CM3215 ChemE Transport Lab:

Measure Heat-Transfer Coefficient for a Brass Sphere

Pre-laboratory Assignment
Review the following: concept of the heat transfer coefficient *h*, and Newton's law of cooling. Look up, record in your notebook, and be prepared to report the values of the following physical properties (along with the appropriate reference):

- thermal conductivity of brass (k);
- thermal diffusivity of brass, $\alpha \equiv k/\rho\hat{C}_p$;
- In your lab notebook, outline how you plan to proceed for this lab;
- Have your calibration curves and pumping head performance curves in your lab notebook for collection by the TA (for the archive).

Introduction
Heat transfer coefficient *h* that governs the heat transfer between a fluid and a solid is a complex function of system conditions such as geometry, fluid velocities, and material properties. For a three-dimensional solid object, the heat transfer coefficient may be measured by building the system of interest, conducting unsteady heat-transfer experiments, modeling the system with differential equations, and comparing measured heat-transfer performance to what is actually seen in the lab. In this laboratory we follow this protocol and measure the heat transfer coefficient of a brass sphere in a well-stirred tank.

Theory: See lecture.

Overall Objectives and Strategy: Measure the heat-transfer coefficient and Biot number of a brass sphere dropped into boiling water. The data collection has been done by a colleague; you must analyze the data. Address all other objectives as discussed in the separate assignment sheet; your answers must include error analysis.

Experimental Procedure

The data collection has been performed by a colleague. Your colleague followed the following procedure. The data of temperature versus time are available on the website.

Prepare the vessel as follows:

1. Fill two 1500 ml beakers with approximately 700 ml of distilled water. Add a stir bar to each beaker and place each on a hot plate with the stir bar moving vigorously.
2. Add ice to one beaker.
3. Bring the water in the second beaker to a boil.
4. Set up a data acquisition system to record the temperature versus time registered by the thermocouple that is embedded into the 1.00 *in* brass sphere supplied.
5. Submerge the brass sphere into the ice-cold water and record the temperature as a function of time until stable. Steady state is achieved when the sphere temperature does not vary by 0.1°C for 5 minutes
6. Working quickly, move the sphere from the ice-cold water to the boiling water.
7. Record temperature as a function of elapsed time using the data acquisition setup and wait for the temperature to equilibrate; steady state is achieved when the sphere temperature does not vary by 0.1°C for 5 minutes.

Shut Down Procedure

1. Shut off both stir plates and allow the plate surfaces to come to room temperature.
2. Discard water and store all equipment.
3. Dry off any wet surfaces with paper towels.

CM3215 Assignment 8:
Measure Heat Transfer Coefficient to a Sphere

Complete the assignment described below; **this is a team assignment.**
Both team members must sign the submission. The assignment is due
2:05pm Wednesday 20 April 2016 in Homework Box A.

References: see documents at the links on our class website or the lecture slides.

Carslaw, H. S. and J. C. Jaeger, *Heat Conduction in Solids*, 2nd edition (Oxford University Press, New York, 1959).

Geankoplis, C. J., Transport Processes and Separation Process Principles, 4th Edition (Prentice Hall: Upper Saddle River, NJ, 2003).

Heisler, M. P., "Temperature Charts for Induction and Constant-Temperature Heating," *Transactions of the ASME*, April, 1947, pp227-236.

Assignment: Determine the Biot number Bi and the heat transfer coefficient h for the data supplied in which a sphere initially at ice temperature is suddenly submerged in stirred boiling water. Outline the fitting strategy you followed in sufficient detail to allow others to perform the same calculations (as an exception, for this assignment you may provide a list rather than a narrative). Report your value of h with appropriate uncertainty limits. Explain how you arrive at your error limits.

Instructions:

- Submit your results in the form of a memo of transmittal explaining your results, with supporting plots attached and organized. All plots must have figure numbers and explanatory captions. Put your names on each page. There will be no appendix. This is not a report.
- This is a group assignment. Both team members must sign the memo header and contribute equally to the submitted results.
- Include discussion of your uncertainty (error analysis).

Background: The data for the *Heat Transfer to a Sphere* assignment comes in the form of center-point temperature $T(r = 0)$ as a function of elapsed time for a brass sphere ($1.00\ in$ diameter). The sphere was initially equilibrated in cold water; at some time it was quickly switched to hot water that was vigorously stirred.

Our task for this assignment is to find the value of h that best represents the conditions under which the data were taken. It is also essential to convey how certain the answer is (i.e. include 95% confidence intervals).