Instrumentation and Measurement

Lab 7

Pressure Loss and Reynold's Number

Date the Lab was performed (mm-dd-yy):04/05/2024..

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Revision Number: Winter 2024

Submission Instruction:

Review the lab report before submitting and put a check mark (√) in the appropriate check box on the left if the item has been duly completed in your lab report. The bracket on the right side will be filled out by your instructor with your gained mark.

1. Submission with handwriting for explanatory questions will not be accepted.
2. Scan and create a SINGLE .pdf of all pages, do not submit each Page of your lab report as a separate file
3. Type the answer of the explanatory questions on your pdf file. You can use the Microsoft Edge browser for typing on a pdf file.
4. The lab report file must be named in the following manner:
   "Your First Name_YourLast Name.pdf",
5. Upload and submit the pdf of your lab report in Blackboard.

Marking:

☐ Section 2	[ ] / 20
☐ Section 3	[ ] / 40
☐ Assignment	[ ] / 40

* Every 20 minutes late is subjected to 10 marks deduction

Pressure Loss and Reynold’s Number

Objective:

1) To study pressure drop in process
2) Reynold’s Number

1) Preparation:

1-1) The pressure of the fluid is divided into three types of pressures: Static (Hydrostatic, Non-Hydrostatic) and Dynamic pressure.

a) Hydrostatic (Head) pressure is the pressure resulting from weight of the fluid. For example water in the tank. The weight of the water applies force to the bottom of the tank. $P_{Hydrostatic} = \rho g h$

b) Non-Hydrostatic (Static) Pressure is the force applied by the non-moving fluid to the surrounding environment (ex, generated by pump) = P

c) Dynamic pressure is the pressure resulting from the motion of the fluid. For example a running gas or liquid can apply pressure to the object in their path. $P_{Dynamic} = \frac{\rho}{2} \times V^2$

1-2) When a fluid is pumped inside the pipe and the path is closed (valve is closed) all the pressure is the static pressure. When the path is opened part of static pressure turns into dynamic pressure and the fluid flows. Higher static pressure, faster flow.

1-3) The flow of fluid through a pipe involves overcoming. When the fluid starts running, it uses a portion of its static pressure for propulsion and converts some into dynamic pressure, resulting in a decrease in static pressure. This decrease of pressure is known as “pressure drop” or “Pressure loss” denoted by ΔP.

1-4) Assume a fluid is running through a pipe, the pressure loss will be higher for a longer pipe and less for a wider pipe. $\Delta P \propto L / A$.

1-5) Pressure drop can happen even through the open valve, because of change of diameter and roughness of the path.

1-6) There are two types of flow profiles, Laminar and Turbulent. The pressure drop for turbulent flow depends on the pipe inner surface roughness. In other words pressure loss depends on flow profile also. The flow profile is determined by a number called Reynold’s Number.

1-7) Reynolds number; $Re = 1488 \times \frac{v \times d \times \rho}{\mu}$

Re = Reynolds number
v = mean velocity [ft / s]
d = inside diameter of pipe [ft]
ρ = density [lb / ft3]
μ = viscosity [cP] ; 1 cP = 0.001 Pa.s
1488 = constant conversion factor

1-8) For more information you can watch following videos:

[Understanding Bernoulli's Equation]
[Understanding Laminar and Turbulent Flow]

