Introduction

Thermal Conductivity Apparatus

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. The TD-8561 Thermal Conductivity Apparatus allows one to investigate the rate of thermal conduction through five common materials used in building construction.

The equation giving the amount of heat conducted through a material is:

$$\Delta \mathbf{Q} = \mathbf{k}\ \mathbf{A}\ \Delta \mathbf{T}\ \Delta \mathbf{t} / \mathbf{h}.$$

In this equation, Δ**Q** is the total heat energy conducted, **A** is the area through which conduction takes place, Δ**T** is the temperature difference between the sides of the material, Δt is the time during which the conduction occurred and h is the thickness of the material. The remaining term, **k**, is the thermal conductivity of a given material.

The units for **k** depend upon the units used to measure the other quantities involved. Some sample conversions between different possible sets of units are shown in Table 1.

	$\frac{\text{Btu in.}}{\text{in.}^2 \text{ sec °R}}$	$\frac{\text{Btu in.}}{\text{in.}^2 \text{ hr °R}}$	$\frac{\text{Btu ft}}{\text{ft}^2 \text{ hr °R}}$	$\frac{\text{Btu in.}}{\text{ft}^2 \text{ hr °R}}$
$\frac{\text{Watt cm}}{\text{cm}^2 \text{ °K}}$	1.338×10^{-2}	4.818	57.82	693.8
$\frac{\text{Watt m}}{\text{m}^2 \text{ °K}}$	1.338×10^{-5}	4.818×10^{-2}	0.5782	6.938
$\frac{\text{Watt in.}}{\text{in.}^2 \text{ °R}}$	9.485×10^{-4}	3.414	40.97	491.7
$\frac{\text{Cal cm}}{\text{cm}^2 \text{ sec °K}}$	5.600×10^{-3}	20.16	241.9	2.903×10^{3}

Table 1

The importance of **k** lies in whether one wishes to conduct heat well (good conductor) or poorly (good insulator). Therefore, the relative size of **k** is of importance to designers and builders, and should be of importance to home owners.

Note further that choosing a material with a small value for **k** does not guarantee a well-insulated structure. The amount of heat conducted out in winter (and therefore needing to be replaced) depends also upon three other factors: area, thickness and temperature difference. The same holds true for heat conducted in during the summer.

The equation for determining k is:

$$\mathbf{k} = \Delta \mathbf{Q}\ \mathbf{h} / \mathbf{A}\ \Delta \mathbf{T}\ \Delta \mathbf{t} = \underline{\quad\quad}$$

The technique for measuring thermal conductivity is straightforward. A slab of the material to be 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. A fixed temperature differential of 100 °C is thereby established between the surfaces of the material. The heat transferred is measured by collecting the water from the melting ice. The ice melts at a rate of 1 gram per 80 calories of heat flow (the latent heat of melting for ice).

The thermal conductivity, k, is therefore measured using the following equation:

$$k = (\text{cal cm/cm}^2 \text{ sec}) = \frac{(\text{mass of melted ice})\ (80 \text{ cal/gm})\ (\text{thickness of material})}{(\text{area of ice})\ (\text{time during which ice melted})\ (\text{temp. differential})}$$

where distances are measured in centimeters, masses in grams, and time in seconds.

The Thermal Conductivity Apparatus includes the following equipment (see Figure 1):

- Base
- Steam chamber with hardware for mounting sample
- Ice mold with cover (Part # 648-03427)
- Materials to test: Glass, wood, lexan, masonite, and sheet rock (The wood, masonite, and sheet rock are covered with aluminum foil for waterproofing.)

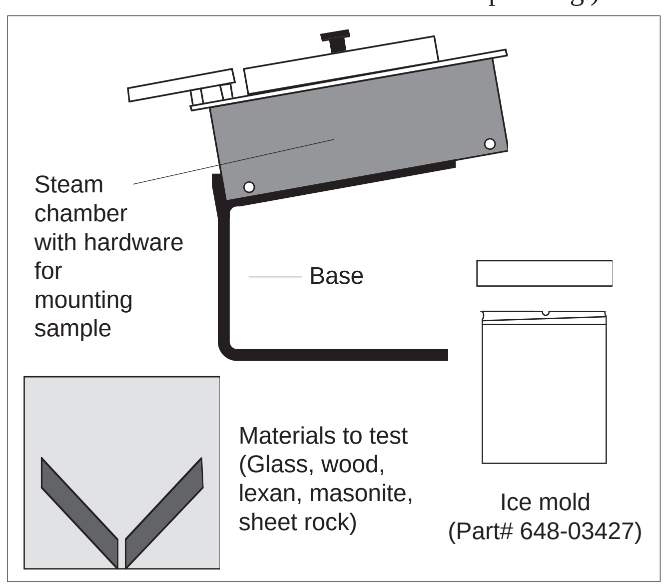

Figure 1 Equipment Included with the Thermal Conductivity Apparatus

Notes

Experiment: Measuring Thermal Conductivity

EQUIPMENT NEEDED:

- — Steam generator that will deliver approximately 10 grams/minute (e.g., PASCO's Model TD-8556 Steam Generator)
- — Freezer
- — Container to collect melted ice (a paper cup is fine)
- — Gram balance to weigh collected water (you could collect the water in a graduated flask, but your results will be less accurate)
- — Container to collect condensed steam
- — Grease such as petroleum jelly ("Vaseline")

Measuring Thermal Conductivity

① Fill the ice mold with water and freeze it. Do not freeze water with lid on jar. (A few drops of a non-sudsing detergent in the water before freezing will help the water to flow more freely as it melts and will not significantly effect the results.)

