SAFETY

The major safety hazard in this laboratory is a shock hazard. Given that you will be working with water and items running on standard line voltages (the pump and the computer) you should pay attention to the possibility of electric shock. If water spills on the desktop, please clean it up IF there is no risk of shock. If water gets near a 110V electrical connection (i.e. a wall outlet or anything connected to it) DO NOT clean it up. Seek a TA, Tinoco (HLS 369), or one of the CEE technicians (Tim Brock, Paul Charles, or Cameron Willkens, who have offices across from the lab) for help.

Note that when the pump is ON the pipe network is under pressure –

DO NOT OPEN ANY PORTS WHILE THE PUMP IS RUNNING.

The result will be a column of water that can reach eye level or above. Before turning on the pumps ensure that all ports are closed (either by a pressure sensor, the dye syringe, or a plug).

Always work with a minimum of two people.

OBJECTIVES

In this laboratory:

1. You will gain physical experience with pipe flows, minor and major losses, and the Reynolds number dependence of the flow characteristics (laminar, transitional, and turbulent flow).

2. You will recreate the famous Osborne Reynolds’ experiment!

THEORY

At this point you should all be familiar with the theory. The major aspects of this flow are that a pump, capable of supplying up to about 4m of head, drives flow through a ½” clear PVC pipe system with various major and minor losses. Using the energy equation you can determine the minor loss coefficients ($K_m$) by monitoring the pressure drop across the various pipe system features. The pipe has been fitted with taps to which you can connect 100kPa (maximum gage pressure reading 100 kPa) pressure transducers. You can also determine the friction factor ($f$) by measuring the distance between ports in a long straight run of pipe and monitoring the pressure drop across these ports.

Experimental Procedure.

1. Open up the Easy Data software (if it is not already open). Press F1 for more options. Ensure that "fluidsdata.cee.cornell.edu" is highlighted in grey in the upper left corner. If not, click "select" and choose "fluidsdata" and hit "ok." Click the button with a file folder on it to retrieve overall configuration of sensors from file; look in Desktop -> Shortcut to CEE3310 -> Lab5 -> CEE3310_Lab5_Configuration.smm. A bar graph of 10 sensors should appear on the screen (in the same order that the sensors are located around the table, starting at the large cylinder).
If a line graph appears, click the 4th button (with the image of a bar graph) to toggle between line/bar graph. Sensors are already enabled to record in Pa, so units of Pa will appear both on the EasyData screen and during data analysis in Excel. The default settings should show all ten pressure sensors (shown on the screen as 0-9). Feel free to switch between bar and line charts.

2. Before turning on the pumps zero the pressure sensors. Your goal is to zero them to atmospheric pressure so you need to have the pump off and the pipe network sufficiently drained such that each pressure sensor has a path to open air. With the system in this configuration just press “zero” in Easy Data. Verify each sensor is within +/- 50 Pa before reactivating the pump. If one of the sensors fluctuates more than +/- 50 Pa, first try to zero the sensors again a few times. If that doesn’t help, discuss the situation with a TA.

3. A submersible pump is located in a tub of water at the end of the pipe system with the large diameter reservoir. Activate the pump by switching on the power strip.

4. If there are air bubbles in the large diameter pipe, bleed the system by opening the valve on top of the large diameter pipe. Keep this valve open until pure water is coming from the tube. You might need to lift the piping a little to eliminate all air bubbles.

5. If there are air bubbles trapped within the piping system, try opening and closing the pipe valve a few times. The sudden change in momentum usually clears these bubbles. If bubbles are trapped at the end of the piping system, try tapping and/or lifting the piping to eliminate these bubbles.

6. Make sure the outlet pipe from the network is NOT submerged (just rotate the outlet a bit so the end is above the water surface in the tank.

7. Your goal is to measure the friction factor (f) in the straight section of pipe (between sensors 1 and 2 as listed on the diagram) and all the head loss coefficients (KL) for each minor loss in the system. The minor losses are:
   a. Contraction from large diameter pipe to 1/2" pipe (0-1)
   b. 90 degrees elbow (2-3)
   c. Large radius 90 degrees bend (3-4)
   d. Expansion from 1/2" to 1" pipe (5-6)
   e. Contraction from 1" to 1/2" pipe (7-8)
   f. Valve (8-9)
   g. Total head loss from the first to last pressure port in the system (0-9)

8. Perform all of the above for two different flow rates, one with the valve set to full open and a second set with the valve closed down to reduce the flow rate by approximately one-half (the valve will be more closed than open). Verify that your pressure sensors are still within +/- 50Pa of zero or re-zero as needed between runs.

9. You can measure the flow rate by timing how long it takes to capture 4000 ml of water in the provided container – dip it under the outflow tube.

10. The final task is to walk in Osborne Reynolds shoes. Using red dye No. 40 (injected by a peristaltic pump), perform a flow visualization of laminar, transitional and turbulent flow. Note the valve will be almost totally closed to get laminar and transition flow (check your Re by measuring the flow rate). Inject a dye pulse by turning on the peristaltic pump for a few seconds.

