Experiment: No. 4 - Minor Losses in Pipe Systems

Learning Objective
Following the completion of this experiment and the analysis of the data, you should be able to
1. Recognize the distinction between major losses and minor losses in a pipe system,
2. explain the process used to estimate the headloss of a fluid flowing through a pipe component, and
3. compute the loss coefficient for a combination of various flow rates flowing through elbows, tees and valves.

Introduction
Most pipe systems consist of straight pipes as well as components such as valves, elbows, and tees. Each component contributes to the total headloss in the fluid moving through a pipe system. Headlosses associated with straight pipes are called major losses. Headlosses associated with valves, elbows and tees are called minor losses. The importance of recognizing major and minor losses is that in some systems the sum of the minor losses may be greater than the major losses.

Valves, elbows and tees are installed in the system to regulate, direct, and combine or divide the flow stream respectively. It is nearly impossible to determine the losses exactly due to the complex fluid effects these components produce. Therefore, a loss coefficient $K_L$ is used to account for these losses. The minor loss coefficient is defined as

$$K_L = \frac{h_L}{V^2 / 2g} \quad \rightarrow \quad h_L = K_L \cdot \frac{V^2}{2g} \quad (Eq. \ 4.1)$$

You should recognize that the $\frac{V^2}{2g}$ portion of Eq. 4.1 represents the velocity head of the moving fluid. The losses due to the elevation head and the pressure head can be determined separately if needed since they depend on the orientation of the flow (i.e. horizontal, vertical or sloped).

Minor losses are often specified in terms of equivalent length, $L_{eq}$, which is the equivalent length of pipe needed to produce the same headloss as the given component. It is defined as

$$L_{eq} = K_L \cdot \frac{D}{f} \quad (Eq. \ 4.2)$$
where

\[ K_L \] Loss coefficient
\[ h_L \] Headloss across the component, ft of water
\[ V \] Fluid velocity, ft/s
\[ g \] Acceleration due to gravity, ft/s²
\[ L_{eq} \] Equivalent length of pipe with the same nominal diameter, ft
\[ D \] Pipe diameter, ft
\[ \xi \] Pipe roughness, ft
\[ \rho \] Fluid density, slug/ft³
\[ \mu \] Fluid dynamic viscosity, lbf*s/ft²
\[ Re \] Reynolds number = \( \rho * V * D / \mu \)
\[ f \] Friction factor (function of pipe relative roughness \( \xi/D \), and \( Re \))

The friction factor, \( f \), may be found on a Moody chart (one is included with the lab packet) if \( \xi, D, \) and \( Re \) are known. It may also be computed using a modified version of what is known as the Jain equation (Chin 2006, p.19)

\[
f = \frac{0.25}{\log\left(\frac{k_s}{3.7D} + \frac{5.74}{Re^{0.9}}\right)}
\]

(Eq. 4.3)

where \( k_s \) is the equivalent sand roughness (which is about the same as \( \xi \)), ft

**Purpose**

The purpose of this experiment is to examine the flow through valves, elbows and tees to

1) Determine the \( K_L \) value and compare it to the value for each component as provided in another reference (textbook, handbook, etc.).

2) Determine the equivalent length for a given component.

**Equipment**

- Hampden Model H-6925 Fluid Circuits Demonstrator (with 0.655-inch diameter sharp-edged orifice plate installed)
- Differential pressure transducer.

**Procedure**

Note: Before you start the experiment and after changing flow rates, the differential manometer should be re-zeroed. To do this, open the valve that connects the two sides of the differential manometer, press the tare button on the digital readout, then close the valve.

1. Close all the valves on the demonstrator. Open the following valves: [13, 8].
2. Determine which component is to be tested. Open the valves for the component to be tested according to Table 4.1.
Table 4.1 - Valves to open for selected components

<table>
<thead>
<tr>
<th>Component</th>
<th>Valves to open</th>
<th>Valve to control flowrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow, short radius (above valve 7)</td>
<td>8, 8, 7, 6, gate valve</td>
<td>Globe valve</td>
</tr>
<tr>
<td>Elbow, long radius (above valve 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gate Valve</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tee (branch)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tee (straight through)</td>
<td>9, 8, 1, 8, 4</td>
<td></td>
</tr>
</tbody>
</table>

3. Attach the pressure transducer tubes to the pressure taps next to the component. Connect the “+” side of the pressure transducer to the upstream side of the component. Connect the “-” side of the pressure transducer to the downstream side of the component. This will measure the head difference across the component \( (h_L = h_1 - h_2) \).

4. Turn the pump power ON.

5. Adjust the Globe valve to obtain a flow of 2 gpm as indicated by the flowmeter. Allow the water to flow for a minute at that rate to pressurize the pipes.

6. Bleed the air trapped in the pressure transducer lines.

7. Record the flow rate along with the representative (average) differential headloss, \( h_L \), in Table 4.2.

   NOTE: Be sure to re-zero (tare) the digital pressure transducer just before each reading. Note that because of the averaging algorithm the pressure transducer display uses it may take several (typically about 5) seconds before it settles to the actual value.

8. Repeat steps 2 through 7 for a total of six (6) different flowrate settings by adjusting the Globe valve for additional flow rates of 4, 8, 12, 16 and 20 gpm (or the highest flowrate that can safely be achieved up to the flowmeter capacity).  
   NOTE: Do NOT exceed the capacity of the differential pressure transducer.

Analysis
Determine the minor losses coefficient for each component using equation Eq. 4.1 by linear regression. Show the data and calculated results in Table 4.2 for the steps outlined below. Include the results in your report.

For each pipe component tested -

1. Plot the headloss observed across the component, \( h_{L,obs} \) (y-axis) vs. \( V^2/2g \) (x-axis).
a. The slope of this line is the $K_L$ value.

b. Compare it to a reference value. List the reference.

2. Take the $K_L$ value and put it back into the equation term $K_L (V^2/2g)$ to find the predicted headloss value, $h_{L,pre}$.

3. Calculate $\xi/D$, $Re$, $f$ for the 10 gpm flowrate.

4. Plot $h_{L,obs}$ vs. $h_{L,pre}$ to evaluate the accuracy of your work. The slope of the line should be close to 1 if the equation is well-calibrated. Comment about whether or not it is close to one and what that means.

5. Evaluate the accuracy of the results found using Eq. 4.1.
   a. Propose a modified version of equation Eq. 4.1 that could produce more accurate results.
   b. Show that the proposed modified equation improves the headloss prediction for the majority of the flowrates used in this experiment.

6. Determine the equivalent length of 1-inch diameter pipe, $L_{eq}$.
   a. To find the equivalent length, use the table provided in the syllabus attachments to find $\rho$ and $\mu$.
   b. Use Eq. 4.2 to find $L_{eq}$.

Report

Please refer to the report requirements included in the syllabus and posted on the course website.

Reference

## Table 4.2 – Summary of results

<table>
<thead>
<tr>
<th>Component</th>
<th>Q (gpm)</th>
<th>$h_{L,obs}$ (ft)</th>
<th>V (ft/s)</th>
<th>$V^2/g$ (ft)</th>
<th>$K_L$</th>
<th>$h_{L,pre}$ (ft)</th>
<th>$\xi/D$</th>
<th>Re</th>
<th>f</th>
<th>$L_{eq}$ (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow, Short Radius</td>
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<td>Gate Valve (fully open)</td>
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<td>Tee (branch)</td>
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<td>Tee (straight)</td>
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