EXPERIMENT 16
THERMAL CONDUCTIVITY

I. THEORY

The purpose of this experiment is to measure the thermal conductivity of two materials.

Heat can be transferred from one point to another by three common methods: conduction, convection and radiation. Each method can be analyzed and each yields its own specific mathematical relationship. In this experiment you will investigate the rate of thermal conduction.

The **heat current** through a uniform material is defined to be the amount of heat that flows through the material divided by the time elapsed, $H = Q/\Delta t$. Experimentally, the heat current is found to be directly proportional to the temperature difference, ΔT, between the sides of the material, provided that the temperatures of various points in the rod do not vary with time, a condition known as **steady-state**. The heat current is also found to be directly proportional to the cross-sectional area, A, through which the conduction takes place, and inversely proportional to the thickness, L, of the material. These results are expressed by the equation

$$H = \frac{Q}{\Delta t} = \frac{kA\,\Delta T}{L}.$$

The proportionality constant k is called the **thermal conductivity** of the material.

The technique for measuring thermal conductivity is straightforward. A slab of the material to be tested is clamped between a steam chamber and a block of ice. The steam chamber maintains a constant temperature given by $T_B = 71.5\ °C + 0.375\ (°C/\text{cm-Hg})\ P$, in which P is the atmospheric pressure and T_B the boiling point of water. The block of ice maintains a constant temperature of 0°C. A fixed temperature differential is thereby established between the surfaces of the material.

The heat transferred is measured by collecting the water from the melting ice. In a time Δt, the amount of heat added to the ice is related to the Latent Heat of Fusion, L_f, and the mass of ice that melts, Δm by

$$Q = L_f\,\Delta m$$

Combining these two equations, we have

$$H = L_f \frac{\Delta m}{\Delta t} = \frac{kA\,\Delta T}{L},$$

where $\Delta m/\Delta t$ is the rate at which the ice is melting.

II. LABORATORY PROCEDURE

1. Gently remove the apparatus from the box.

2. Fill the steam generator approximately 2/3 full and plug it in. You will turn it on later.

3. Measure the mass of the container for collecting melted ice.

4. Record the type of material of the first object to be used (your instructor will tell you which objects to use). Measure its thickness using a micrometer. Be sure to check the zero correction of the micrometer and record both the raw measurement and the corrected thickness of the material.

5. Mount the sample onto the steam chamber as shown in the figure. Take care that the sample material is flush against the water channel, so water will not leak. Then tighten the thumbscrews.

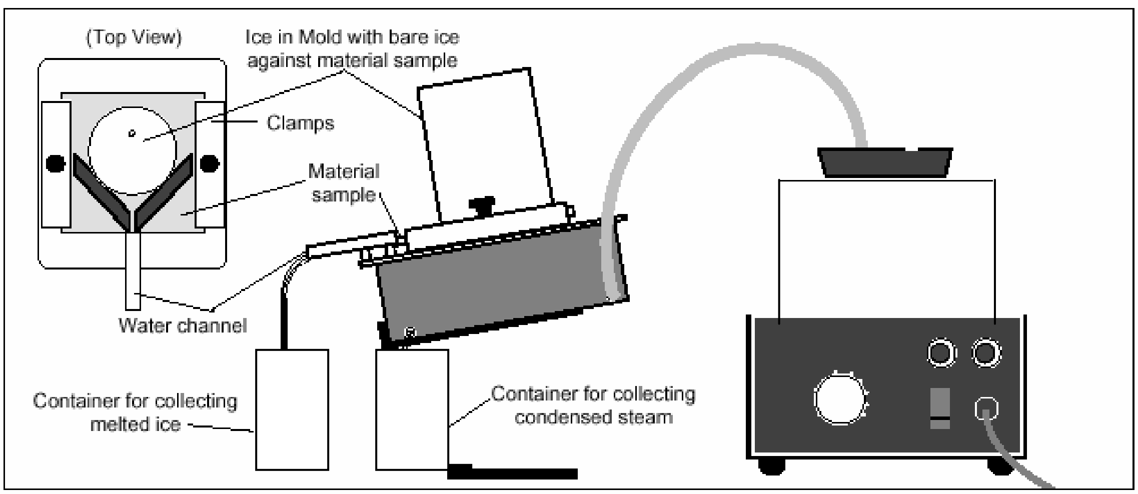

Figure Experimental Setup

6. Place the ice on top of the sample as shown in the figure. Do not remove the ice but make sure that the ice can move freely in the mold. Just place the open end of the mold against the sample, and let the ice slide out as the experiment proceeds.

7. Let the ice sit for several minutes, so that it begins to melt and the side against the sample becomes flat and is in full contact with the sample. (This also should bring the temperature of the ice up to 0°C.) Make sure that all the melted ice is collecting in the container supplied.

8. Measure the diameter of the ice block, using a vernier caliper.

9. Although you will not connect it to your apparatus yet, turn on the steam generator so the water will begin to warm. Empty the container for collecting melted ice. Let the ice melt for 10 minutes and measure the mass of the container and melted ice. (This will be used to determine the ambient melting rate of ice.)

10. Connect the steam generator to your apparatus and let steam run into the steam chamber. Wait 5 minutes for a steady-state to be established. Empty the container for collecting melted ice. Let the ice melt for an additional 5 minutes and measure the mass of the container and melted ice again.

11. Measure the diameter of the ice block again.

12. Repeat steps 4-11 for a second material.

13. Record the atmospheric pressure in the room.

14. Empty all containers into the sink. Clean up any spilled water. Gently return the apparatus to the box.

III. CALCULATIONS

1. From the atmospheric pressure measured, calculate the boiling point of water during your experiment.

Perform the following calculations for each material used.

2. Determine the average diameter of the ice block during steps 8-11. Use this average value to find the average area of the ice block in contact with the object.

3. Determine the rate at which ice melted with no steam in the steam chamber and with steam in the steam chamber. From these rates and the heat of fusion of water, determine the rate at which heat flowed through your object.

4. Determine the thermal conductivity of your object. Compare your value to a standard value.