

Aim : To find the coefficient of thermal conductivity of a bad conductor by Lee's method.

Apparatus : Lee's disc apparatus consist of a metallic disc resting on a deep hollow cylinder (steam chamber) of same diameter, circular disc of the specimen of a bad conductor (ebonite or card-board), stop watch, two thermometer, boiler, heater, screw gauge and vernier caliper.

Theory : Thermal conductivity (k), is the property of a material that indicates its ability to conduct heat. Conduction will take place only if there exists a temperature gradient in a solid (or stationary fluid) medium. Heat moves along a temperature gradient, from an area of high temperature and high molecular energy to an area with a lower temperature and lower molecular energy. Conductive heat flow occurs in direction of the decreasing temperature because higher temperature is associated with higher molecular energy. This transfer will continue until thermal equilibrium is reached. The rate at which the heat is transferred is dependent upon the magnitude of the temperature gradient, and the specific thermal characteristics of the material. Thermal conductivity is quantified in the units of W/mK , and is the reciprocal of thermal resistivity, which measures an objects ability to resist heat transfer.

Lee's method is used to measure the thermal conductivity of a poorly conducting material, such as glass, wood, or polymer. This was one of the earliest methods used to measure thermal conductivity that gave reliable results and is a steady state method.

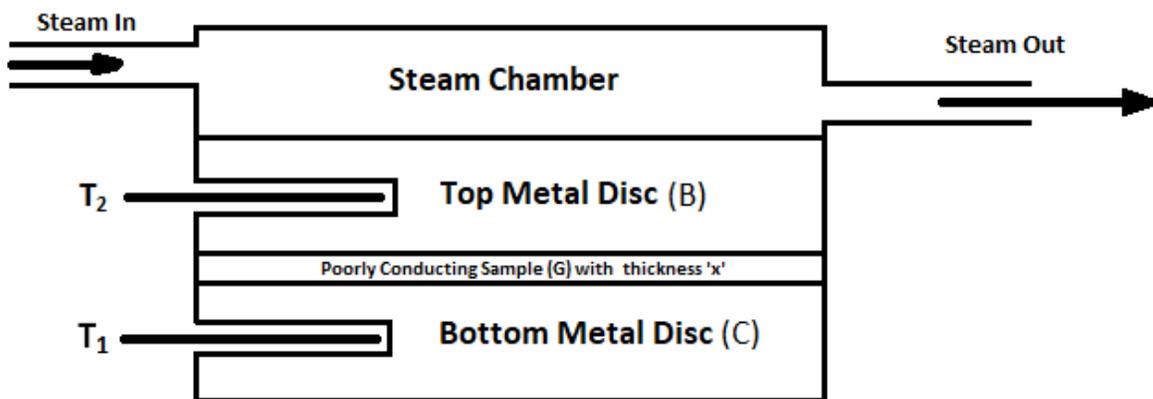
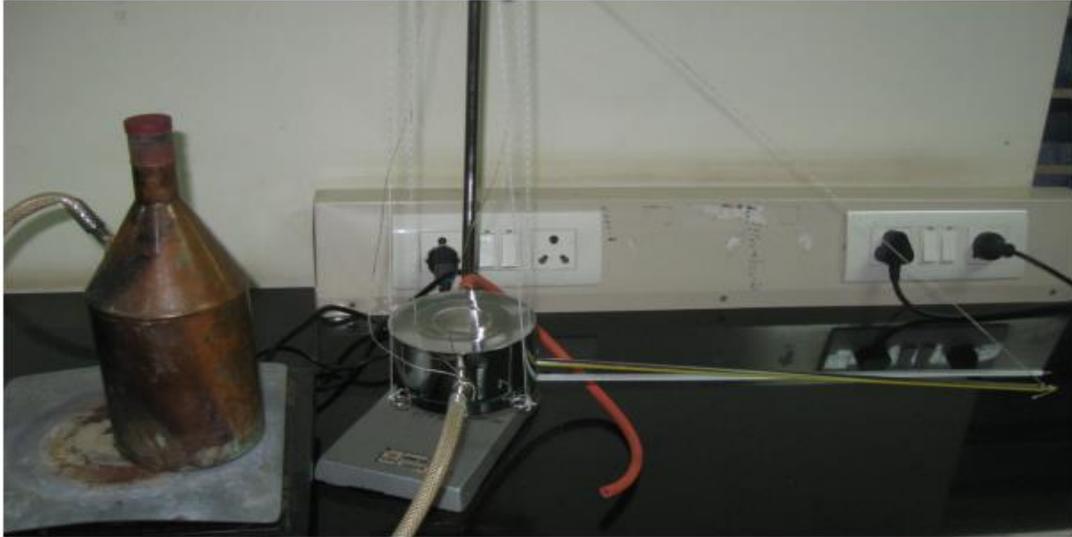


