THERMAL CONDUCTIVITY

Introduction:

You know from experience that heat flows from hot to cold. If you stick a poker into a fire, the end that you're holding gradually gets warmer – the heat from the fire only slowly travels up the poker. How fast or slow heat travels through an object depends on many things. You know that certain materials conduct heat better than others. Touching a cold piece of wood or a cold piece of metal tells you this straight away – wood conducts heat poorly, and therefore the cold sensation is only passing, but metals transport heat much better – the heat from your fingers is used to heat up the entire piece of metal, and if you're not careful the metal might freeze to your fingers! The extent to which materials conduct heat can be quantified by a parameter known as the thermal conductivity, symbol k. Heat conduction is not only determined by the material, but also by its shape, and by the temperature difference between the two ends. You will probably guess straight away that the higher the temperature difference between the ends, the more heat will flow. If you were to grab a longer poker and stick it into the fire, it would take longer for the end you hold in your hands to get warm. However, if you made the poker wider it would be easier for the heat to get across. Finally the heat input is important as well: the more heat you put into one end of the bar, the more heat will flow to the other end. From these considerations it follows that in order to measure the thermal conductivity of a certain material, we need to measure the heat input, its length, its diameter and the temperature difference. In its simplest form, an experiment might look like this: one end of the bar will be heated by means of a steam chamber or power supply, and you measure the amount of energy (heat) going in per second. You measure the length and diameter of the rod, and the temperature difference between the two ends of the rod. There is however one difficulty with this approach: eventually, the heat will spread out throughout the bar, and the entire bar will attain the same temperature. To circumvent this problem we keep the other end of the bar cooled.

Experimental Set-up:

The Searle's apparatus to measure the thermal conductivity of a solid is shown in Fig. 1. The solid is taken in the form of a cylindrical rod A B. One end A of the rod goes into a steam chamber through which steam is passed from a boiler. A copper tube is coiled around the other end B of the rod. This end B is cooled by circulating a steady flow of water maintained in the copper tube by constant water level tank. The flow of water is adjusted using pinch cork such that water comes drop by drop from the exit side. Water enters the tube at the end away from the steam chamber and it leaves at the end nearer to it. Thermometers T3 and T4 are provided to measure the temperatures of the outgoing and incoming water. Two holes are drilled in the rod and the temperature of the rod is also measured at these places with the help of thermometers T1 and T2. The whole apparatus is covered properly with layers of an insulating material like wool or felt, so as to prevent any loss of heat from the sides. Steam is passed into the steam chamber and a stream of water is maintained. The temperatures of all the four thermometers rise initially and ultimately become constant when the steady state is reached. The readings θ_1, θ_2, θ_3 and θ_4 are noted in steady state.

EXPERIMENT-I

Object:

To determine the thermal conductivity of copper using Searle's Apparatus

Apparatus Used:

Searle's Thermal Conductivity Apparatus, 04 Thermometers, Steam Boiler, Measuring Cylinder, Constant Water Level Tank, Pinch cork, Stop watch , Rubber tube and Hot Plate.

Formula Used:

The coefficient of Thermal Conductivity K for a material is given by

$$K=\frac{md\ (\theta_3-\theta_4)}{A\ (\theta_1-\theta_2)}\ \text{cal/gm./}^{o}\text{C/sec} \qquad (1)$$

Where A = Area of cross section of the rod (πr^2 where r is the radius of the copper rod (D/2)

θ_1 & θ_2 = Steady temperatures at the two fixed point of the rod in steady state.

d = Distance between two thermometer T_1 and T_2

m = Mass of water collected per second

θ_3 & θ_4 = Steady temperatures of water at exit and at entrance respectively.

Method:

1. Make the set-up as shown in Fig. 1

2.Fill the steam generator with water up to about 2/3rd height. Keep it on a Hot plate and switch 'ON' the Hot plate then steam is being formed in the steam generator . Pass a steady current of steam from the boiler through the rubber tube into the steam chamber to heat the end 'A'. Place a tray below the outlet 0 of the stem chamber to collect the condensed water.

3. Allow the water to flow through the copper coil by adjusting the height of constant level tank or by the use of a pinch cock adjust the rate of flow of water through copper coil so that water comes out as a trickle through the outlet end

4. Insert all the 04 thermometers in their respective places as shown in Fig. 1

5.Attain the steady state i.e. reading of temperature of all the four thermometers should be constant and there should not be any further increase in temperature.

6. After steady state when the readings of all the four thermometers remain constant for nearly 05 minutes, note the thermometer.

7. Now place a clean and dry measuring cylinder below the outlet of the copper coil and collect the water flown for a known time. Calculate the mass of water flowing per second.

8. Repeat the above procedure 3 to 4 times.

9. Measure the distance between the two fixed point where the thermometer T_1 and T_2 inserted.

10. Measure the diameter of the rod and calculate the value of K using formula as given above.

Observations and Tabulations:

(i) The distance 'd ' between the points along the bar or between the Thermometer T_1 and T_2 .

(ii) Determination of the diameter of the experimental rod.

Least count of the vernier calipers = cm.

Zero error of the vernier calipers if any = $\pm$ cm.

