Pressure Loss in Pipes

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Learning Outcomes

Integrate	Apply the Darcy–Weisbach equation to pressure loss, flow rate and friction factor calculations.
Concept	See the relationship between velocity and head loss for laminar and turbulent flow.
Integrate	Understand the limitations of applying empirical correlations to experimental results.
Design	Practice the steps of experimental design.

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Pressure Loss in Pipes:
Pre-experiment Activity

A pre-experimental activity must be completed before starting this experiment. Failure to complete these tasks may result in being refused entry into the laboratory.

1 Aims and objectives.

To understand how the pressure being lost in pipes due to friction and what parameters affect the extent of pressure loss.

To determine the friction factors for a variety of pipes and to use the collected data from the experiment to produce your own moody diagram then compare it to the standard Moody diagram.

2 Background

Fluid flow in pipes can be analysed by considering the principles of conservation of energy and conservation of mass. During this experiment, the pressure loss due to friction in pipes is investigated. The corresponding friction factor will be experimentally determined using Darcy's equation for a variety of pipes and plotted to produce a Moody diagram for comparison.

To account for energy lost through friction between a fluid and a pipe wall, the Darcy–Weisbach equation can be utilised. This is shown in equation 1,

$$h_L = \lambda \frac{l}{D} \frac{V^2}{2g} \qquad \textbf{[1]}$$

where h_L is the head loss due to friction, λ is the friction factor, l is the length of the pipe, D is the pipe diameter, V is the fluid velocity and g is the gravitational constant. This equation should help you estimate the head loss due to friction in pipes with different roughness and different diameters at different flow velocities.

3 Planning and preparation

3.1 Health and Safety

The standard diamond health and safety rules should be followed in this lab. In addition, care needs to be taken with the water used in the experimental set up. The water is treated with a biocide agent. All attempts should be made to avoid skin contact with the water. However, if the water does come into contact with your skin, ensure it is washed off using one of the laboratory sinks. Ensure you wash your hands once you have completed the experiment.

3.2 Experimental Design when supplied with a rig

Before starting this experiment, you will be expected to consider the experimental design. For this first session, you will be guided through the process in the laboratory with assistance available from staff.

Determine what are you trying to do, i.e. what is the aim of the investigation?

You should think carefully about this because it will shape every subsequent aspect of the experimental design and execution. One way to start is to think about what the nature of the final, processed result will be. For example, if there is a graph you are trying to plot, what will be the axes of this graph? From there, you can work backwards to determine the raw data and steps needed to achieve this outcome.

In your laboratory notebook, write down the aim of the experiment here, which you will have read in the pre-experimental activity before arriving.

Determine what you need to record.

Usually, you are trying to determine a relationship between a variable you set (the independent variable) and something that reacts to that variable (the dependent variable). Determine what readings from the experiment you need to record to obtain this relationship. All other factors should be left constant to ensure they are not influencing the relationship between the independent and department variables of the experiment. The equipment and its instrumentation may not directly record the properties in which you are interested. The outcome specified in the aim may require raw data taken from the experimental equipment to be processed.

Play with the experimental apparatus to determine what raw data (in the exact units that the instrumentation displays) is capable of producing. Determine how this raw data can be processed to produce the aims of the experiment. Write this information down.

Write a procedure

Consider how the equipment operates and determine the steps needed to obtain readings from the instrumentation. Consider how to start the equipment, alter the independent variable and how to record the dependent variable. What will you do if one of the values you are trying to measure is out of range of the equipment you choose? Consider what settings you will make for the independent variable or, if you can't determine this before starting the experiment, determine the method you will use to make a decision while the experiment is ongoing. Consider how to shut down the experiment.

In your laboratory notebook, write your procedure.

Reduce uncertainty

Consider the uncertainty associated with the raw data that is being collected. Consider if this uncertainty can be reduced by changing the method and determine how the error/uncertainty will be recorded in the experimental record. How will you ensure results are repeatable?

Write down this information.

Health and Safety

This activity has been fully risk assessed by staff before starting the experiment. The risk assessment is on MOLE. However, please consider here the potential risks that the experiment could present and what precautions you will put in place to ensure they are unlikely to cause serious harm, as part of a comprehensive experimental design process. If you are concerned about any health and safety issue please consult a member lab staff.

List the potential risks and precautions here in your laboratory notebook.

4 Experimental setup

The equipment will be set up as shown in figure 1. A pump supplies water from the sump in the Cussons hydraulic bench to the constant head inlet tank through a flow regulating valve. The water level in the inlet tank should be maintained at a constant height to supply the test specimen with a constant inlet pressure. Any excess water supplied by the pump will return to the sump via the inlet tank overflow hose. Under the constant head from the inlet tank, the water flows through the test specimen. The test specimen has two pressure tapings at either end, used to determine the pressure drop between two points **360 mm** apart. The water then enters the variable (and adjustable) head outlet tank before flowing out of the outlet pipe. The height of the outlet pipe can be adjusted to alter the flow rate. Water from the outlet pipe collects in the stepped measure tank, where the volume flow rate can be calculated. Finally, the water returns to the sump to be recycled into the hydraulic circuit.

