ME 105 – Mechanical Engineering Lab
Spring Quarter 2003

---

1. TEMPERATURE MEASUREMENTS

This experiment is designed to demonstrate a number of temperature measurement techniques based on thermometers, thermocouples, thermistors, RTDs, and pyrometers. These devices are very common in laboratory and industry applications.

You will measure the temperature of melting ice, boiling water, and water at room temperature using some of the devices mentioned above. The use of thermocouples will be investigated, in particular with respect to electronic measurement devices. The response time of thermocouples will also be studied. A typical thermistor and 3-lead RTD will be used as well. You will also be introduced to a modern general use pyrometer. You will have available LabView's digital voltmeter and oscilloscope as well as bench-top versions of these instruments for measurements in this lab.

Be very careful! You will be working with boiling water. Make sure the containers are secure, and use hot pads, as appropriate.

Pre-Lab Reading

Read this handout carefully to find out what you will be doing during this session. For additional information consult Holman and the section on "Radiation" in your Heat Transfer textbook.

Pre-Lab Work

Plan ahead! Prepare an outline in your lab notebook for the data acquisition you will perform during this experiment that includes tables with blank boxes to be filled with raw data and processed data. Headings, subheadings, etc., as well as brief reminders about what you will be doing and in what order, will help. Make sure to look up and include at the appropriate place(s) any property values, formulae, etc., that you might need during the session. It would also be an excellent idea to include comments or (educated) guesses about what you think will happen, or about trends you anticipate in your measurements, so that you can spot any problems or unusual results. This pre-lab outline will be graded by the TAs at the beginning of the session who will also answer questions about the pre-lab reading material.

Required Equipment

Thermocouples (type K)
Thermistor
Platinum RTD (3-lead)

Pyrometer
Hot plate with instrumented black body
Electronic Temperature Converter
Ohmmeter
Millivoltmeter
Computer/LabView
Mercury thermometer
Digital Thermometer
Deionized water
Ice
Hot plate
Aluminum cooking pot with thermocouple well in lid
Insulated containers

Experimental Work

Preparation of Hardware

WARNING: Be careful of the boiling water and the steam being evolved from the boiling water. Severe burns and/or scalding can result from contact with your skin.

Prepare boiling water in the aluminum pot provided (make sure it does not run out of water later on), fill one of the insulated containers with water at room temperature and the other with a mixture of ice and water (ice might have to be added during the session). The use of the pyrometer will be coordinates by your TA.

Experimental Procedures

A. Mercury Thermometers

Measure the temperature of the 3 water baths with the thermometer. (Pay attention to the immersion depth required!) After recording the raw values, convert all results to Kelvins. Note the accuracy of your measurements. (Note: ask the TA to demonstrate the use of a higher accuracy "calibration" thermometers.)

For simplicity, use the value measured by the general-use Hg thermometer as your "calibration reference" to compare other results to during the rest of this session. (Does the Hg thermometer need recalibration?)

B. Thermocouples

1. **Direct thermocouple connection**. Make your thermocouple by stripping the ends of both wires and twisting them together. Connect a thermocouple directly to the voltmeter. Measure and record the voltages generated when you dip the thermocouple in the 3 waterbaths. Using the table included in the appendix,

convert the voltages to temperature (in K) and compute the absolute and relative difference between the measurements obtained with the Hg thermometer and the thermocouple you just made. Is this a good measurement? What has happened?

2. **Ice point reference**. Connect the end of each thermocouple lead to the alligator clip on the end of the banana leads. Connect the banana leads to the voltmeter. Dip the Cr/Cu and Al/Cu junctions (thermocouple/alligator clip junction) in the ice bath and remeasure the temperature of the 3 baths with the Cr/Al junction. Convert to temperatures and compare to the Hg measurement. How is the thermocouple working differently?

3. **Electronic temperature converter**. Remove the Cu leads and connect the Cr/Al junction to the electronic temperature converter via the thermocouple connector. Connect the converter to the voltmeter and measure the temperatures of the 3 baths. Compare to the Hg measurements. Is it working? Now, open up the TC connector and switch the wire positions. Measure again. How different are the results?

4. **Direct readout**. Connect your simple Cr/Al junction to the digital thermometer. Use it to measure the temperature of your baths at the top, mid-depth, and bottom. (Do not stir the water!) What is happening?

5. **Dynamic response**. Connect your simple Cr/Al junction to the temperature converter and the converter to the computer data acquisition system for use with LabView's oscilloscope. Adjust the oscilloscope settings as instructed in handout. Dip this room temperature junction in the ice water. Note how long it takes for the temperature to reach a "steady state" value.

C. Thermistor

1. Using the ohmmeter, measure the resistance of the thermistor when dipped in the ice, room temperature and boiling baths. Be careful not to let the bare lead contact the water, or you will see an error based on the conductivity of the water. Using the tabulation provided in lab, determine the corresponding temperatures and compare to the Hg measurements.

D. RTD

1. Determine the nominal type ("standard resistance") of the RTD you were given by measuring the resistances between all leads. Figure out what the purpose of the 3 leads is. Measure the resistance of the element when dipped in the ice, room temperature and boiling baths. Use the tabulation provided in lab to determine the corresponding temperatures making all necessary corrections. Compare to the Hg measurements.

E. Pyrometer

WARNING: Be very careful with the hot plate used in this part of the experiment as it could inflict severe burns.

IMPORTANT: The pyrometer should not be used closer than 2 m from the hot black body, and should not be pointed at it for more than 5 seconds at a time. Wait at least one minute between measurements with the pyrometer turned off and pointed away from the hot source.

NOTE: use the audio signal to ensure optimum target acquisition.

1. **High temperature**. Positioning the pyrometer at 2 m, measure the temperature of the hot black body for emissivity settings of 0.2 and for black paint. Do the same again at 6 m. Compare to the thermocouple measurement. What is the effect of distance and emissivity this time?

2. **Transparent material**. With the correct emissivity setting, position the pyrometer at 2m again and remeasure the temperature of the hot black body with the piece of plexiglass inserted in the field of vision close to the pyrometer. What is the effect of the plexiglass on the measurement?

F. Radiation Shield

1. Observe the temperature measured by the calibration thermometer that is exposed to direct solar radiation and the thermometer that is shielded from that radiation. What is the effect of the radiation shield?

Reports

Answer the questions posed in the text of the experimental procedure. Use the "raw" data collected to calibrate the thermocouple, thermistor and RTD with a polynomial fit. Compare your correlations with the tabulations provided in lab.

Additional questions to answer:

A. 1. Give an estimated accuracy of each type of measurement device.

2. Mention briefly their ranges of applicability, main advantages, and disadvantages.

B. Thermocouples

1. Explain any problem observed with the direct thermocouple connection.
2. Explain why you need an ice point reference.
3. What does the electronic temperature converter do?
4. Explain the effect of the connector polarity.
5. Explain any temperature gradients observed in the baths.

C. RTD

Explain the purpose and use of the third wire.

D. Pyrometer

1. How strong an effect does the emissivity setting have on the readings?
2. What is the effect of measurement distance?
3. What is the effect of the plexiglass plate?