Lab 7. Calibration of the level sensor

Introduction

The purpose of this lab is to calibrate the level sensor that will be used in the liquid-level loop — we want the digital representation of the actual liquid level in a tank.

Here, we use a differential pressure sensor whose low-pressure side is open to the atmosphere. The sensor measures pressures, $h$, in the range of 0-5 inches of water; its corresponding output is 0.25-4.00V (grey case) or 0.50-4.50V (black case). A tube, the level probe, is attached to sensor, and this is fixed in the tank – see the Figure on the next page. As the liquid level rises in the tank, the pressure of the air trapped within the tube increases.

To use the pressure sensor as a level sensor, we need to establish a relationship between the level in the tank and the pressure experienced by the sensor. The behavior of the level sensor may be understood by decomposition into separate blocks.

The application of the ideal-gas law and hydrostatics gives the expected form of the relationship between $L$ and $h$ — this is developed in the Theory with the Figure on the next page; this shows what $h$ represents.

Experimental

Stage 1: Determination of the relationship between $L$ and $h$

1. Fill the tank to various levels; measure corresponding values of $L$ and $h$.
2. Plot $L$ vs. $h$ (x-axis) and determine the relationship between them — Graph 1.

Stage 2: Programming

3. Write a subroutine, Calc_Level, within a new program to calculate $L_{\text{digital}}$ — pay attention to the choice of units and the optimum resolution. To do this successfully you need to know $L_{\text{max}}$ — this will be depend upon the sensor and level probe associated with your station.

Stage 3: Comparison of $L_{\text{digital}}$ and $L$, the actual level.

4. Fill the tank to various levels; measure values of $L$ and record the corresponding values of $L_{\text{digital}}$.
5. Plot $L_{\text{digital}}$ vs. $L$ (x-axis) — Graph 2.

Homework

1) Present the data and graph from steps 1 and 2 above.
2) Summarize the properties of the level sensor as follows:

$L_{\text{max}} =$ \text{The zero is ...}

The span is ... \text{The range is ...}

3) Present your code§ for Calc_Level (the submission of whole program is not necessary).
4) Present the data and Graph 2 from steps 4 and 5 above. Comment on Graph 2.

** Display the trend line with the correlation coefficient; think about whether the line should be forced through the origin, or not.
§ For example, try copying and pasting the subroutine into a worksheet.
Theory

The zero-level corresponds to the liquid level at the bottom of the probe, not the tank, — see A in the Figure. The pressure and the volume of the air trapped within the level probe and sensor are \( P(L) \) and \( V(L) \), respectively. For the liquid level in A, the pressure within the probe is:

\[
P(0) = P_{\text{atm}}, \text{ the atmospheric pressure.}
\]

As liquid rises above the zero level, the air within the probe and sensor is compressed as shown in B. The application of hydrostatics gives:

\[
P(L) = \rho gh + P_{\text{atm}} \quad [1]
\]

where \( \rho \) is the density of liquid and \( h \) is the head of liquid. Because the pressure sensor is set up to measure the gauge pressure, it measures \( \rho gh \) — expressed as a head of water. Air behaves as an ideal gas under these conditions and the trapped air is in a closed system, so

\[
P(L)V(L) = P(0)V(0)
\]

Now,

\[
V(L) = V(0) - A(L-h),
\]

where \( A \) is the effective internal cross-sectional area of the probe and sensor. With substitution into eq 1 and rearrangement, we get

\[
L = [\rho g V(0)/\{ A(\rho gh + P_{\text{atm}})\} + 1]h
\]

Now the maximum pressure measured by the sensor corresponds to 5in.H2O, or \( \rho gh_{\text{max}} = 1.25 \text{kPa} \), so \( \rho gh_{\text{max}} \ll P_{\text{atm}} \)

Therefore, to a good approximation:

\[
L = [\rho g V(0)/(A P_{\text{atm}}) + 1]h
\]

The plot of \( L \) vs. \( h \) should be linear. It is important to recognize the liquid level, \( L \), is measured with respect to the bottom of the probe – not to the bottom of the tank.

***This homework is due at the beginning of class on Wednesday March 31. It will be considered as part of the project grade.***