3705 Lab: Refrigerator Efficiency Measurement

OBJECTIVE: To measure the efficiency of a refrigerator based on a TEC (Thermo-electric cooler) module.

EQUIPMENT: TEC assembly, water (500 CC), styrofoam chamber, thermistor, recording multimeter.

THEORY: In class you derived the coefficient of performance of an ideal refrigerator;

$$\eta = \frac{Q_c}{W} \tag{1}$$

For the special case of a perfect refrigerator, that is, a perfectly reversible one, the efficiency is the carnot refrigerator efficiency,

$$\eta_{carnot} = \frac{T_c}{T_h - T_c} \tag{2}$$

PROCEDURE: This procedure must be done over two sessions. First familiarize yourself with the TEC/heatsink assembly. **Never put more than 6 amps through this TEC or you will destroy it.** You will also be using thermistors as part of your automated data acquisition for the laboratory. You will thus need (the publishedyour instructor will give it to you as well as an analytic form for converting these thermistor measurements to actual temperatures) a calibration curve for the thermistors. Record room temperature. Measure 500 ccs of cold tap water and place ice cubes in it and let the temperature of the water drift down to about 15 degrees or so below room temperature. Load only 500 ccs of water (no ice, ice, baby!) into the refrigerator. Now assemble lid, thermistor, and fan assembly and put it on the refrigerator. Start and leave on the fan throughout this entire experiment (on 12 volts please!). Now wait 4 minutes and take data for its warming curve. This may take several hours! You will not need to log more than one thermistor reading per minute! This first run will help you determine the overall thermal load at various temperatures for the refrigerator.

For the second session, plug in the TEC (red wire is positive!) to a DC power supply rated to about 20 volts and about 10 amps. Turn on the TEC to about 4 amps, wait 3 minutes and start logging the temperature (again, one point per minute) of the water. **Never put more than 6 amps through this TEC or you will destroy it.** Record the voltage on the TEC. You may notice that as the system runs the current may drift off somewhat from 4 ampstry to change the operating conditions (i.e. increase/decrease the voltage and record the new voltage and the sample number when you switched to it) to maintain 4 amps. Record until the temperature either goes past the initial temperature that the cold water was at OR until the temperature simply plateus. This may take a while!

ANALYSIS: Use the bicolumnar data (time and thermistor) from the data collection in the first part to determine the passive heat load

$\mathrm{d}Q_{passive}/\mathrm{d}t$ (in watts) as a function of the temperature (^{o}C) of the refrigerator. Use the data from the second part to determine the $\frac{\mathrm{d}Q_{c,net}}{\mathrm{d}t}$ (also in watts) that is leaving the water. Combine these two data sets at each temperature to determine the actual amount of heat the TEC is transporting out of the refrigerator, that is, $\frac{\mathrm{d}Q_c}{\mathrm{d}t} = \frac{\mathrm{d}Q_{c,net}}{\mathrm{d}t} + \mathrm{d}Q_{passive}/\mathrm{d}t$. Now, using your voltages at the various times, compare these $\frac{\mathrm{d}Q_c}{\mathrm{d}t}$ with the $\frac{\mathrm{d}W}{\mathrm{d}t} = P$ (power consumed) of electrical energy input to determine and graph the coefficient of performance of your TEC refrigerator as a function of the temperature difference across the TEC.

Conclusion: Compare that graph with the expected maximum efficiency of Carnotyou may want to include two lines on the graph, one for the TECs performance and the maximum due to Carnot (though you may have to creatively scale one of them to actually put them on the same graph!). Compare also the trends in each data set.