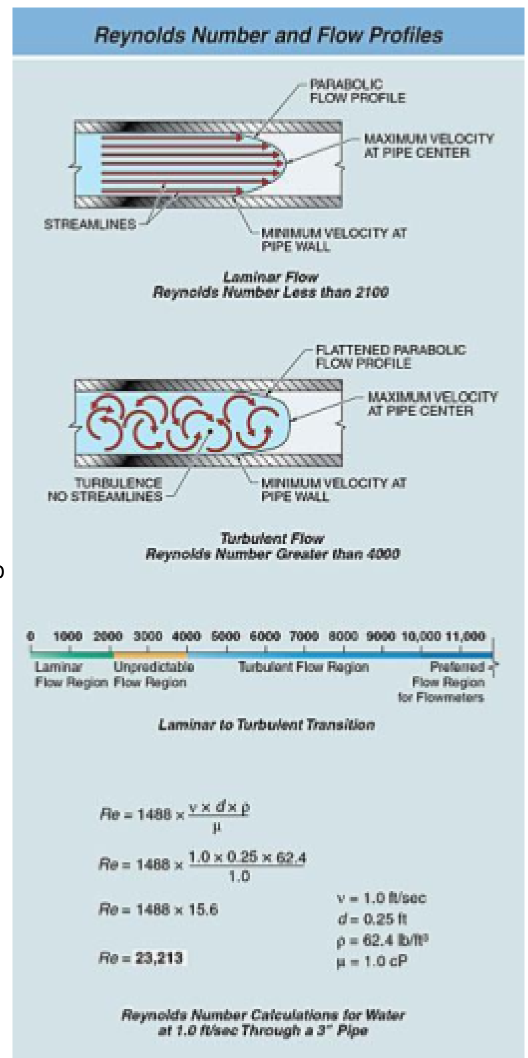

Figure L7-1

2) Making the process:

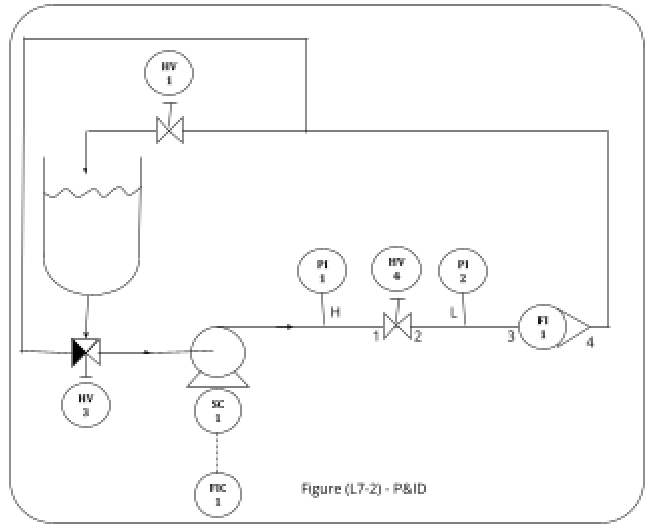
Figure (L7-2) - P&ID

2-1) Setup the system as shown in the front P&ID (Figure L7-2).

2-2) On the pump unit,

a) Open HV1 completely (turn the handle fully counterclockwise)
b) Close HV2 completely (turn handle fully clockwise)
c) Set HV3 for directing the full reservoir flow to the pump inlet (turn handle fully clockwise)
d) Open the HV4 fully

2-3) Make sure the reservoir of the pumping unit is filled with about 12 liters (3.2 gallons US) of water and the baffle plate is properly installed at the bottom of the reservoir.

2-4) Turn on the pump with full speed and read the pressure values across the valve.

PI-1 10 .... psi   Pi-2 9 .... psi

ΔP(Pressure loss across the valve) 1 .... psi   Maximum Flow 10.5 .... L/min

2-5) Close HV4 and write down the pressure value.

PI-1 15 .... psi   Pi-2 0 .... psi   ΔP(Pressure loss across the valve) 15 .... psi

Instructor Signature for section 2 ....

3) Measurement:

3-1) Take a pressure transmitter from the cabinet.

3-2) Calibrate the transmitter as Lab4 instruction by using the air pressure and air pressure gauge to calibrate the transmitter for 0-100 kPa and 0.2 - 5 volt. You might need to repeat the adjustment process a few times to get a proper calibration.

3-3) Disconnect the air supply and write the transmitter voltage output for 0 kPa and then connect 100 kPa air pressure to the transmitter and write the voltage below.

0 kPa 0.201 .... Volt   100 kPa (14.5 psi) 5.0 .... volt

3-4) Round down (floor) the maximum flow value from step 2-4. Then set the pump speed so that the rotameter shows the rounded flow value. For example let's assume you measured the maximum flow as 12.7 L/m. The floor of 12.7 is 12 L/m. Then you set the motor speed so that you see 12 L/m on the rotameter . For the next step you set the flow at "Floor (Maximum Flow) -1 = 12-1=11 L/m.

3-5) Use your calibrated transmitter to measure gauge pressure at points 1, 2, 3, and 4 (The points are indicated in P&ID). For the measurement, the high pressure inlet of the transmitter will be connected to the measurement point and the low pressure inlet is not connected to anywhere and sensing the atmospheric pressure. Fill out the Table L7-1

3-6) Perform the steps 3-4 and 3-5 to fill out the Table L7-1.