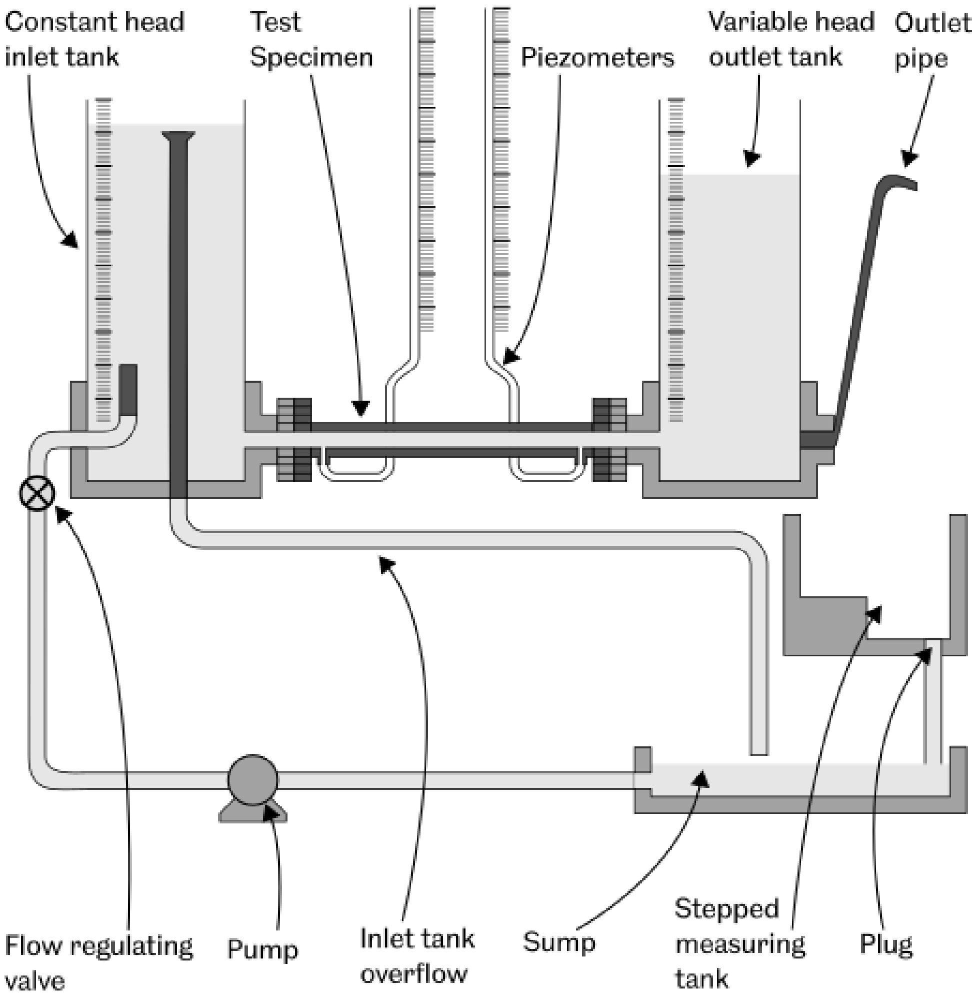


Figure 1: Experimental set up to measure pressure in test specimen.

Four different specimen pipes are available to test (**2 pipes** per group). These are listed in table 1.

Table 1: Test specimens used in the experiment

	Expected Flow Type	Nominal Bore	Tapping distance	Located on Bench
Specimen 1	Laminar	3 mm	360mm	Defined during the lab session
Specimen 2	Turbulent	6 mm (rough)	360mm	
Specimen 3	Turbulent	7 mm	360mm	
Specimen 4	Turbulent	10 mm	360 mm	

The following procedures should be followed on each of the test specimen pipes:

Aspects and procedures to consider when running this experiment:

1. Note the bore of the pipe on the bench you are using, which can be found printed on the sticker attached to the test specimen pipe. **This may be slightly different to the nominal value given in table 1**.
2. Ensure the black flow regulating valve is fully closed (by rotating anti-clockwise) before turning on the pump, by flicking the metal power on/off switch to the "On" position.
3. The experiment can be started by slowly opening the flow regulating valve (by rotating clockwise) and watching the water level rise in the inlet tank. As the water level reaches the top of the overflow pipe, adjust the flow regulating valve to create a constant height of water in the inlet tank.
4. Check that air bubbles are not trapped in the piezometers or connecting tubes. If air is present, perform the bleeding procedure. (Try disconnecting the hose and connecting it again). If a digital manometer is available you can record the pressure drop using this instrument. Ensure you have no bubbles in the connecting tubes.
   TIP! Ensure you keep your hands on the flow regulating valve as the water rises and ensure it doesn't flow over the top edge of the inlet tank.
5. Alter the height of the outlet pipe to change the flow rate passing through the pipe.
6. **Do not drop the height of the outlet pipe below the height of the specimen, or air will be drawn into the apparatus and affect the results.**
7. You can measure the pressure drop across the pipe by reading the manometer heads (water levels).
8. Repeat this measurement for at least **six** different flow rates in each pipe to cover different regimes of flow (laminar and turbulent).
9. To finish, fully close the flow regulating valve (by rotating anti-clockwise) and turn off the pump. **Do not leave the flow regulating valve open when the pump is off, or air will be drawn into the apparatus, affecting results.**