② Run jar under warm water to loosen the ice in the mold.

➤ **NOTE:** Do not attempt to "pry" the ice out of the mold.

③ Measure and record **h**, the thickness of the sample material.

④ Mount the sample material onto the steam chamber as shown in Figure 2.

➤ **NOTE:** Take care that the sample material is flush against the water channel, so water will not leak, then tighten the thumbscrews. A bit of grease between the channel and the sample will help create a good seal.

⑤ Measure the diameter of the ice block. Record this value as $\mathbf{d_1}$. Place the ice on top of the sample as shown in Figure 2. 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.

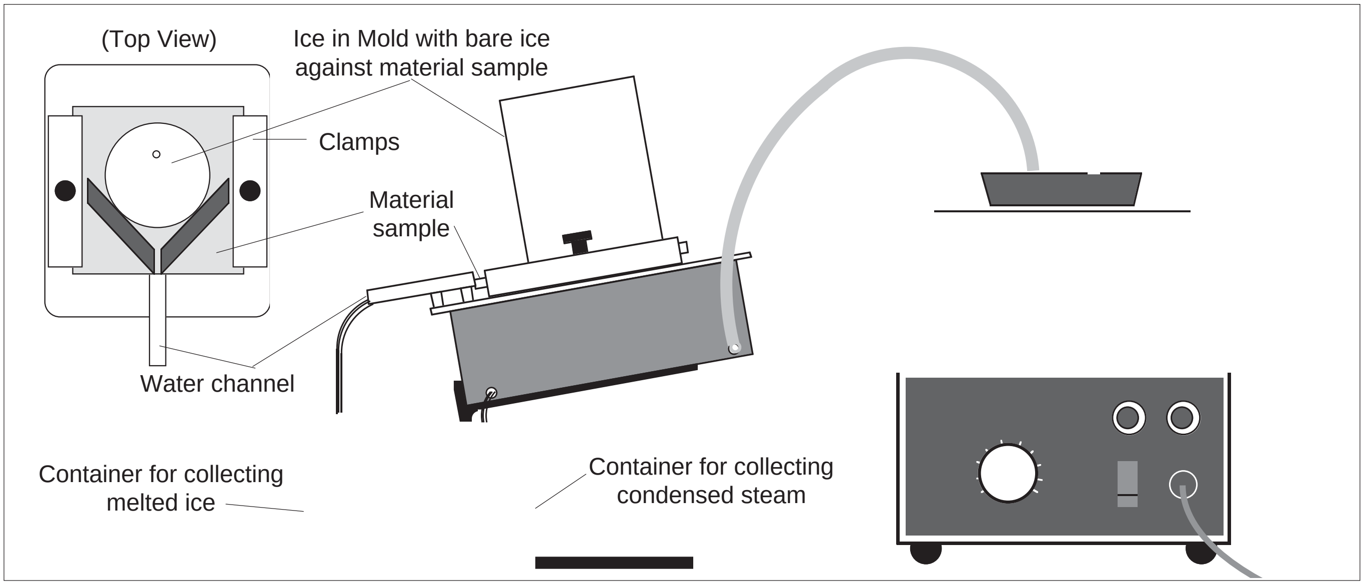

Figure 2 Experimental Setup

⑥ Let the ice sit for several minutes so it begins to melt and comes in full contact with the sample. (Don't begin taking data before the ice begins to melt, because it may be at a lower temperature than 0 °C.)

⑦ Obtain data for determining the ambient melting rate of the ice, as follows:

a. Determine the mass of a small container used for collecting the melted ice and record it.

b. Collect the melting ice in the container for a measured time $\mathbf{t_a}$ (approximately 10 minutes).

c. Determine the mass of the container plus water and record it.

d. Subtract your first measured mass from your second to determine $\mathbf{m_{wa}}$, the mass of the melted ice.

⑧ Run steam into the steam chamber. Let the steam run for several minutes until temperatures stablize so that the heat flow is steady. (Place a container under the drain spout of the steam chamber to collect the water that escapes from the chamber.)

⑨ Empty the cup used for collecting the melted ice. Repeat step 7, but this time with the steam running into the steam chamber. As before, measure and record $\mathbf{m_w}$, the mass of the melted ice, and **t**, the time during which the ice melted (5-10 minutes).

⑩ Remeasure the diameter of the ice block and record the value as $\mathbf{d_2}$.

DATA AND CALCULATIONS

① Take the average of $\mathbf{d_1}$ and $\mathbf{d_2}$ to determine $\mathbf{d_{avg}}$, the average diameter of the ice during the experiment.

② Use your value of $\mathbf{d_{avg}}$ to determine **A**, the area over which the heat flow between the ice and the steam chamber took place. (Assume that **A** is just the area of the ice in contact with the sample material.)

③ Divide $\mathbf{m_{wa}}$ by $\mathbf{t_a}$ and $\mathbf{m_w}$ by **t** to determine $\mathbf{R_a}$ and **R**, the rates at which the ice melted before and after the steam was turned on.

④ Subtract $\mathbf{R_a}$ from **R** to determine $\mathbf{R_0}$, the rate at which the ice melted due to the temperature differential only.

⑤ Calculate **k**, the conductivity of the sample:

k (cal cm/cm^2 sec) = __________

$\Delta\mathbf{T}$ = Boiling point of water (100 °C at sea level) - 0°C.

Data and Calculations Table

h	d_1	d_2	t_a	m_{wa}	t	m_w	d_{avg}	A	R_a	R	R_0

$$\frac{(R_0)\,(80\ \text{cal/gm})\,(h)}{(A)\,(\Delta T);}$$ __________