Flow in L/m	Transmitter output voltage at point 1 - V1	V2	V3	V4	Delta V21(valve) = V1 - V2	Delta V32(Hose) = V3 - V2	Delta V43(Rotameter) = V4 - V3
Floor (Maximum Flow)	3.55	3.14	1.69	1.5	0.41	-1.45	-0.19
Floor (Maximum Flow) -1	2.95	2.63	1.38	1.17	0.32	-1.25	-0.21
Floor (Maximum Flow) -2	2.45	2.18	1.25	1.02	0.27	-0.93	-0.23
Floor (Maximum Flow) -3	1.8	1.72	1.03	0.83	0.08	-0.69	-0.2
Floor (Maximum Flow) -4	1.30	1.15	0.63	0.54	0.15	-0.52	-0.09
Table (L7-1)							

3-7) Disconnect the circuit. Return the components and hoses to their storage location. Wipe off any water from the floor and the Process Control Training System

Instructor Signature for Section 3 ....

4) Assignment:

4-1) Regarding steps 2-4 and 2-5 and the measurements, Calculate the pressure drop at the point of PI-1 before and after HV-4 is closed. By comparing the PI1 values, calculate the water speed when the valve is fully opened using the dynamic pressure concept and its dependency to flow speed. Use calculated water speed and the hose diameter (= 12.7 mm) to calculate the water flow rate and compare it with maximum flow rate measured in 2-4 . Flow rate is defined as volume of the fluid passing through in time unit. Explain what could cause this difference. show calculations in steps *(10 Marks)*

ΔP (Before & After HV4 Closed) ....1........ psi 6.89 kPa water speed..1.46... m/s Calculated Flow rate 11.1 L/min

Difference between calculated and measured 0.6.. L/min

P = PI-1 (After) - PI-1 (Before)
P = 10 psi - 9 psi
P = 1 psi or 6.89 kpa

$$P\ (dynamic) = \left(\frac{p(Density)}{2}\right) \bullet V\ (water\ speed)^2$$

$$V = \sqrt{\frac{2P}{p}}$$

$$V\ (m/s) = \sqrt{\frac{2 \bullet (5 * 144 psf)}{62.4}}$$

$$V = 4.8\ ft/s$$

$$V = 1.46\ m/s$$

$$Q\ (Flow\ Rate) = A\ (Area) \cdot V\ (Speed)$$

$$Q = \frac{1}{4} \cdot \pi \cdot D^2 \cdot V$$

$$Q\ (L/min) = \frac{1}{4}\pi(0.0127 m^2) \cdot 1.46 m/s \cdot 60 \cdot 1000 L$$

$$Q = 11.1\ L/min$$

$$\Delta Q = 11.1 - 10.5$$

$$\Delta Q = 0.6\ L/min$$

4-2) Based on Table L7-1, Plot the voltage drops vs flow rates curve for the valve, hose and Rotameter in Figure L7-3. Label the curves as “Valve”, “Hose” and “Rotameter” respectively. *(15 Marks)*

4-3) The pressure transmitter used in step 3-7 is a linear transmitter then the measured voltage drop in Table L7-1 is proportional to pressure drops across the valve, hose and the rotameter. Following your graph in the above figure what is the relation between flow rate and the pressure drop? *(5 Marks)*

The Lower the Flow Rate the Smaller the pressure drop, will become.

4-4) Consider the valve, hose and Rotameter by the amount of pressure loss they caused, and fill out the below empty spaces.

Highest pressure loss caused by Hose mid pressure loss Valve lowest pressure loss Rotameter *(5 Marks)*

