

Cover Page for Lab Report – Group Portion

Head Losses in Pipes

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Name 1: _____

Name 2: _____

Name 3: _____

[Name 4: _____]

Date: _____

Section number: ME 325._____ Group letter: (A, B, ...) _____

Score (For instructor or TA use only):

Lab experiment and results, plots, tables, etc. - Procedure portion	_____ / 45
Discussion	_____ / 15
Neatness & grammar	_____ / 10
TOTAL	_____ / 70

Comments (For instructor or TA use only):

Procedure and Presentations of Results

A. The Test Rig and Its Operation

A continuous pipe flow rig is used in this lab experiment, as sketched in Figure 2. The flow is pumped from the water tank as shown, and makes a 180° turn so that the flow exits back into the water tank. Quick connects are used so that various test specimens, such as long straight sections of pipe, or sections of pipe with various minor loss devices, can be easily interchanged. Each test specimen has two static pressure taps installed so that the head loss between the pressure taps can be measured directly, using a differential pressure transducer. Quick connect pressure line couplings are used to connect the pressure taps to the pressure transducers, so that the pressure lines can be connected quickly and easily as well. The volume flow rate through the test rig is measured by a magnetic resonance flow meter with a digital readout.

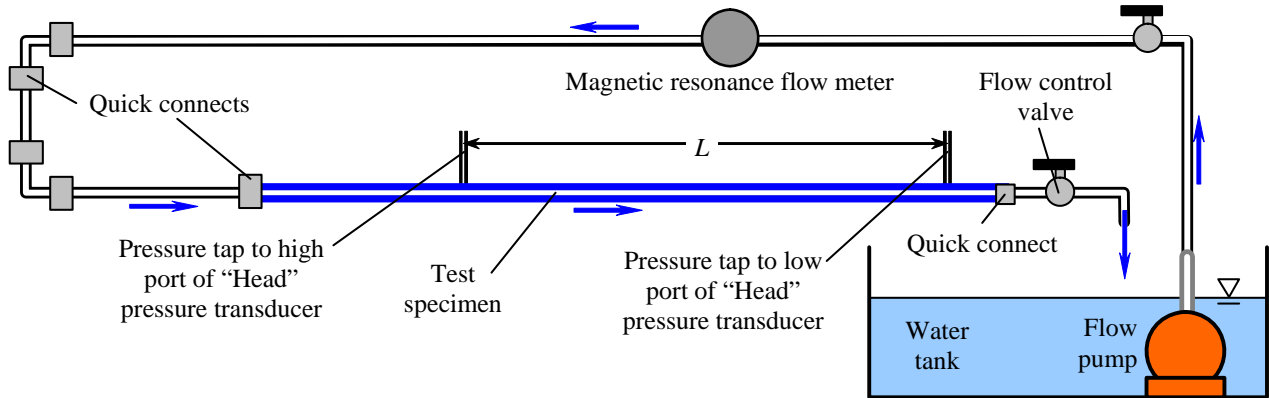
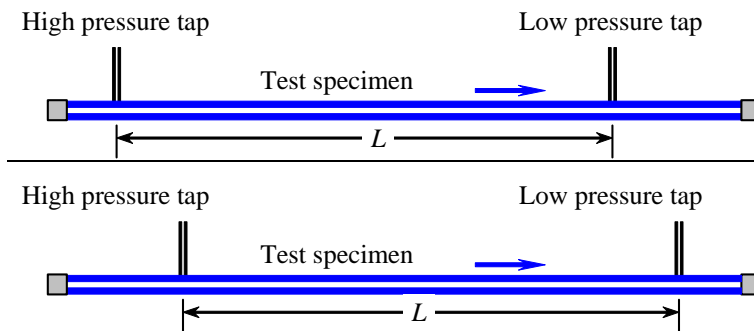


Figure 2. Schematic diagram of the pipe flow test rig.

- (3) 1. There is a correct and an incorrect way to install the pipe test specimens. Circle the correct way, and give a brief explanation for your choice:



Explanation:

- (6) 2. Standard pipe sizes are not always what they claim to be (actual inner diameter \neq nominal inner diameter). For example, the inner diameter of standard 3/4-inch galvanized iron pipe is *not* exactly 0.750 inches ID. The diameters are listed in Table 1 below. Measure L for each pipe specimen (L is defined here as the distance between pressure taps – the length of pipe through which the head loss is to be measured). Finally, measure the distance from the beginning of the pipe specimen to the first (high pressure) pressure tap. This is the entrance length of pipe, $L_{e, \text{available}}$, which is *available* for the flow to become fully developed. Later on, you will be asked to calculate the *required* entrance length, $L_{e, \text{required}}$, for each pipe and for each flow condition for comparison. Record these values on Table 1.