5 Results

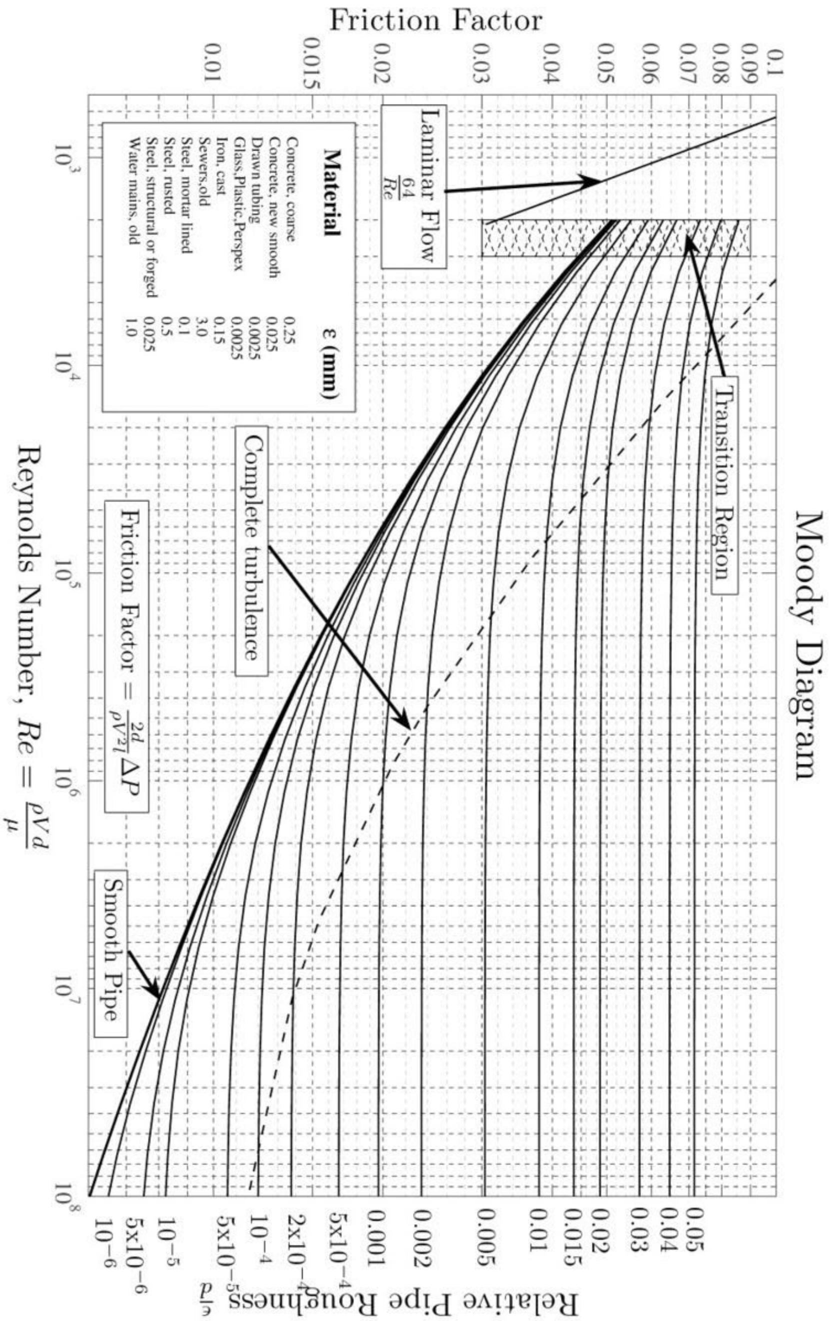
1. Process the raw data using the excel provided

Pipe Diameters (mm):

h_{Loss}	ΔP	Flow Rate		Velocity	λ (exp)	Re	λ (theory using Moody)
(m)	(Pa)	($l.min^{-1}$)	($m^3.s^{-1}$)	($m.s^{-1}$)			

2. Use the excel sheet on your laptop to plot the Reynold number (Re) (on the x axis) against the experimental friction factor λ (on the y axis) for the 3 mm and the 7 mm pipe. What is the difference in the trends shown between laminar and turbulent flow?

Plot values of Reynolds number and experimental friction factor on the Moody diagram below to determine if they line on the expected lines. Copies are available in the lab and can be stuck into your laboratory notebook.



6 Discussions and conclusions

Try to answer the following questions.

1. How accurate where your experimental results compare with the moody diagram?
2. What is the reason behind installing an inlet tank in this experiment?
3. Which diameter has significant effect on the pressure loss in the pipes?
4. Which of the following has more significant effect on the pressure loss; Diameter or velocity?
5. Why is important to determine the friction factor in pipes?