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Research Article

THERMAL CONDUCTIVITY OF BAD CONDUCTORS REVISITED

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ABSTRACT
A slightly different method based on calorimetric principle is discussed to determine the thermal conductivity of poor conductors by the apparatus designed which is of considerable interest to graduate students.

Key Words: *Thermal Conductivity, Bad Conductors, Calorimetric Principle, Apparatus Designed*

INTRODUCTION
The power of transmitting heat through conduction is possessed by all substances to a varying degree. For finding the conductivity of poor conductors the substance can not be used in the form of a long bar or rod like good conductors as the heat loss from the sides would be considerably compared with the heat actually conducted through the substance itself. For this, the substance is generally employed in the form of a thin plate, sphere or cylinder (Saha and Srivastava, 1969).

Lees and Charlton (1896) apparatus is one in which the bad conductor is employed in the form of a disc and its thermal conductivity is measured by applying Newton's law of cooling. Besides the application of Newton's law of cooling one can also measure the thermal conductivity by using simple calorimetric method which is as follows.

A slab or disc of material to be tested is placed between a steam chamber which maintains a constant temperature of 100^0C and a copper disc which maintains a constant temperature at the steady state. This steady state temperature is recorded with the help of a thermometer. A fixed temperature differential is thereby established between the surfaces of the material under consideration and heat is conducted through at a constant rate. A certain amount of water is taken in an insulated copper glass of known mass and bottom diameter. Initial temperature of the glass-water system is recorded. At the steady state the glass-water system is placed on the copper disc and is allowed to receive heat for a certain time interval, say 10-12 minutes. The rise in temperature of glass-water is recorded. The thermal conductivity of the bad conductor can, therefore, be calculated by using the following formula.

MATERIALS AND METHODS
The amount of heat conducted through a material is given by

$$\Delta Q = \frac{KA\Delta T\Delta t}{h},$$

Where ΔQ is the total heat conducted, A, the area through conduction takes place, ΔT, is the temperature difference between sides of the material, Δt is the time during which the conduction occurred and h is the thickness of the material.

If an insulated copper glass of mass M_g and specific heat S_g with M_w amount of water is placed on the copper disc which is on the upper surface of the bad conductor and maintains a constant temperature at the steady state then the heat received by the glass-water system during the time interval Δt is calculated as

$$\Delta Q = \left(M_g S_g + M_w\right)\Delta\theta,$$

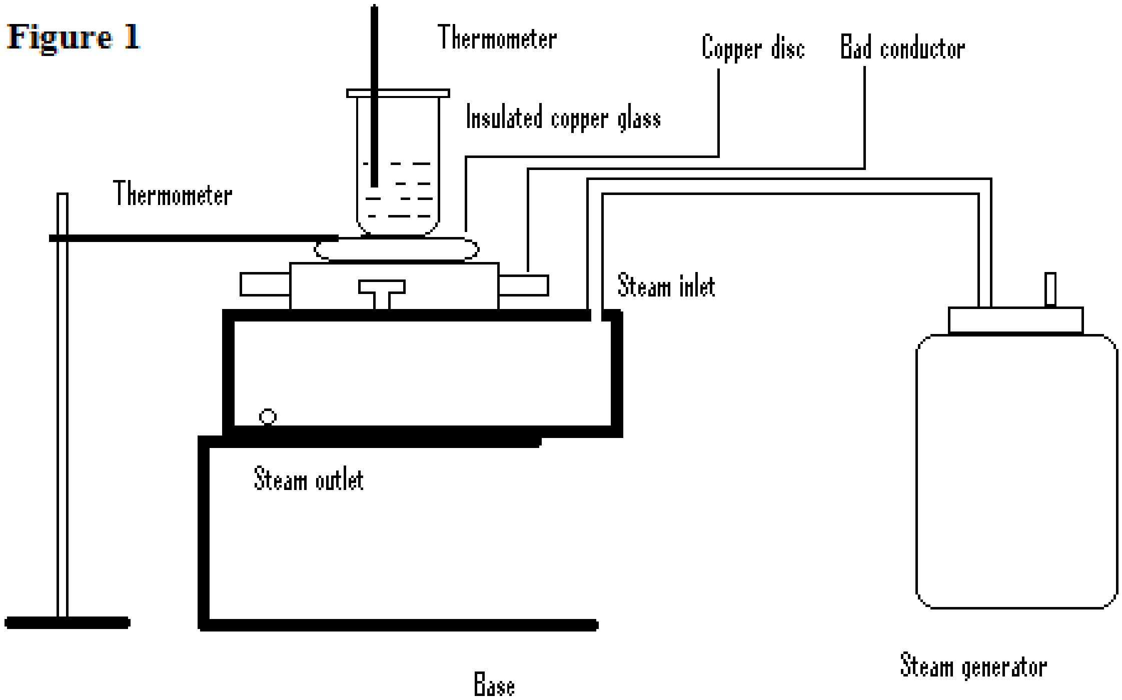
Where $\Delta\theta$ stands for the rise in temperature of the glass-water system during time interval Δt. From above two equations thermal conductivity K can be computed by using the relation.

$$K = \frac{\left(M_g S_g + M_w\right)\Delta\theta\, h}{A\Delta T\Delta t}\ .$$

The Thermal Conductivity Apparatus Includes the Following Equipments (Figure 1)

• Steam generator and steam chamber • Thermometers • Copper disc of thickness about 1cm • Insulated copper glass with cover • Materials [Cardboard, Ebonite, Plywood Plasterboard (gypsum), glass (ordinary) etc.] to test in the form of thin plate.

Figure 1



Procedure for Measuring Thermal Conductivity

• The sample of the bad conductor is clamped on the steam chamber and the copper disc is placed on it.
• The diameter of the bottom of the insulated copper glass of known mass is measured through which heat is conducted.
• A certain amount of water (measured by a measuring cylinder) is put in the insulated copper glass and temperature is recorded.
• The steam is allowed to pass through the steam chamber and the reading of the thermometer on copper disc, placed on the upper surface of the bad conductor, is monitored constantly.
• When steady state is reached (temperature remains constant over a long period of time), temperature is recorded and the insulated copper glass with water is placed on the copper disc. The glass-water system is allowed to receive heat for a certain time interval (say 10-12 minutes) measured by a stopwatch and also the final temperature of glass-water system is noted.

RESULTS AND DISCUSSION

Following the procedure we have measured the thermal conductivity of certain bad conductors and found these values are in agreement (Kaye and Laby, 1995) (within 10-15 % error) under normal laboratory condition as shown in Table 1. However the values for Cardboard, Plywood and Plasterboard (gypsum) may vary considerably. Some materials like Cardboard, Plywood and Plasterboard (gypsum) were covered with aluminum foil for water proofing and were found experimentally no measurable effect on the conductivity of the sample. It is our belief that the present method will be appreciable to intermediate and graduate students.

Table 1: Thermal Conductivity

Substance	K (Measured Value) in W/m^0K	K (Standard Value) in W/m^0K
Cardboard	0.182	0.21
Ebonite	0.151	0.17
Plywood	0.138	0.125
Plasterboard (Gypsum)	0.18	0.16
Glass (Ordinary)	0.95	0.86

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Lees CH and Charlton JD (1896). *Philosophical Magazine* **41** 495.
Saha MN and Srivastava BN (1969). *A Treatise on Heat* (Allahabad: The Indian Press [Pub] Pvt. Ltd.) 5^{th} Edition.