Ministry of Higher Education and Scientific Research
Al-Mustaqbal University College
Air Conditioning and Refrigeration Technologies

Heat Transfer Laboratory

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Experiment No. (1)

Thermal conductivity measurement of a metal bar

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Experiment (1)

أسم التجربة: قياس معامل التوصيل الحراري للمواد الصلبة.

Experimental Title: Thermal conductivity measurement of a metal bar.

Objective: To determine the thermal conductivity coefficient of a metal**.**

Theoretical Part:

Thermal conductivity is the physical property of the material denoting the ease with a particular substance can accomplish the transmission of thermal energy by molecular motion. Thermal conductivity of material is found to depend on the chemical composition of the substance or substance of which it is a composed, the phase (i.e. gas, liquid or solid) in which it exists, its crystalline structure if a solid, the temperature and pressure to which it is subjected, and whether or not it is a homogeneous material.

Fourier's Law of conduction is given by the following relationship:

$$Q = -k A \frac{dT}{dx} \qquad (1.1)$$

Where

Q is the rate of heat transfer (W).

k is the thermal conductivity (W/m.K).

A is the cross-sectional area through which the heat is transferred (m^2).

dT/dx is the temperature gradient, a linearly decreasing relationship of temperature over distance that we expect to observe through the thermocouples on the apparatus.

The rate of heat transfer can also be calculated by the voltage V (Volts) and the current I (Ambers):

$$Q = V * I \qquad (1.2)$$

The cross sectional area of the metal bar is given by:

$$A = \frac{\pi}{4} d^2 \qquad (1.3)$$

Temperature is measured at discrete points along the rod in this experiment. It is therefore appropriate to rewrite Equation (1.1) in a different form:

$$q = kA\left(\frac{\Delta T}{\Delta x}\right) \qquad (1.4)$$

Where

ΔT is the temperature difference between any two thermocouples (adjacent or not).

Δx is the distance between the two thermocouples of interest.

For one dimensional heat flow, and based on Figure 1.1, we can write the following:

$$\frac{q}{A} = \frac{k_L(T_1 - T_{IL})}{x_L} = k\frac{(T_{IL} - T_{IR})}{x} = \frac{k_R(T_{IR} - T_6)}{x_R} \qquad (1.5)$$

Where

T_1 is the temperature at the warmest point on the rod at the left end.

T_{IL} is the interface temperature between the left end rod and the center rod.

T_{IR} is the interface temperature between the center rod and the right end rod.

T_6 is the temperature at the coolest point of the rod on the right.

x corresponds to the appropriate distances.

The interface temperatures are sketched in Figure (1.1). Thermal conductivity (k) values correspond to the appropriate materials.

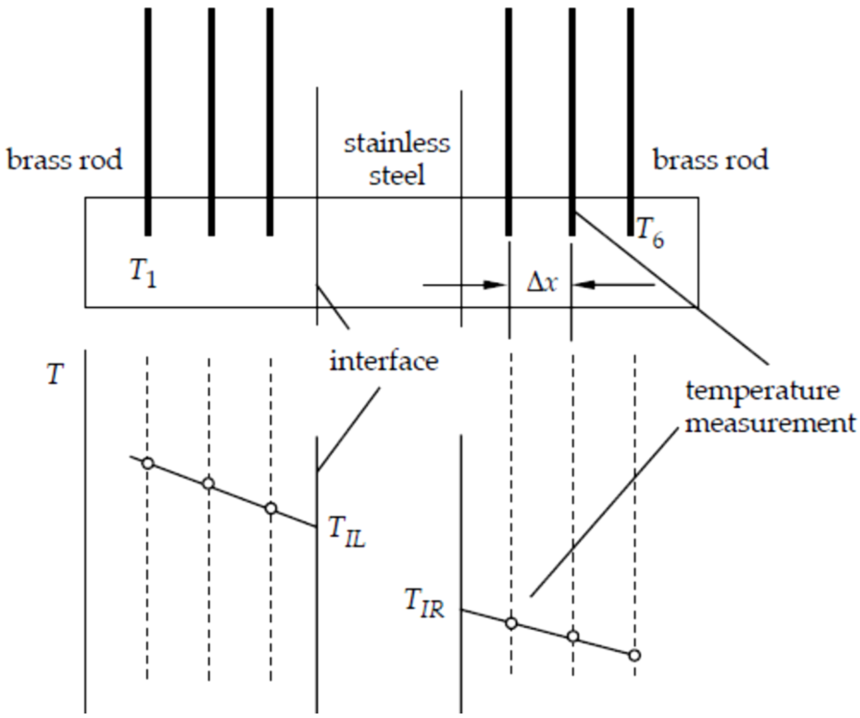

Figure (1.1) Schematic of the experimental set up.

Table (1.1) thermal conductivity of some common materials

Metal	Thermal Conductivity kcal / hr – m - ^{0}c	State
SOLID'S Pure Copper	330	20 degree
Brass	95	- - do - -
Steel (0.5%C)	46	- - do - -
S. S.	14	- - do --

Mechanism of Thermal Energy Conduction in Metals:

Thermal energy may be conducted in solids by two modes:

1. Lattice Vibration.

2. Transport by free electrons.

In good electrical conductors a rather large number of free electrons move about in the lattice structure of the material. Just as these electrons may transport electric charge, they may also carry thermal energy from a high temperature region to a low temperature region. In fact, these electrons are frequently referred as the electron gas.

