CM3215 ChemE Transport Lab:

Pressure Measurement and Calibration of the DP Meter

Pre-laboratory Assignment

Read the SDS (Safety Data Sheet) for Blue Fluid 175 (available on the course website), and note the advice on the handling and hazards of this chemical. Prepare data tables in your laboratory notebook for recording data for this laboratory. Prepare a safety section in your laboratory notebook detailing all safety issues associated with this laboratory.

Introduction

The accuracy of instruments is only as good as their calibrations. In this laboratory, we calibrate the Honeywell Differential Pressure meter (the DP meter = unit under test) using an air-over-Blue-Fluid-175 manometer as the standard. The density of the Blue Fluid 175 is established in laboratory measurements with pycnometers.

Theory: See lecture.

Overall Objectives and Strategy: Calibrate the Honeywell DP meter against the air-over-Blue-Fluid manometer. Impose various pressures simultaneously on both devices by using a hand air pump and record pressure readings from both devices. Address all other objectives as discussed in **Data Analysis** below.

Experimental Procedure

Overall procedure:

1. Obtain a sample of Blue Fluid 175 (Meriam Instrument Company, Cleveland, OH) and a pycnometer from the TA.
2. Inspect the pycnometer and ensure that it is clean and dry (see Procedure A in the appendix). Clean if necessary.
3. Measure the density of Blue Fluid (see Procedure B in the appendix).
4. Calibrate the DP cell (see Procedure C in the appendix); the DP cell has an output range from 4 to 20 mA; make sure to take pressure readings which correspond to both the high (up to 20mA) and to the low readings; take 15-20 readings. Randomize the order in which you take data to eliminate systematic error.
5. Shut down the station (see Shut down procedure in the appendix)

Data Analysis – address all these points in your report

1. Calculate the class-average density of Blue Fluid and the standard deviation of the collected data of your section. Report your results with the appropriate number of significant figures and a 95% confidence interval on the mean based on the lab section replicates.
2. How does the measured density of Blue Fluid 175 compare to the literature value? Be quantitative (i.e., do not say “it us close” say “they differ by 0.1%” or “they are within the measured 95% confidence interval of the mean”).
3. Construct a calibration curve for the DP cell that shows differential pressure reading (in psi, which is lb_f/in^2) versus electrical signal. This electrical signal in mA could be directly connected to a computer for on-line data acquisition. Give some thought to which variable you would put on the x-axis and which on the y-axis.

4. Use LINEST in Excel to obtain the uncertainty limits on the slope and intercept obtained.
5. Calculate a best fit line to the pressure/current calibration curve. **Record your calibration curve in your lab notebook for future use. Place a printout of your calibration plot in your lab notebook for future use.**
6. Compare your measured calibration curve with historical data for the same lab station (data are on the web). Be quantitative in your comparison.
7. What is your estimate of the highest pressure you can accurately measure with the DP meter? What is your estimate of the lowest pressure you can accurate measure with the DP meter? (HINT: the lowest pressure you can measure accurately is not zero, and it is not negative; there is a detection limit that determines the lowest signal that is obtainable). Explain your logic for choosing the values you report.
8. In the report appendix, include raw data tables. Attach as well your error analysis worksheets (do not include raw data tables in the body of the report).

References:

Morrison, Faith A, "Replicate Error Worksheet," Handout in CM3125 Laboratory, Michigan Technological University, Houghton, MI; accessed 1 February 2015 at www.chem.mtu.edu/~fmorriso/cm3215/ReplicateErrorWorksheet.pdf

Morrison, Faith A, "Reading Error Worksheet," Handout in CM3125 Laboratory, Michigan Technological University, Houghton, MI, Accessed 1 February 2015 at www.chem.mtu.edu/~fmorriso/cm3215/ReadingErrorWorksheet.pdf

Morrison, Faith A, "Calibration Error Worksheet," Handout in CM3125 Laboratory, Michigan Technological University, Houghton, MI; accessed 3 September 2014 at www.chem.mtu.edu/~fmorriso/cm3215/CalibrationErrorWorksheet.pdf

Morrison, Faith A., "Obtaining Uncertainty Measures on Slope and Intercept of a Least Squares Fit with Excel's LINEST," Department of Chemical Engineering Michigan Technological University, Houghton, MI on the web at www.chem.mtu.edu/~fmorriso/cm3215/UncertaintySlopeInterceptOfLeastSquaresFit.pdf ; accessed 1 February 2015.