Figure 1 Experimental setup for Lee's Disc steady state thermal conductivity measurements.

The apparatus shown in Fig. 1 consists of two parts. The lower part C is circular metal disc. The experimental specimen G, usually rubber, glass or ebonite (here it is glass) is placed on it. The diameter of G is equal to that of C and thickness is uniform throughout. A steam chamber is placed on C. The lower part of the steam chamber, B is made of a thick metal plate of the same diameter as of C. The upper part is a hollow chamber in which two side tubes are

provided for inflow and outflow of steam. Two thermometers T_1 and T_2 are inserted into two holes in C and B respectively. The complete setup is suspended from a clamp stand by attaching threads to these hooks. Two good conductivity metal discs (of the same metal) and allow the setup to come to equilibrium, so that the heat lost by the lower disc to convection is the same as the heat flow through the poorly conducting disc.



Photograph of thermal conductivity measurement setup

At the steady state, rate of heat transfer (H) by conduction, which is expressed by Fourier's Law is given as;

$$H = k A \frac{(T_2 - T_1)}{x} \quad (1.)$$

where k is the thermal conductivity of the sample, A is the cross sectional area and $(T_2 - T_1)$ is the temperature difference across the sample thickness ' x ' (see Fig. 1), assuming that the heat loss from the sides of the sample is negligible.

When steam flows for some time, the temperatures recorded (T_1 and T_2) gradually remain steady. This is the steady state. Let at the steady state,

Temperature of C = T_1

Temperature of B = T_2

Surface area of G = $A (= \pi r^2)$

Conductivity of G = k

Thickness of G = x

Hence amount of heat flowing through G per second, H is given by Eq. (1). When the apparatus is in steady state (temperatures T_1 and T_2 constant), the rate of heat conduction into the brass disc C is equal to the rate of heat loss from the bottom of it. The rate of heat loss can be determined by measuring how fast the disc C cools at the previous (steady state) temperature T_1 (with the top of the brass disc covered with insulation). If the mass and specific heat of the lower disc are m and s , respectively and the rate of cooling at T_1 is dT/dt , then the amount of heat radiated per second is,

$$H = M s \frac{dT}{dt} \quad (2.)$$

At steady state, heat conducted through the bad conductor per second will be equal to heat radiated per second from the exposed portion of the metallic disc. Therefore, equating Eqs. (1) and (2), we get the coefficient of the thermal conductivity of the sample as

$$k = \frac{M s \frac{dT}{dt} x}{(T_2 - T_1)} \quad (3.)$$

Procedure :

1. Fill the boiler with water to nearly half and heat it to produce steam.
2. Put the specimen, steam chamber etc. in position and suspend it from the clamp stand. Insert the thermometers T_1 and T_2 in position.
3. Pass steam from the inlet of the cylindrical vessel and wait till the steady state is reached. This will take 30-40 minutes to reach the steady state.
4. Temperatures recorded in the thermometers will show a rise and finally will be steady at T_1 and T_2 . Then, wait for 10 minutes after reaching the steady state to confirm that actual steady state is reached or not. Note the steady temperatures indicated by the thermometers T_1 and T_2 . Interchange the thermometers T_1 and T_2 and again note down the temperature readings.
5. Remove the steam chamber and the specimen G. C is still suspended. Heat C directly by the steam chamber till its temperature is about $T_1 + 10^\circ$.
6. Remove the steam chamber and wait for 30-60 seconds so that heat is uniformly distributed over the disc C.
7. Place the insulating material on C. Start recording the temperature at intervals of 30 seconds. Continue till the temperature falls by 10°C below T_1 .
8. Plot a graph between temperature and time.
9. Take weight of C by a weighing balance. Measure the diameter of the specimen by using vernier calipers. Calculate the surface area, $A = \pi r^2$.
10. Measure the thickness of the specimen by screw gauge. Take observations at 3 or 4 spots and take the mean value.

