LAB 4: Thermal Conductivity

Goal: To determine the composition of a thermal insulator by finding its thermal conductivity, k.

Equipment List:

Pasco steam generator with stopper and tubing
Pasco steam chamber
Ice block
Styrofoam cover for ice block
Sample material slab, a tile of one of wood, lexan, sheetrock, or Masonite
Vernier calipers
Timer
Balance
Collecting cups
Paper towels

Background: The thermal conductivity, k, is a constant which measures how well or poorly a material conducts heat. The thermal conductivity is related to the heat transferred by:

$$k = \frac{P\Delta x}{A\,\Delta T}$$

where $P = \frac{Q}{\Delta t}$ is the "heat current", or rate of heat transfer.

To find the thermal conductivity, the material tested is clamped between a steam chamber, which maintains a constant temperature of 100°C, and a block of ice, which maintains a constant temperature of 0°C. Therefore, a fixed temperature differential of 100°C is established. The heat transferred, Q, is measured by collecting the water from the melting ice. The ice melts at a rate of 1 gram per 80 calories of heat or 333.5 J/g. This is the latent heat of fusion. From this we can find Q:

$$Q = mL_f$$

Thus the thermal conductivity can be expressed:

$$k = \frac{mL_f\Delta x}{\Delta t\,A\,\Delta T}$$

where

A is the area of ice in contact with the sample
Δx is the thickness of the sample
m is the mass of melted ice
ΔT is the temperature differential
Δt is the time during which the ice is melted

Procedure:

1. Set up the apparatus as shown in Figure 1. The sample material slab is the gray square shown in the top view. It is seated on top of the steam chamber and held in place with the clamps. The ice is going to be placed on top of the sample. Fill the steam generator about 2/3 full and set it to 7, but do not attach the tubing yet. If hot water begins to spray from the hole in the stopper, it is overfull; remove some water.

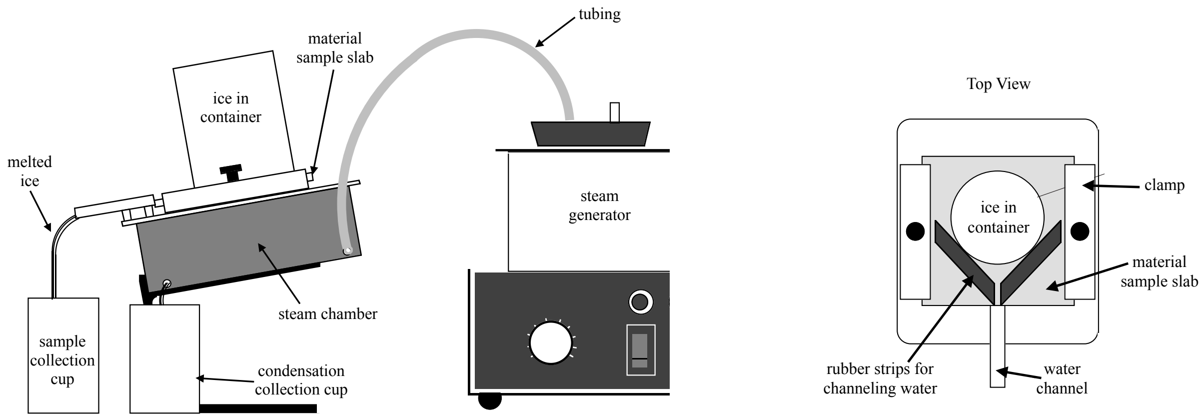

Figure 1: Equipment set up, side view and top view of ice and sample on steam chamber.

2. Measure the mass of the sample collecting cup, m_{cup}, and the slab thickness, Δx.
3. Carefully remove the ice from the mold and place it onto the slab. Cover the ice with the insulating foil-covered styrofoam container.
4. Collect ice-melt water in the sample collection cup for 10 minutes and then weigh it to find the ambient melting rate. Assume the ambient melting rate is constant. Record this value.
5. Run steam into the upper inlet of the steam generator with the tubing. Place a container under the lower drain spout to catch the condensed steam. Run the steam into the steam chamber for several minutes to allow the temperature to stabilize.
6. Measure the diameter, d_1, of the ice with the vernier calipers and empty the meltwater collection cup. Replace the cup and collect melted ice for 10 minutes, then measure the mass of the collected meltwater and the diameter of the ice, d_2.
7. Empty the collecting cup again, and repeat the test: collect melted ice for another 10 minutes then measure the mass of collected water and the final diameter of the ice, d_3.

Analysis:

1. Find the average diameter for your two trials: $d_{\text{avg1}} = \frac{1}{2}(d_1 + d_2)$ for trial 1 and $d_{\text{avg2}} = \frac{1}{2}(d_2 + d_3)$ for trial 2. Use these two average diameters to compute the cross sectional area A for each trial used in the calculation of k.
2. Calculate k for each trial and average.
3. Compare with the accepted values by calculating the percentage difference. Expect 10–15% error under normal conditions.

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\begin{aligned}
k_{\text{wood}} &= 0.11 - 0.14 \text{ W/Km} \\
k_{\text{lexan}} &= 0.19 \text{ W/Km} \\
k_{\text{sheetrock}} &= 0.43 \text{ W/Km} \\
k_{\text{masonite}} &= 0.047 \text{ W/Km}
\end{aligned}
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