Second Sound and Heat Capacity of ^{4}He

Pre-lab

1. Explain the concept of the speed of sound measurements.
2. Why are the metalized membranes DC-biased?
3. What are the sources of heating that affect the heat capacity measurements?
4. What is the procedure for filling the He dewar with liquid He? What could go wrong in transferring liquid He?

Liquid He is expensive, so it is important that you carefully plan your experiments. There are three sets of experiments that you can readily perform in this laboratory.

1. First you will measure the speed of second sound. The detailed experimental approach can be found in the document "Second Sound in Superfluid Liquid He." This will require that you familiarize yourself with the acoustics of the cylindrical resonator.
2. The second experiment is the measurement of the heat capacity of liquid ^{4}He.
   a. Before you place the apparatus into the cryostat, you need to make some measurements so that you can determine the volume of liquid helium below the liquid-gas level as seen from outside the cryostat. This volume will be needed for your heat capacity measurements. Your instructor will give you some advice on how the determine the inside diameter of the inner dewar and the relationship between the liquid level inside and a cm scale on the outside of the outer dewar.
   b. For the heat capacity experiment, you should do at least three warm-ups from ~ 1.5K with different voltages V_H across the heater with current I_H passing through it: 7V, 10V & 14V. During the warm-ups, you'll be recording the resistance R_T of a calibrated thermometer as a function of time t. From this R_T vs t behavior, you can compute T vs t, where T is the temperature. You should derive the following equation, for total delivered power P_{total}: $P_{total} = C \cdot V \cdot (dT/dt)$, where C is the heat capacity per unit volume and V is the volume of liquid helium. From this equation you can compute C vs T.
   c. However, since heat is leaking into the liquid helium from room temperature, one has:

      $$P_{total} = V_H \cdot I_H + P_{background}.$$

      So you need to evaluate $P_{background}$. You do this by recording R_T vs t with $V_H = 0$ for a short time at the beginning of the warm-up. Then you set $V_H \neq 0$ and note the change in R_T vs t. After you have converted R_T vs t into T vs t, you can determine dT/dt for both $V_H =$ and $V_H \neq 0$ cases close to point where these two cases intersect. From these two values of dT/dt, you can obtain $P_{background}$ from $V_H \cdot I_H$. You will need to do this analysis for all three V_H. Is $P_{backrground}$ about the same for these three V_H?

      There is a Mathcad program on the lab computer for calculating dT/dt from your T-vs-t data.
3. Fountain Effect: this is an interesting experiment that is still under development. Your instructor will provide some options on this experiment.