S. No.	Observed diameter in cm.						Mean diameter X in cm.	Corrected diameter d in cm.
	In one direction			$\frac{a+b}{2}$In other direction				
	M.S. Reading	V.S. Reading	Total a cm	M.S. Reading	V.S. Reading	Total b cm	$\frac{a+b}{2}$	
1								
2.								
3.								

(iii) **Table for mass of water collected**:

S. No.	Time in Minutes	Thermometers readings				Mass of water collected	Time of water collected after steady state	Mass of water collected per second
		θ_1	θ_2	Θ_3	θ_4			
1.	2.							
2.	4.							
3.	6.							
4.	8.							

11. Calculate mean value of mass of water collected per second from table (iii).
12. The steady state temperatures as noted from table (iii)

θ_1 = ^oC θ_2 = ^oC

θ_3 = ^oC θ_4 = ^oC

Calculations:

Calculate the value of K using equation (1) given above.

Results:

1. The Thermal conductivity K of Copper obtained experimentally = cal/gm./ ^oC/sec
2. The standard value of Thermal conductivity K of Copper = 0.918 cal/gm./ ^oC/sec

The experimentally observed value of K is always with in $\pm$ 10% on the standard value

Precautions:

1. Water should always flow from constant water level tank
2. A number of observations of the rate of flow of water should be made and their mean value Should be used for calculations.
3. The steady state position should be attained correctly.
4. Water should be collected only when steady state attained.
5. Water should be collected 3 to 4 times and mean value of water collected per second be used in calculations.

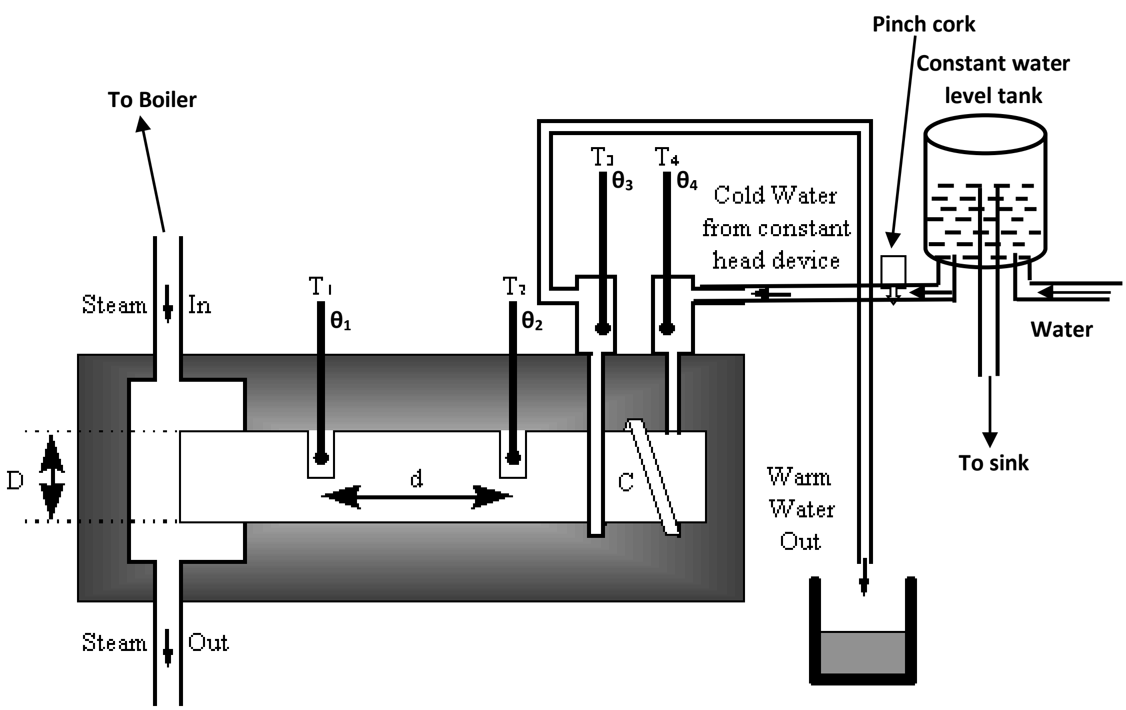

Fig. 1 Searle's Conductivity Apparatus

Error Calculation

1. There is an error in assuming that no heat lost along the bar, but no correction has been made for this, although this will obviously affect the values of T_2 and T_1.
2. The absolute error in each of the temperature differences $(T_1 - T_2)$ and $(T_3 - T_4)$ is the sum of the absolute errors in reading the two thermometers.
3. Errors in m arise from errors in determining the mass of water collected.
4. Errors in the time t depend on the accuracy of the stop-watch.
5. Errors in measuring with the Vernier calliper are at least 0.05 mm, but may be bigger (estimate how precisely you can measure D and d).
6. The fractional error in k is given by: $\frac{\Delta k}{k} = \frac{\Delta m}{m} + \frac{\Delta d}{d} + \frac{\Delta T_3 + \Delta T_4}{T_3 - T_4} + \frac{2\Delta D}{D} + \frac{\Delta T_1 + \Delta T_2}{T_1 - T_2} + \frac{\Delta t}{t}$, hence determine the absolute error �k.