Tank Filling Exercise

Engineering of Everyday Things
Gerald Recktenwald
Portland State University
gerry@me.pdx.edu
eet.cecs.pdx.edu/students

Tank Filling Lab Exercise **Participant Code:** ______________

1 Apparatus

Figure 1 shows the equipment for this laboratory exercise. The key components are:

1. Two cylindrical tanks, one with straight walls (single diameter) and another with a step-shaped wall (two diameters);
2. A pressure transducer mounted on the side of each tank;
3. A power supply to provide electrical energy to the transducer;
4. A data acquisition device (DAQ) for digitizing the transducer output;
5. A computer to record and display the digitized output of the transducer.

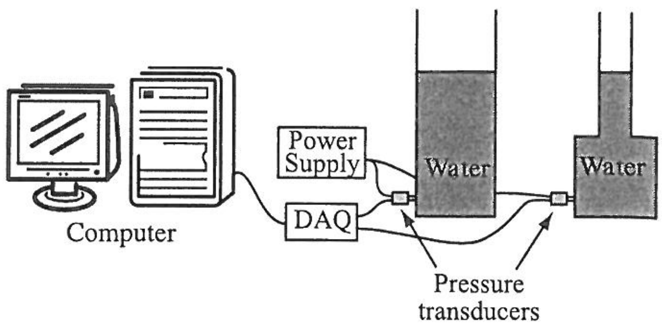

Figure 1: Apparatus for the tank-filling experiment.

2 Lab Preparation

This experiment is likely to take about two hours to complete.

As part of the lab exercise you will be asked to make simple plots of measured data. You can use Excel or MATLAB if you wish, but you must attach hard copies of your plots to these worksheets. If you are working in a group make sure each member of the group has a hard copy of each plot attached to their worksheets. Make sure the plots are labelled so that the instructor can correctly grade the plots as part of the worksheet.

Learning Objectives

The laboratory exercise involves measurements and analysis related to the variation of pressure with the amount of water in a tank.

After successfully completing this exercise students will be able to

- Identify a pressure transducer and explain its role in measuring/transmitting pressure values to a data collection system;
- Identify the fluid properties and other physical variables that determine the pressure at some depth in a tank partially filled with water and open to air;
- Predict the trend in pressure with tank depth;
- Compute the pressure at any depth below the free surface of a tank partially filled with liquid;
- Predict how the relationship between pressure and depth changes with the shape of the tank.

Before continuing, please complete the pre-lab quiz.

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3 Tank with Uniform Diameter

This exercise involves recording the pressure transducer output with different amounts of water are in the straight-walled tank. The pressure is measured with a pressure transducer connected to the data acquisition system and the personal computer.

3.1 Pressure Transducer Measurements

1. Start the *Virtual Instrument* (VI). The Lab Assistant should have LabVIEW running on the computer running and the VI loaded.

   a. Click on the "Run" arrow

   b. The display of the transducer voltage should change in the least significant digits.

2. Data collection.

   a. Add some water to the tank.
   b. In Table 1, record the depth of water in the tank and the voltage output from the transducer. For now, ignore the last three columns ("Pressure", "Independent variable (x)" and "Dependent variable (y)").
   c. Repeat steps (1) and (2) enough times to establish a clear trend in the data. At least four readings are necessary. Make sure your readings are spread over the entire range of the possible fluid depths for the tank.
   d. Inspect the raw data you have recorded
      - Be sure to label the data with appropriate units. Be sure your units are consistent.
      - What is the appropriate reference point for the depth of water measurement? In other words, where is the physical location of the "zero depth" point in the tank?

Table 1: Data for the straight-walled tank experiment.

Measured		Calculated		
Water Depth	Transducer Output	Pressure	Independent variable (x)	Dependent variable (y)

3.2 Calibration and Data Conversion

To relate the preceding measurements to the standard model of fluid behavior, the voltage output of the pressure transducer must be converted to pressure.

Calibration data from the manufacturer: At $p = 0$ the transducer output is 1 V. At $p = 1$ psig, the transducer output is 5 V.

1. Use the grid to the right to create a plot of pressure versus voltage for the transducer. Be sure to label the axes. Assume that the transducer output is linear with pressure.

2. Using the plot you just created as a guide, what is the calibration formula for the pressure transducer? In other words, if $p = f(v)$ what is $f(v)$?

3. Apply your calibration formula to the transducer output data from table 1 and fill in the *Pressure* column in the Table 1.

3.3 Analysis of Pressure Data

1. What is (are) the independent variable(s) for the measured and converted data in Table 1? What is (are) the dependent variables?

   Dependent Variable(s):

   Independent Variable(s):

   Choose one pair of definitions for the dependent and independent variables to complete the last two columns of Table 1. It may be helpful to read the next step (on the next page) before you complete Table 1.

