Class :2nd stage
Subject: thermodynamics
Ass.lec. Zainab Abdul-kareem Farhan
E-mail: zainab.abdul-kareem@mustaqbal-college.edu.iq

Experiment No.(7): Measurement the efficiency of thermal insulators

Aim of the experiment

To compare the effectiveness of different materials as thermal insulators.

Theory:

Heat transmission modes

It is important to know how heat is transferred in holds. Heat is transferred by conduction, convection or radiation, or by a combination of all three. Heat always moves from warmer to colder areas; it seeks a balance. If the interior of an insulated fish hold is colder than the outside air, the hold draws heat from the outside. The greater the temperature difference, the faster the heat flows to the colder area.

Conduction. By this mode, heat energy is passed through a solid, liquid or gas from molecule to molecule in a material. In order for the heat to be conducted, there should be physical contact between particles and some temperature difference. Therefore, thermal conductivity is the measure of the speed of heat flow passed from particle to particle. The rate of heat flow through a specific material will be influenced by the difference of temperature and by its thermal conductivity.

Convection. By this mode, heat is transferred when a heated air/gas or liquid moves from one place to another, carrying its heat with it. The rate of heat flow will depend on the temperature of the moving gas or liquid and on its rate of flow.

Radiation. Heat energy is transmitted in the form of light, as infrared radiation or another form of electromagnetic waves. This energy emanates from a hot body and can travel freely only through completely transparent media. The atmosphere, glass and translucent materials pass a significant amount of radiant heat, which can be absorbed when it falls on a surface (e.g. the ship's deck surface on a sunny day absorbs radiant heat and becomes hot). It is a well-known fact that light coloured or shiny surfaces reflect more radiant heat than black or dark surfaces, therefore the former will be heated more slowly.

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Heat energy

One kilocalorie (1 kcal or 1000 calories) is the amount of heat (energy) needed to raise the temperature of one kg of water by one degree Celsius (°C). The SI standard unit for energy is Joule (J). One kcal is approximately 4.18 kJ (this varies slightly with temperature). Another unit is the Btu (British thermal unit). One Btu corresponds roughly to 1 kJ.

Thermal conductivity

In simple terms this is a measure of the capacity of a material to conduct heat through its mass. Different insulating materials and other types of material have specific thermal conductivity values that can be used to measure their insulating effectiveness. It can be defined as the amount of heat/energy (expressed in kcal, Btu or J) that can be conducted in unit time through unit area of unit thickness of material, when there is a unit temperature difference. Thermal conductivity can be expressed in kcal m^{-1} $°C^{-1}$, Btu ft^{-1} $°F^{-1}$ and in the SI system in watt (W) m^{-1} $°C^{-1}$. Thermal

Thermal resistivity

The thermal resistivity is the reciprocal of the k-value (1/k).

Thermal resistance (R-value)

The thermal resistance (R-value) is the reciprocal of l (1/l) and is used for calculating the thermal resistance of any material or composite material. The R-value can be defined in simple terms as the resistance that any specific material offers to the heat flow. A good insulation material will have a high R-value. For thicknesses other than 1 m, the R-value increases in direct proportion to the increase in thickness of the insulation material. This is *x*/l, where *x* stands for the thickness of the material in meters.

Permeance to water vapor (pv)

This is defined as the quantity of water vapour that passes through the unit of area of a material of unit thickness, when the difference of water pressure between both faces of the material is the unit. It can be expressed as g cm $mmHg^{-1}$ m^{-2} day^{-1} or in the SI system as g m MN^{-1} s^{-1} (grams metre per mega Newton per second).

Resistance to water vapors (rv)

This is the reciprocal of the permeance to water vapour and is defined as rv = 1/pv.

The main advantages of insulating the fish hold with adequate materials are:

- to prevent heat transmission entering from the surrounding warm air, the engine room and heat leaks (fish hold walls, hatches, pipes and stanchions);
- to optimize the useful capacity of the fish hold and fish-chilling operating costs;
- to help reduce energy requirements for refrigeration systems if these are used.

Procedure:

The method consists in placing an insulation product between two environments at different temperatures to generate a temperature difference (ΔT). Then, the amount of energy needed to maintain a constant temperature either side of the insulator is measured. Once the thermal flow has stabilised, the measurement can be made. The quantity of energy equals the thermal flow passing through the product. This is the thermal conductivity. The thermal resistance or R value defined is a ratio between the thickness (e) & the thermal conductivity (k) of an insulation product (R = e /(k)).

1. Fill the beaker with the water.
2. Place the beaker on the electrical heater.
3. Put a piece of cardboard between the two carbon steel disk as a lid. The lid should have a hole suitable for a thermometer.
4. Place two thermometer into the two disk.
5. Record the temperature in the upper disk and the lower one.

6. Record the temperature of the disks every 2 minutes for 20 minutes.
7. Repeat steps 1-6, each time packing the space between the two disks and with the chosen insulating material.
8. Plot a graph of temperature (y-axis) against time (x-axis).

Results

Time (mins)	No insulation (°C)	Material 1 (°C)	Material 2 (°C)
0	...	...	...
2	...	...	...
...	...	...	...

Analysis

Plot all of the curves on the same axes. This will make the materials easier to compare.

This graph shows:

- The curve which takes the longest time for the water temperature to drop (the shallowest) should be the material which is the best insulator.
- The temperature falls quickly at high temperatures and slowly at low temperatures.
- When the upper disk is at a high temperature, there is a big difference between the temperature of the disk and the temperature of the surrounding air. This means there is a high rate of transfer.
- When the lower disk is at a lower temperature, there is less difference between the temperature of the disk and the temperature of the surrounding air. This means there is a lower rate of transfer.