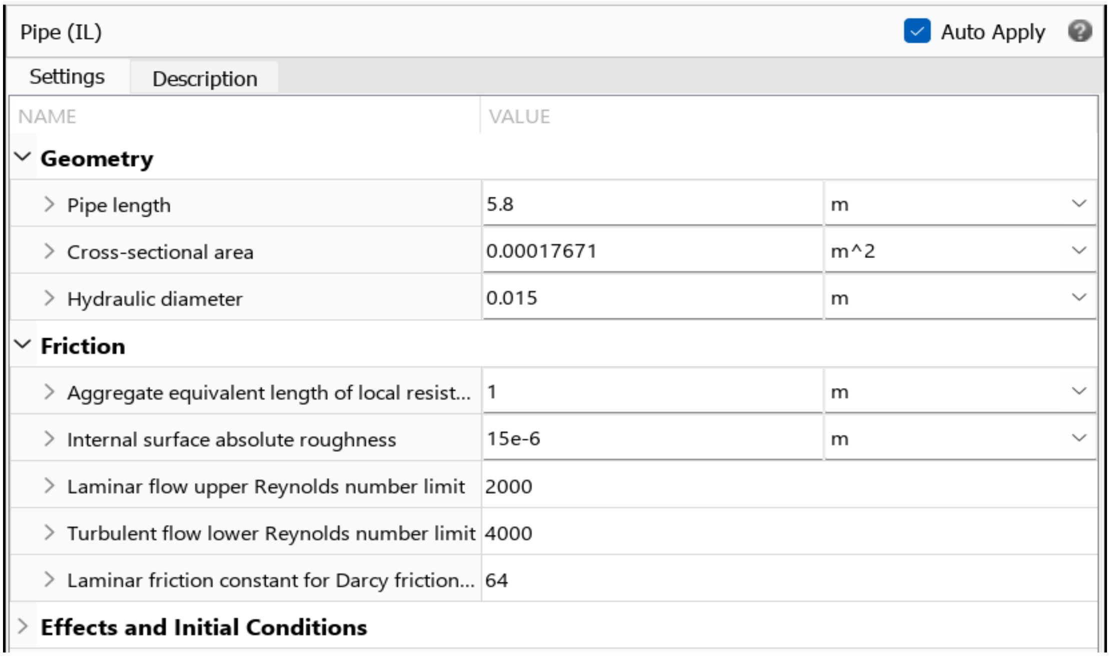
Figures 3.10 and 3.11 correspond to parameters introduced in the elements corresponding to the network that is placed in the upper part of the screenshot.

The following images will show the parameters introduced corresponding to the network in the lower part of the screenshot:



NAME	VALUE	
Parameters		
Source type	Constant	
Flow rate type	Volumetric flow rate	
Volumetric flow rate	0.000467	m^3/s

Figure 3.12. Screenshot of parameters introduced in an element of the simulation



NAME	VALUE	
Geometry		
Pipe length	5.8	m
Cross-sectional area	0.00017671	m^2
Hydraulic diameter	0.015	m
Friction		
Aggregate equivalent length of local resist...	1	m
Internal surface absolute roughness	15e-6	m
Laminar flow upper Reynolds number limit	2000	
Turbulent flow lower Reynolds number limit	4000	
Laminar friction constant for Darcy friction...	64	
Effects and Initial Conditions		

Figure 3.13. Screenshot of parameters introduced in an element of the simulation

As we can see in Figure 3.8, the simulation gave a result of 3.004e+05 which means that the total pressure drop for this installation was calculated to be 300400 Pa by the simulation software.

4. Conclusion

In this final project we have seen how to calculate pressure drops both manually and using computational simulations in Simulink from MATLAB software. In this project we have also learned some theory behind this calculations and why they are important to be carried out.

In the first case we analysed, when comparing this result to the one obtained manually before (58573.2 Pa) we can see that they are really close, having only a difference of:

$$\%Difference = \frac{96260 - 96231.38}{96260} \cdot 100 = 0.0297\%$$

As we can see in the equation above the difference between both results is 0.0297%, this difference between them could be explained because when calculating manually we tend to round numbers to less decimal places that they really have making the result we get a bit unprecise. As there is only a difference of 28.62 Pa we can conclude that the simulation was successful and our results were correct.

For the second case that was analysed in this final project, when comparing the result obtained in the simulation to the answer we got when calculating the pressure drop manually which was 60096.95 Pa we can see that the difference is of:

$$\%Difference = \frac{98950 - 97630.91}{98950} \cdot 100 = 1.33\%$$

As we can determine from the equation above both results are quite similar to each other as there is only a 1319.09 Pa difference. This difference can be justified as before because when people calculate something manually we tend to round things up resulting in a slight difference between the actual answer and the one we get. Another way of justifying this difference could be because the coefficient K used by me and by MATLAB could be slightly different also resulting in the difference in the final answer.

Finally, when analysing the third and last case when comparing the answer obtained in Simulink when doing the simulation and the answer we obtained when calculating manually we can see that there is a difference of:

$$\%Difference = \frac{300400 - 270689.48}{300400} = 9.89\%$$

As we can see from the result obtained when calculating the percentage difference between both results this difference is much greater than the ones obtained for the other cases analysed. We might be able to explain the difference between both results because of the rounding up when calculating manually, however due to the difference being nearly 10% it seems unlikely that this is the only factor involved in this. Another reason could be that Simulink calculated this pressure drop using a different process to the one that was used when calculating manually. If we had to extrapolate this results to the real world and choose between them when designing the water network it would be wiser to design the network using the result obtained in the simulation as it is much more unlikely for a computer to make a mistake than it is for a human. Also it would be wiser because the result obtained for the pressure drop is higher for the simulation which means that if this is used, in the worst case scenario we would still be able to use the installation as the only thing that would happen is that we would have applied a security factor by making it safer to use. However if the result that was used was the one obtained manually and the correct answer was greater than this the installation could be in serious trouble making it impossible to be used due to safety risks as cavitation.

5. Bibliography

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