Notes:
A. If the water is too red from previous experiments, drain and refill the system. When you refill the tub use fresh water using the green hose provided. Have somebody hold the hose in the tank (conservation of linear momentum!) and watch the water level. You should fill the system until the level is just about 6” below the top of the tank with the pipe system off.

B. Unless you wear a lot of red, take care during the dye injection. The red dye is harmless but it will stain (and we are not liable for this).
Make sure you have collected the data in Tables 1 and 2 before turning off the power switch and leaving the lab.

As part of your report:

a) Calculate the quantities required in Table 3.

b) For each of the 10 ports calculate EGL and HGL, and plot the two lines using a solid line for EGL and dashed line for HGL on a plot with the approximate location of each port ($x$ location = position downstream of port 0).

c) For each of the losses measured between ports calculate the following values from your measurements (Measured) and use minor and major loss theory to predict the value (Predicted), as requested in Table 4.

d) Finally, make sketches of the laminar, transitional, and turbulent dye visualizations and report the associated Reynolds numbers.

Provide a simple write-up. Submit the above tables filled in along with your EGL/HGL plot and sketches. One submission per group with the names of those who participated clearly marked. The reports are due no later than Monday, June 25, 2012 at 2:30pm in the Lab.
Table 1: Fixed parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water temperature ($^\circ$C)</td>
<td></td>
</tr>
<tr>
<td>Total length of 1/2&quot; diameter pipes (i.e. sum of all 1/2&quot; pipe between ports 0 and 9)</td>
<td></td>
</tr>
<tr>
<td>Radius of gradual 90 degree bend</td>
<td></td>
</tr>
<tr>
<td>Distance from port 0 to port 1 (m)</td>
<td></td>
</tr>
<tr>
<td>Distance from port 1 to port 2 (m)</td>
<td></td>
</tr>
<tr>
<td>Distance from port 2 to port 3 (m)</td>
<td></td>
</tr>
<tr>
<td>Distance from port 3 to port 4 (m)</td>
<td></td>
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<tr>
<td>Distance from port 4 to port 5 (m)</td>
<td></td>
</tr>
<tr>
<td>Distance from port 5 to port 6 (m)</td>
<td></td>
</tr>
<tr>
<td>Distance from port 6 to port 7 (m)</td>
<td></td>
</tr>
<tr>
<td>Distance from port 7 to port 8 (m)</td>
<td></td>
</tr>
<tr>
<td>Distance from port 8 to port 9 (m)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Flow rates and pressures

<table>
<thead>
<tr>
<th>Quantity</th>
<th>$Q_{full}$ (valve fully open)</th>
<th>$Q_{half}$ (valve half open)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Q$ (ml/s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure at port 0 (Pa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure at port 1 (Pa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure at port 2 (Pa)</td>
<td></td>
<td></td>
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<tr>
<td>Pressure at port 3 (Pa)</td>
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<td></td>
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<tr>
<td>Pressure at port 4 (Pa)</td>
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<tr>
<td>Pressure at port 5 (Pa)</td>
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<td></td>
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<tr>
<td>Pressure at port 6 (Pa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure at port 7 (Pa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure at port 8 (Pa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure at port 9 (Pa)</td>
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<td></td>
</tr>
</tbody>
</table>

Table 3:

<table>
<thead>
<tr>
<th>Quantity</th>
<th>$Q_{full}$ (valve fully open)</th>
<th>$Q_{half}$ (valve half open)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V$ (m/s) for 1/2&quot; pipe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Re$ for 1/2&quot; pipe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V$ (m/s) for 1&quot; pipe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Re$ for 1&quot; pipe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>Measured</td>
<td>Predicted</td>
</tr>
<tr>
<td>-------------------</td>
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<td>-----------</td>
</tr>
<tr>
<td></td>
<td>$Q_{full}$ (valve fully open)</td>
<td>$Q_{half}$ (valve half open)</td>
</tr>
<tr>
<td>$h_L$ (between 0 and 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$K_m$ (between 0 and 1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$h_L$ (between 1 and 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$f$ (between 1 and 2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$h_L$ (between 2 and 3)</td>
<td></td>
<td></td>
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<tr>
<td>$K_m$ (between 2 and 3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$h_L$ (between 3 and 4)</td>
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</tr>
<tr>
<td>$K_m$ (between 3 and 4)</td>
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</tr>
<tr>
<td>$h_L$ (between 5 and 6)</td>
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</tr>
<tr>
<td>$K_m$ (between 5 and 6)</td>
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<td></td>
</tr>
<tr>
<td>$h_L$ (between 6 and 7)</td>
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<td></td>
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<tr>
<td>$f$ (between 6 and 7)</td>
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<td></td>
</tr>
<tr>
<td>$h_L$ (between 7 and 8)</td>
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<tr>
<td>$K_m$ (between 7 and 8)</td>
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<td></td>
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<tr>
<td>$h_L$ (between 8 and 9)</td>
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<td></td>
</tr>
<tr>
<td>$K_m$ (between 8 and 9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$h_L$ (between 0 and 9)</td>
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