Table 1. Measured pipe diameter, length, and available entrance length.

Pipe section	Measured inner diameter (inches)	Length L (inches)	Available entrance length $L_{e, \text{available}}$ (inches)
1/2-inch copper	0.545		
3/4-inch copper	0.789		
3/4-inch galvanized	0.831		
1/2-inch PVC	0.610		
1-inch PVC	1.047		
1.5-inch PVC	1.699		

3. Install one of the test specimens into the pipe flow rig.

B. Calibration of the Electronic Pressure Transducer associated with Head Loss

To simplify the task of data collection, the major head loss h_{major} through the test specimen is measured electronically by the computer data acquisition system. The Validyne electronic differential pressure transducer marked “Head” consists of a thin stainless steel diaphragm within a chamber. Each side of the chamber has a port, which will be connected to one of the pressure taps. Specifically, the *low* pressure side of the diaphragm will be connected to the static pressure tap at the *downstream* end of the test specimen, while the *high* pressure side will be connected to the static pressure tap at the *upstream* end. When the flow loop is running, providing a head loss through the test specimen, the larger pressure upstream causes the diaphragm inside the pressure transducer to deflect slightly. This deflection is measured electronically and is converted into a DC voltage, which is displayed by the Validyne display unit. This voltage is also sent to the computer’s Analog-to-Digital (A/D) converter for processing. As presently set up, the A/D converter can read voltages in the range from -5 to 5 volts. However, the Validyne display unit output is an analog voltage that ranges from only -2 to 2 volts. The display unit actually displays the voltage times a factor of 100. For example, a reading of 158 on the display unit corresponds to an analog voltage output of 1.58 volts. A reading of 200 units corresponds to the maximum 2.00 volts of the unit. Thus, ***to avoid clipping of the signal, never exceed 200 units on the “Head” display unit while acquiring data with the computer.***

Prior to data collection, the differential pressure transducer must be calibrated to measure the proper head, and to set the span such that nearly the full range of the display unit is utilized (for highest accuracy). The maximum head loss for any pipe specimen in this lab will be limited to 200 inches of water column, and the unit will be calibrated such that 100 inches of water corresponds to 100 display units, or 1.00 volts. There is a calibration stand in the lab, which is set up to provide 48.0 inches of water head as a calibration point. In this lab experiment, therefore, the head transducer will be calibrated such that **0.480 volts (48.0 display units) corresponds to 48.0 inches of water head.** (48 inches per 0.48 volts is the same as 100 inches per 1.0 volts.) To calibrate the transducer, follow these steps:

1. Place both stainless steel calibration containers on the *top* shelf of the calibration stand, side by side.
2. Add water to the calibration containers (if necessary) until they are about 3/4 full (and approximately equal in level).
3. Connect the clear tubing from the tanks to the low pressure and high pressure inlets of the pressure transducer.
4. ***This step is critical! Any trapped air bubbles in any of the lines will lead to severe calibration errors.*** If bubbles are visible in the manometer tubes, gently tap the tubes near the bubbles to try to move the bubbles out the tops of the tubes. If the bubbles persist, empty the stainless steel containers into the tank. Then drain the manometer tubes into a bucket using the quick disconnects at the bottoms of the manometer tubes. Reconnect the manometer tube fittings. Now refill the stainless steel containers as in step 2. If the manometer tubes still contain persistent bubbles, ask your TA for assistance. Now open *both* bleed valves on top of the differential pressure transducer to bleed any air bubbles trapped in the lines or in the transducer chamber itself. *Note:* These valves are *open* when the switch handle is *vertical*, and are *closed* when the handle is *horizontal*. Bleed *all* of the air bubbles out of both lines; visually inspect the lines to be sure they are free of bubbles. If you are unable to get rid of the air bubbles, get help from your Instructor or TA before proceeding. When all air bubbles have been removed, close all thumb valves, and close both transducer bleed valves. You are now ready to calibrate.
5. Add water to (or drain water from, using the blue thumb wheel pincher on the drain lines) one of the calibration containers if necessary until the water in *both* containers is at the *same* level (approximately 68 inches on the manometer scale, which has an arbitrary datum plane).
6. At this point, there is zero pressure difference across the pressure transducer. If necessary, adjust the “ZERO” potentiometer on the “Head” Validyne display unit until the reading is zero.
7. *Carefully* move the left (low pressure) calibration container from the high shelf to the low shelf. *If not done slowly, new bubbles may form in the manometer tube* – take your time here or you may have to start over.
8. Add water to (or drain water from) the low pressure calibration container if necessary until the *difference* in height between the two manometer tubes is exactly 48.0 inches (as measured by the two manometer tubes and ruler).
9. At this point, the pressure difference across the pressure transducer is 48.0 inches. Adjust the “SPAN” potentiometer on the pressure transducer display unit (if necessary) until the reading is **48.0 units**. As discussed above, this calibrates the transducer to 48.0 inches of water head per 0.48 volts (100 units to 100 inches of water).
10. Now that the span has been set, the zero may have shifted slightly. Slowly return the low pressure calibration container to the upper shelf. The Validyne display unit should return to zero. Repeat Steps 5 through 9 if necessary until *both* the zero setting and the pressurized setting are correct.
11. The differential pressure transducer is now properly calibrated. (A linear transducer response is assumed, and is quite accurate.) Return the low pressure calibration tank to the upper shelf.
12. Disconnect both clear tubing lines from the pressure transducer using the quick connects, and close the thumb valves on these lines so that the water in the calibration tanks does not flow out.

13. Using the blue quick connects, and working over a bucket to avoid spillage, connect the high pressure port of the pressure transducer to the pressure tap at the *upstream* end of the pipe. Connect the low pressure port of the pressure transducer to the pressure tap at the *downstream* end of the pipe.

C. Data Collection

1. Before beginning data collection, confirm that the flow meter is properly configured to read L/min. If the display currently does not read a volume flow rate, try the down or up arrow to reach the volume flow rate screen. Note that the screen on the flow meter does not need to be touched, but simply holding your finger in front of the correct arrow will select it. If the units are not correct (it reads m/s or gal/min), hit the down arrow to select Basic Settings, the right arrow to select Units, and the down arrow again to select L/min, and then hit enter three times to return to the main screen. The enter button has a small letter E on it, and is in the upper left hand corner of the flow meter screen. If the display still is not reading correctly, get help from your instructor or TA.
 2. Add water if necessary to the water tank so that the flow pump is fully submerged. Verify that one of the pipe test specimens is properly installed, and the flow control valve is partially open. If no pipe test specimen is in place, ask your Instructor or TA for assistance in installing it the first time. It should not be necessary to use wrenches or other tools to install the pipe specimen. Turn on the flow pump and make sure there are no significant leaks through any of the connections (some dripping is okay). If leaks persist, call your instructor or TA for assistance.
 3. Bleed the flow system of all air bubbles every time you change pipe specimens or turn off the flow pump. **Note: This is a very critical step! Air bubbles in any of the pressure lines will lead to gross errors in your data.** To bleed the air bubbles properly, close the flow control valve about 95% of the way (**not fully closed because this will burn out the flow pump**). This lowers the flow rate to a trickle, and increases the head in all the tubes, which aids in purging out any trapped air bubbles in the lines. Open both bleed valves above the pressure transducer. Tap on the tubing quick connects to release trapped air bubbles, and watch them until they move all the way through the pressure line, through the pressure transducer, and out the bleed valve. Close both bleed valves.
 4. Start program PipeFlowMeasure from the computer's desktop or Start Menu. In the *User Control* window, Enter Parameters. In the *User Entries* window that pops up, Save Results File, and enter a file name for your data set. For uniqueness of your data file, name your file something indicative of your group and of the test specimen, such as "Smith_groupC_copper_75.txt", where "Smith" is the name of one of the group members, and the 3/4-inch copper pipe is being used in this example. Enter the length of the pipe between pressure taps, the inner diameter of the pipe, and the calibration constant. Unless calibrated otherwise, the constant should be 1.0 V = 100.0 inches of water head, since the Head transducer is calibrated at 48.0 units (0.480 V) per 48.0 inches of water head. OK.
- (3) 5. Practice measuring the volume flow rate *manually* (with a graduated cylinder or bucket and stopwatch) at some arbitrary (low) flow rate. Depending on the flow rate, it may take some practice, and you may need to try using different containers to measure the flow volume. When you are confident that you can measure the flow rate properly, enter the values in the spaces below:

Manual volume flow rate calculation:

Measured volume: _____ mL
 Measured time: _____ s
 Calculated flow rate: _____ L/min

Compare the manually measured flow rate to the display of the flow meter. If the difference is more than a few percent, consult your instructor or TA before proceeding. If the manual reading and the flow meter reading are close, you can trust the flow meter from now on, and there is no need to measure the flow rate manually anymore.