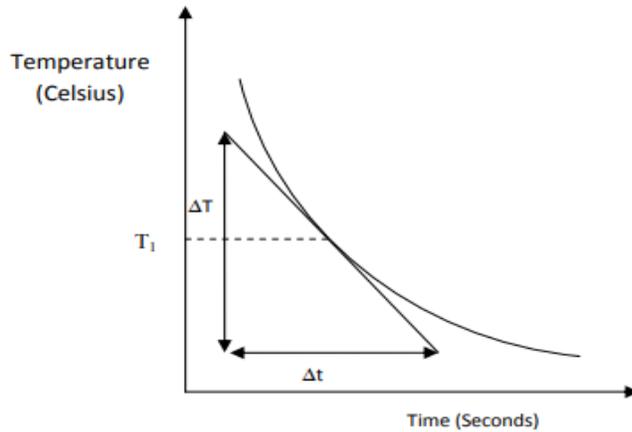


Fig. 3

Observations :

Mass of the metallic disc, $M = \text{_____ gm}$

Specific heat of metal, $s = 0.0959 \text{ kilo-cal/kg}$

Diameter of the disc (using vernier calipers) :

S. No.	Diameter (in cm)
1.	
2.	
3.	

Mean diameter, $D = \text{_____}$

Radius of the disc, $r = \text{_____}$

Thickness of disc (using screw gauge) : Pitch = _____, Least Count = _____

S. No.	Initial reading I (in cm)	Final reading F (in cm)	Difference (I-F) (in cm)	Mean (in cm)
1.				
2.				
3.				

Mean thickness, $x = \underline{\hspace{2cm}} \text{ cm}$

Steady state of thermometers :

1.) $T_1 =$ i. ii.

2.) $T_2 =$ i. ii.

Mean temperatures $T_1 = \underline{\hspace{1cm}} \text{ }^\circ\text{C}$ and $T_2 = \underline{\hspace{1cm}} \text{ }^\circ\text{C}$

Observations for cooling curve :

No. of observations	1	2	3	4	5	6 till temperature falls 10°C below T_1
Time (in seconds)									
Temperature of disc T_1 (in $^\circ\text{C}$)									

Corresponding to T_1 , rate of cooling $\frac{dT}{dt}$ is $^\circ\text{C}/\text{sec}$ (from the graph)

Coefficient of thermal conductivity :

$$k = \frac{M s \frac{dT}{dt} x}{(T_2 - T_1)}$$

Precautions :

- 1.) The diameter of the insulating disc should be equal to that of the cylindrical vessel and the metallic disc.
- 2.) The thermometer should be placed close to the face of the disc of the specimen.
- 3.) There should be a good thermal contact between the disc of material and the lower surface of the cylindrical surface and the upper surface of the circular metallic disc.
- 4.) The steady state temperature should be recorded only when the readings T_1 and T_2 remain constant after an interval of about 10 minutes.

5.)

Standard values of coefficient of thermal conductivity of bad materials :

Type of bad material	Coefficient of thermal conductivity (W/mK)
Polystyrene Foam	0.026
Wood - Pine	0.113
Natural Rubber	0.138
Teflon	0.251
Packed Snow	0.469
Pyrex Glass	1.13
Wet Soil	1.506
Manganese	6.694
Stainless Steel	13.389
Lead	34.3

Question: Is thickness of the material alters the conducting nature? Comment.

Question: Lee's Disc method is not suitable to determine the thermal conductivity of the good conductor. Justify.

Question: Bad conductors should be thin. Why?