Energy may also be transmitted as vibrational energy in the lattice structure of the material. In general, however, this latter mode of energy is not as large as the electron transport and it is for this reason that good electrical conductors are almost always good heat conductors, i.e. Copper, Aluminum and silver. With increase in the temperature; however the increased lattice vibrations come in the way of the transport by free electrons for most of the pure metals the thermal conductivity decreases with increase in the temperature for some metals.

The heater will heat the bar at its end and heat will be conducted through the bar to other end. The thermal conductivity of the bar will be calculated using the following equation:

$$Q = k A \frac{\Delta T}{\Delta x}$$

where,

ΔT is the temperature difference. $(T_1 - T_6)$

Δx is the distance between the two thermocouples (0.2)

A is the cross sectional area of the bar $[(\pi/4)\ d^2]$.

Experimental procedure

Apparatus:

Figure (1.2) the experimental Apparatus

As shown in Figure 1.2, the experimental device consists of a metal bar, one end of which is heated by an electric heater while the other end of the bar projects inside the cooling water jacket. The middle portion of the bar is surrounded by a cylindrical shell filled with the asbestos insulating powder. The temperature of the bar is measured at eight different sections, namely (1 to 8) see Figure (1.3), while the radial temperature distribution is measured by two separate thermocouples (9 and 10) at two different sections in the insulating shell.

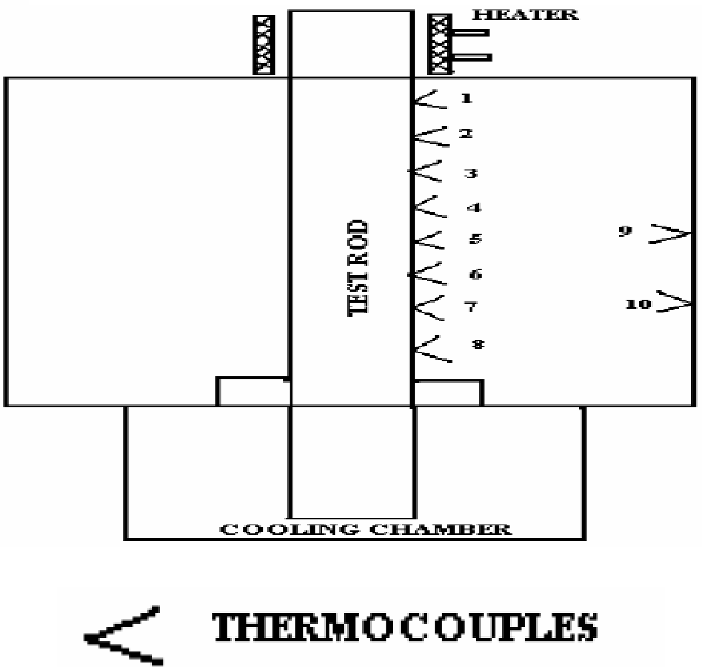

Figure (1.3) locations of the thermocouples

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Detailed information of the experimental set up is as follows:

1. Total length of the metal bar is (410 mm)
2. The diameter of the metal bar is (25 mm)
3. Test length of the bar is (200mm)
4. Eight thermocouples are mounted on the bar.
5. Two thermocouples are located in the insulation shell.
6. Heater coil (Bald type): Nichrome.
7. Water jacket diameter is (80 mm)
8. Temperature indicator, 13 channels: 200 Degree.
9. Dimmer-stat for heater coil: 2A / 230 V.
10. Voltmeter (0 to 300) volts.
11. Ammeter (0 to 2) Amps.

Procedure:

1. Start the electric supply.
2. Adjust the temperature in the temperature indicator by means of rotating the knob for compensation of temperature equal to room temperature. (Normally this is per adjusted)
3. Give input to the heater by slowly rotating the dimmer-stat and adjust it to voltage equal to (80 V), (120 V) etc.
4. Start the cooling water supply through the jacket and adjust it about (350 cc per minute).
5. Go on checking the temperature at some specified time interval, say 5 minute, and continue this till a satisfactory steady state condition is reached.
6. Note the temperature reading (1 to 10).
7. Note the mass flow rate of water in kg/minute and temperature rise in it.

Observation Table:

Sr.no	V (Volt)	I (Amp)	Q = V*I (Watt)	T_1 (ºC)	T_2 (ºC)	T_3 (ºC)	T_4 (ºC)	T_5 (ºC)	T_6 (ºC)	dT/dx	K (W/m.K)
1.											
2.											
3.											
4.											
5.											

Discussion:

1- Is there any difference between the theoretical and experimental results?

2- Does the thermal conductivity values of solid materials change by changing the temperatures?

3- Plot and discuss the heat supplied (Q) against thermal conductivity (k).

4- On what does the thermal conductivity depend?