6. In the *User Control* window, Set Flowrate. The computer will prompt you to enter the measured volume flow rate in liters per minute. Enter the flow rate reading from the flow meter display. OK to start acquiring data for your first data point.
- (3) 7. Compare the head loss on the Validyne display to that recorded by the computer to ensure that this reading is being acquired properly. (Recall that **one unit on the Validyne display represents one inch of water head.**)

Manual head loss calculation:

Validyne display: _____ units
 Validyne head reading: _____ inches of water

Computer-acquired head loss:

h_{major} _____ inches of water

If the computer-acquired head loss is significantly different than what you read manually, something is not set correctly – ask your instructor or TA for assistance.

8. Take data with this test specimen at several flow rates, after adjusting the volume flow rate with the control valve. For each data point, enter the volume flow rate reading from the magnetic flow meter. The head loss reading is recorded directly by the data acquisition system. Cycle up and down from a trickle to maximum possible flow rate. Don't worry about the order of your data collection – the order is irrelevant. Keep an eye on the Validyne display unit. *Do not take data if the reading exceeds 200 units (2.00 volts)*, or the signal will be clipped. When finished, exit the program. The data should automatically be stored onto the file you created previously. Be sure to take enough data points to generate a smooth, repeatable curve. Some duplication is appropriate to test for repeatability.
- (10) 9. Install a different pipe test specimen. To interchange test specimens, turn off the flow pump, disconnect the blue tubing quick connects from the static pressure taps. Be sure there is a bucket under the pipe quick connect at the upstream end of the pipe to catch water that will leak out when this connection is broken. Carefully disconnect the pipe quick connect at the downstream (valve) end of the pipe. Then disconnect the pipe quick connect at the upstream end of the pipe and remove the pipe test specimen. Incline it slightly so that any remaining water in the pipe can drain into the water tank. Install the new test specimen by reversing this procedure. The pipe quick connects should require only hand tightening to be fairly leak free. Bleed the flow system of all air bubbles, restart the program PipeFlow Measure, and repeat Step 8 for the new test specimen.

Repeat for *all* the pipe specimens. *Be sure to select a different file name for each test specimen, or else you will overwrite (and lose) your previous data.* Using Excel or Notepad, make a printout of the data file for each case, making sure each table is properly titled and labeled.

See Tables _____.

10. Finally, when finished with the data acquisition, turn off the flow pump. You may leave the water in the tank, and you may leave the last test specimen in the rig. Restore all other test specimens to their original locations. Be sure to copy all your calibration and data files onto the computer's desktop or onto a portable media device before you leave.

D. Presentation of the Data

- (10) 1. For each test specimen, and for each flow rate, calculate the Darcy friction factor, f , and the required entrance length, $L_{e, \text{required}}$. (This is most easily done with a spreadsheet.) Prepare a table of all the experimental results for each pipe section. The table should include volume flow rate, average velocity, Reynolds number, head loss, Darcy friction factor, required entrance length, and available entrance length for each case. Label and attach each table to this report. Show some sample calculations in the space below:

See Tables _____.

Sample Calculations:

- (10) 2. Prepare a plot of friction factor f versus Reynolds number for the pipes tested here. In other words, prepare your own limited version of the Moody chart. For comparison, include on your plot the published data for a smooth pipe. These data can be manually picked off the Moody chart, or the Colebrook equation can be used to obtain f versus Re_d for a smooth pipe. Put data from *all* the pipes on the same plot, being sure to identify the pipes with a legend. Label and attach your figure to this report.

See Figure _____.

Discussion

- (5) 1. How does your “Moody chart”, (your plot of friction factor versus Re_d) compare with the published Moody chart?
- (5) 2. Are your results more accurate at low flow rates, or at high flow rates? Why?
- (5) 3. Discuss possible sources of error in this lab experiment. How might the lab be improved?