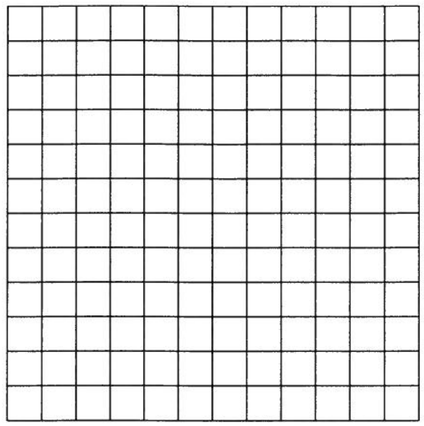
Definitions:

An *independent variable* is an input or parameter that is directly controllable by the person performing the experiment. An independent variable is often, though not always, the quantity on the x axis of a plot.

A *dependent variable* is the output or result of changing a system. A dependent variable is often, though not always, the quantity on the y axis of a plot.

In an experiment, both independent and dependent variables are measured.

2. Use following the grid to make a plot of the data in the last two columns of Table 1. Plot your choice of the independent variable on the horizontal axis and the dependent variable on the vertical axis. Be sure to label your axes.



3. What, if any, observations can you make from the plot you just created?

4. Is the pressure related to the water depth, water volume, or some other parameter? How does the data support your answer?

5. List at least two possible parameters that may effect the pressure. (*Hint*: One of the parameters is a property of the fluid.)

STOP

Before continuing, show your lab manual to the instructor. It's important at this point to make sure you are on the right track.

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4 The Step-Walled Tank

Repeat Experiment from Section 3.1, but use the step-walled tank instead of the straight-walled tank. Record your data in the Table 2 below.

- Since the tank diameter varies with depth, record the tank diameter at the free surface along with the depth measurement. The values in first column will be either 7.62 cm (3 inch) or 15.2 cm (6 inch).
- Make at least two measurements from water levels in the larger diameter tube and two measurements from water levels in the smaller diameter tube.
- Be sure to add units to the table.
- Use the calibration developed in Section 3.2 to convert the pressure transducer output to pressure.

What your independent and dependent variables for this experiment?

Dependent Variable(s):

Independent Variable(s):

Table 2: Data for the step-walled tank experiment.

Measured			Calculated	
Diameter	Water Depth	Transducer Output	Independent variable (x)	Dependent variable (y)

STOP

Before continuing, show your lab manual to the instructor. It's important at this point to make sure you are on the right track.

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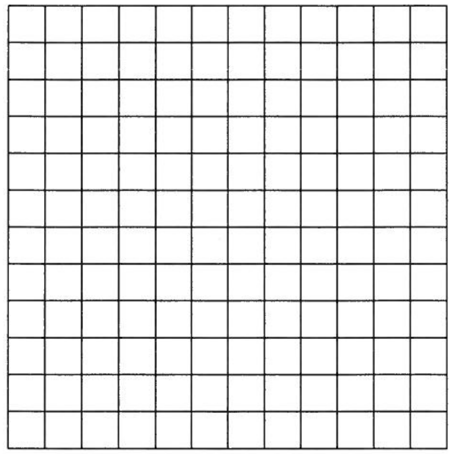
5 Comparing Measurements from the Two Tanks

Plot the data measured in Section 3.1 and Section 4 on the same axes. Label the axes appropriately.



1. Does the change in diameter at the free surface affect the pressure? Does this make sense based on your personal experience or intuition?

2. Draw a line on the graph that follows the data as closely as possible. What is the numerical value of the slope? What are the units of the slope? For example, if you plotted pressure as a function of depth, what is the nominal value of the slope in units of N/m^3 or lb_f/ft^3?

3. What theoretical model or equation explains the data?

4. The theoretical model identified in the preceding step includes a fluid property that you can extract from the slope of the measured pressure versus depth data. What is that property?

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6 Reflection, Discussion and Extension

1. List the key similarities and differences for the two tanks.

   Similarities:

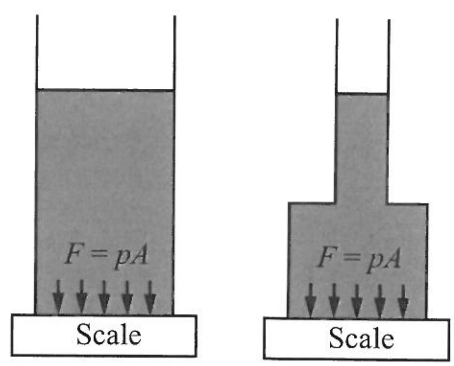
   Differences:

2. How do the differences in the shape of the tanks affect the variation of pressure with depth?

3. Does the theory "explain" the data? In other words, given the agreement (or disagreement) between the theory and measurements, how well will theory predict the pressure versus depth relationship for any shape of tank?

4. If a heavy object such as a rock was placed into either of the tanks before the water was added, what effect would it have on the pressure indicated by the transducer? Why? If the rock was added after the water was filled to a given depth, would the result be different? Why?

5. Suppose the two tanks are placed on scales as depicted in the sketch to the right. For a given depth of water, the straight-walled tank will weigh more than the step-walled tank. Considering the static equilibrium at the interface between the bottom of the tank and the top of scales, it would appear that the pressure in the bottom of the step-walled tank needs to be less than the pressure at the bottom of the straight-walled tank. How do you resolve the paradox?



STOP

Give your completed worksheet to the instructor and take the post-lab quiz before leaving.

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