Thermal conductivity by Lee's Method

Motivation and Aim

In this experiment the thermal conductivity of a bad conductor is measured.

Apparatus

1. Lee's Apparatus
2. Bad conductor samples (glass and ebonite discs).
3. Two thermometers
4. Boiler and Heater
5. Stop watch
6. Weighing balance
7. Vernier Calliper

Procedure

Fill the boiler with water to nearly half and heat it to produce steam. In the mean time, weigh the disc D_1 on which the apparatus rests. Further, measure the diameter of specimen disc d with a vernier calliper and its thickness using a screw gauge at several spaces and determine the mean thickness.

Clamp the glass specimen between the base disk D_2 of the steam jacket and the auxiliary brass disc D_1. Insert the thermometers (either mercury thermometer or thermocouples) in the two brass disks D_1, D_2. Check if they show the same readings at room temperature. If not, note the difference T'.

Connect the boiler outlet with the inlet of the steam chamber by a rubber tube. Continue passing steam until the two brass disks reach a steady temperature. Note down the temperatures T_1 and T_2 of the two discs.

The second part of the experiment involves the determination of the cooling rate of disc D_1 alone. Remove the sample disc. Heat the disc D_1 directly by the steam chamber till its temperature is about $T_1 + 10^\circ$ C. Remove the steam chamber and place the insulating disk on it. Record the temperature of the brass disc at half minute intervals. Continue till the temperature falls to about $T_1 - 7^\circ$ C.

Theory

Fourier's Law of heat conductance gives the rate of transfer of heat between two objects at temperatures T_2 and T_1 connected by a conductor with conductivity k and cross-sectional areas A (assumed uniform) and length l as

$$\frac{\Delta Q}{\Delta t} = k\frac{A}{l}(T_2 - T_1)$$

This equation governs the rate of heat transfer from disc D_2 to D_1 in the first half of the experiment.

The instantaneous rate at which a warm body loses heat to surroundings is given by Newton's law of cooling (which is a special case of Stefan's law, when the temperature differences are small, and there are losses other than radiative losses).

$$\frac{dT}{dt} = -b(T - T_a),$$

where T_a is the ambient temperature.

This law governs the rate at which the disc D_1 cools in the second half of the experiment. If m is the mass of the disk and s is the specific heat of the material of D_1 (brass in this case), then the rate at which heat is lost by the disc D_1

$$\frac{\Delta Q_1}{\Delta t} = ms(dT_1/dt)$$

Analysis

In the steady state achieved in the first half of the experiment, the heat supplied by the steam is lost by cooling of disc D_1. Hence the heat balance in the experiment is given by combining equations two heat transfer equations.

$$ms\frac{dT}{dt} = k\frac{A}{l}(T_2 - T_1)$$

dT/dt for D_1 can be determined from the cooling curve obtained in the second part of the experiment. As an approximation a single value of dT/dt can be used for this calculation. It is calculated at the value T_1 during the cooling of the disc D_1 from $T_1 + 10^\circ$ C to $T_1 - 10^\circ$ C. From the known value of $s = 0.380$ J/g/K for brass, k can be determined.

Note that if the two thermometers do not initially show the same reading, the difference $T_2 - T_1$ will have to be corrected by the quantity T' determined at the beginning of the experiment.

Points to Ponder

1. Why is it necessary to have a thin disk in the experiment?
2. Would this method work for measuring the conductivity of a good conductor?
3. In the cooling part of the experiment, why is the brass disc D_1 covered by the glass disc? Is it crucial to do so?
4. Why do we take the cooling data asymmetrically around T_1 in the second half of the experiment?