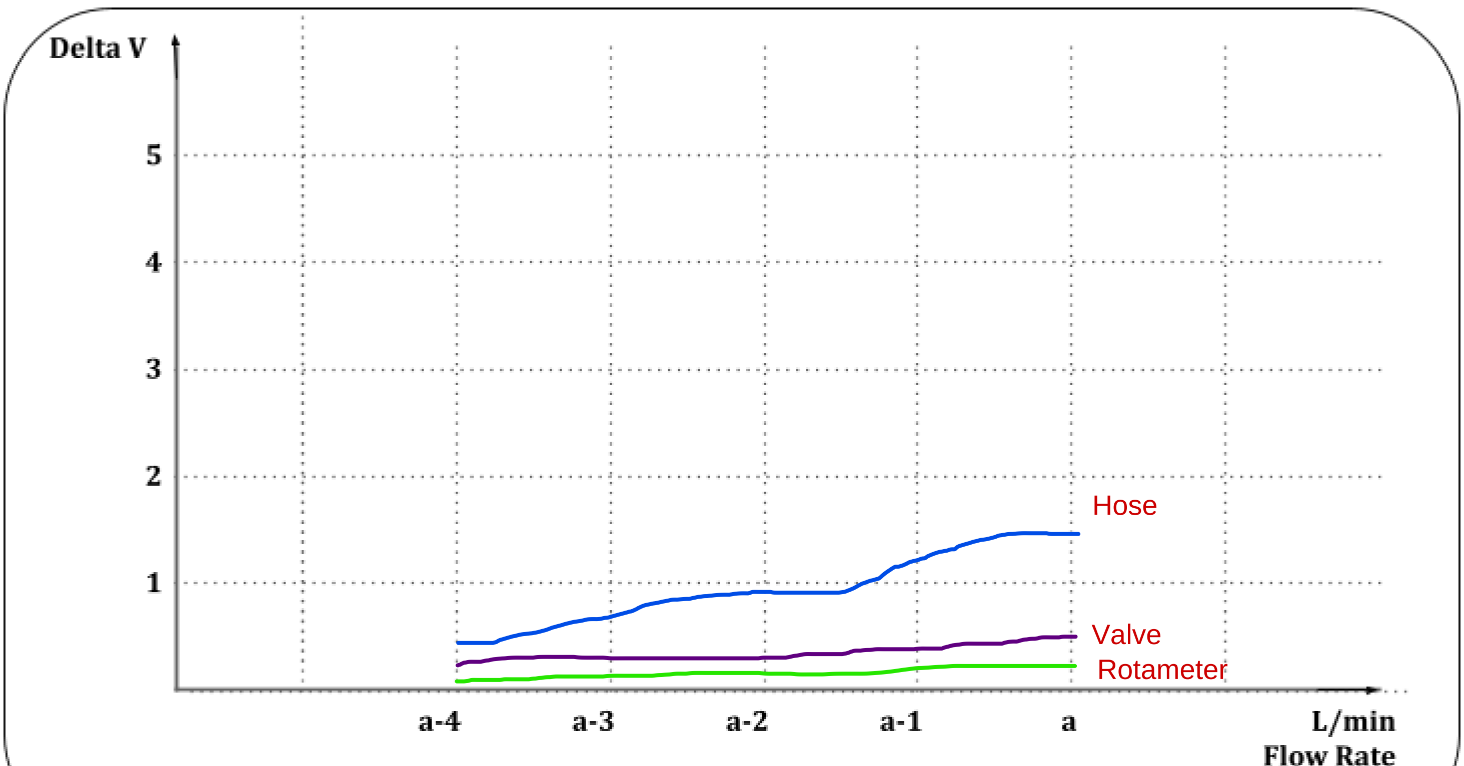

Figure (L7-3)

4-5) Calculate the Reynolds number for the flow inside the hose and determine whether the fluid flow through the hose was laminar, transitional, or turbulent at a given flow rate using Figure L7-1. Assume Assume hose inner diameter = 12.7 mm and water density is 1000 kg/m³ and viscosity 1 cP. show calculations in steps. *(5 Marks)*

$$v = \frac{10\,Lpm}{\frac{\pi}{4}\cdot(0.0127)^2 m^2 \cdot \frac{1}{1000} m^3/m \cdot \frac{1}{60}\,sec}$$

$$p = 1000\,kg/m^3 \Rightarrow 62.43\,lb/ft^3$$
$$d = 12.7mm \Rightarrow 0.041\,ft$$

$$v = 1.32\,m/s \cdot 3.2808399$$
$$v = 4.33\,ft/s$$

$$Re = 1488 \cdot \frac{4.33 \cdot 62.43 \cdot 0.041}{1}$$
$$Re = 16491.8$$

Therefore the Fluid Flow is/was Turbulent