J. S. Fritz and G. H. Schenk, Quantitative Analytical Chemistry, 5th edition (Allyn and Bacon, Inc, Boston, 1987); see excerpt at www.chem.mtu.edu/~fmorriso/cm3215/2013VolumetricGlasswareError.pdf; accessed 1 February 2015.

Appendix: Detailed Procedures

Air-Pressurized System Shut-Down Procedure

1. Release the pressure from the system by loosening the knurled nut on the hand pump.
2. Disconnect the quick-disconnect pressure taps of the DP meter from the manometer stand.
3. Turn off the DC power for the DP meter (south wall).
4. Dry off any wet surfaces with paper towels.
5. Turn off all the electronic devices and properly store them.

Procedure A: Pycnometer cleaning

1. Clean the pycnometer thoroughly using water; use a pipette bulb or ear syringe to force (several times) clean, distilled water through the capillary in the lid of the pycnometer.
2. Add a small quantity of acetone to the pycnometer and rinse thoroughly. Again use a pipette bulb to force acetone through the capillary in the lid of the pycnometer. Be sure to expose <u>every</u> internal surface of the glassware with acetone; this will make it possible to dry the glassware (the acetone scavenges the water).
3. Dry the glassware with the high-pressure dry air provided (should take less than half a minute if all water has been scavenged by the acetone).

Procedure B: Measuring the specific gravity of Blue Fluid 175

1. Use disposable gloves when handling Blue Fluid 175.
2. Obtain a pycnometer with matching lid; record the ID.
3. Record room temperature.
4. Weigh the clean, dry pycnometer and lid.
5. Fill the pycnometer with Blue Fluid and fit the lid into the bottom. Fluid will squirt out of the capillary in the top so that a precise volume is retained in the vessel.
6. Wipe the pycnometer clean with a Kimwipe and weigh the filled pycnometer. Do not wipe the top of the lid, as capillary action with the paper wipe will draw some fluid out of the lid.
7. Calculate density as net weight of fluid divided by the volume of the pycnometer, which is $10.00 \pm 0.04 ml$ (see Fritz and Schenk, 1987 or the back of the class calibration worksheet).
8. Return fluid from the pycnometer to the original container for storage and reuse.
9. Clean all glassware (see Procedure A) and all tabletop surfaces.
10. Record room temperature.

Procedure C: Calibrating the DP cell

1. Activate the Honeywell DP cell by turning on the DC power switch on the grey box on the south-side wall (only one group, the safety group, needs to do this each laboratory period).
2. Obtain a multi-meter from the cabinets on the east wall. Set up the multi-meter to read mA signal from the DP cell (the black is the *common* or *ground* signal). The multi-meter must read to 0.01 mA at least.
3. Record the zero differential pressure reading by releasing any residual pressure in the DP cell pressure tap lines. This is done by pressing with thumbs on the tips of both of the (male) quick-disconnect fittings attached to the DP meter. The DP meter will read 4.0 mA (this value may vary between 3.8 and 4.4 mA).
4. Connect the DP cell pressure taps (black vinyl tubes; red is to be connected to the "high" side) to the air-pressurized system built into the stand for the air-over-Blue-Fluid manometer.
5. Pressurize the system using the bulb pump on the system stand. This device is similar to the devices used in a medical doctor's office to measure blood pressure. **CAUTION: Use great care! It is easy to over pressurize and cause Blue Fluid to be blown from the manometer.** The proper procedure is to lightly close the knurled nut on the hand pump and gently pump up the pressure in short bursts. Take extra care when the manometer fluid approaches the top of the manometer.
6. Record electrical signal from the DP meter (current in mA) versus actual differential pressure between atmospheric and the air-pressurized system (as lengths read off of the meter sticks attached to the air-over-Blue-Fluid manometer).
7. Release the pressure from the system by loosening the knurled nut on the hand pump.
8. Repeat steps 5 to 7 for additional pressures until sufficient data are acquired.