Practical: Thermal Physics & Statistical Mechanics

Aim: To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.

Web Link

https://www.youtube.com/watch?v=00_lbv2LDS8

Description

A heating coil is mounted axially along a horizontal glass tube. This glass tube is further surrounded by a glass jacket to minimise convection of heat. The coil is made of manganin or nichrome. Small length brass tubes are jointed to the two ends of the glass tube by sealing wax. The ends of the heating coil are brought out for external electrical connection by means of two screws. The free ends of the brass tubes are connected with hollow iron bases which have three extra openings i.e. two vertical and one horizontal. The horizontal openings are used for inlet and outlet of water. In one of the vertical openings on both ends of the glass tube a thermometer is inserted through rubber stopper. The other vertical opening on both sides are used to remove any air bubble which might have crept in while flowing water from the tank.

The water reservoir is a small metal vessel having three openings at the bottom. One of the openings is connected to the tap, the middle one to the sink, and the other to the inlet end of the Callender-and-Barnes calorimeter. The height of the reservoir is adjusted and water is allowed to flow through the tube at a constant pressure.

The outlet end of the calorimeter is connected to a small glass tube having a nozzel at the free end by means of a rubber tube. The rate of flow of water from the nozzle is controlled by means of the reservoir attached to the input end. The temperature of the inlet and outlet water are given by the respective thermometers. T_1 and T_2.

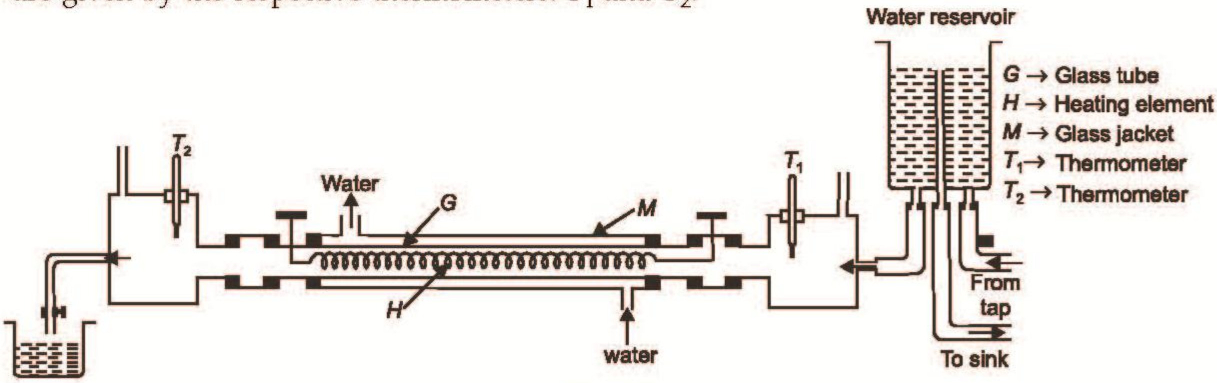

Fig. 8.1

Theory: When a steady electric current flows through the heating coil and a steady flow of water is maintained through the tube, the temperatures at all parts of the apparatus become steady. Under such steady-state conditions, the amount of electrical energy supplied during a known time interval is consumed in heating the amount of water which flows through the tube during the same interval and a small amount of heat is lost by radiation etc., to the surroundings during that interval.

Let the current flowing through the heating coil = I_1 amps
the potential difference between the ends of the coil = V_1 volts
the rate of flow of water through the tube = m_1 gm/sec
the temperature of the inlet water = θ_1°C
the temperature of the outlet water = θ_2°C
and the mean specific heat of water between the temperatures t_1 and t_2 = s

Therefore, we can write

$$\frac{V_1 I_1}{J} = m_1 s\,(\theta_2 - \theta_1) + h_1 \quad ...(1)$$

Where J is the mechanical equivalent of heat (also called Joule's equivalent) and h_1 is the amount of thermal leakage per second from the surface of the tube due to radiation etc.

If V_1, I_1, and m_1 are changed to V_2, I_2, and m_2 while keeping the temperature rise unaltered, then for the same surrounding temperature we can write

$$\frac{V_2 I_2}{J} = m_2 s\,(\theta_2 - \theta_1) + h_2 \quad ...(2)$$

Subtracting Eq. (1) from Eq.(2), we obtain

$$\frac{V_2 I_2 - V_1 I_1}{J} = s\,(m_2 - m_1)\,(\theta_2 - \theta_1) + (h_2 - h_1)$$

For all practical purposes, we may consider $h_1 = h_2$

$$\boxed{J = \frac{V_2 I_2 - V_1 I_1}{s\,(m_2 - m_1)\,(\theta_2 - \theta_1)}}$$

Thus, by measuring V_1, V_2, I_1, I_2, m_1, m_2, θ_1 and θ_2, and knowing s, J can be determined in Joules/Calorie.

8.2 OBJECT

To determine the Mechanical Equivalent of heat (J) by the Callender and Barnes method.

Apparatus used: A Callender and Barne's calorimeter, AC mains with a step down transformer, an AC Ammeter and an AC Voltmeter, switch, a rheostat, a stop watch, a measuring jar and 2 thermometers.

Formula used: $J = (E_2C_2 - E_1\,C_1)/(m_1 - m_2)\,(\theta_2 - \theta_1)\,s$ for water $S = 1.0$ Cal/gm °C.

Procedure:

1. Connect the apparatus as shown in the Fig. 8.2.
2. Adjust the tap and the water reservoir till the rate of flow of water through the tube is about (one) c.c per second.

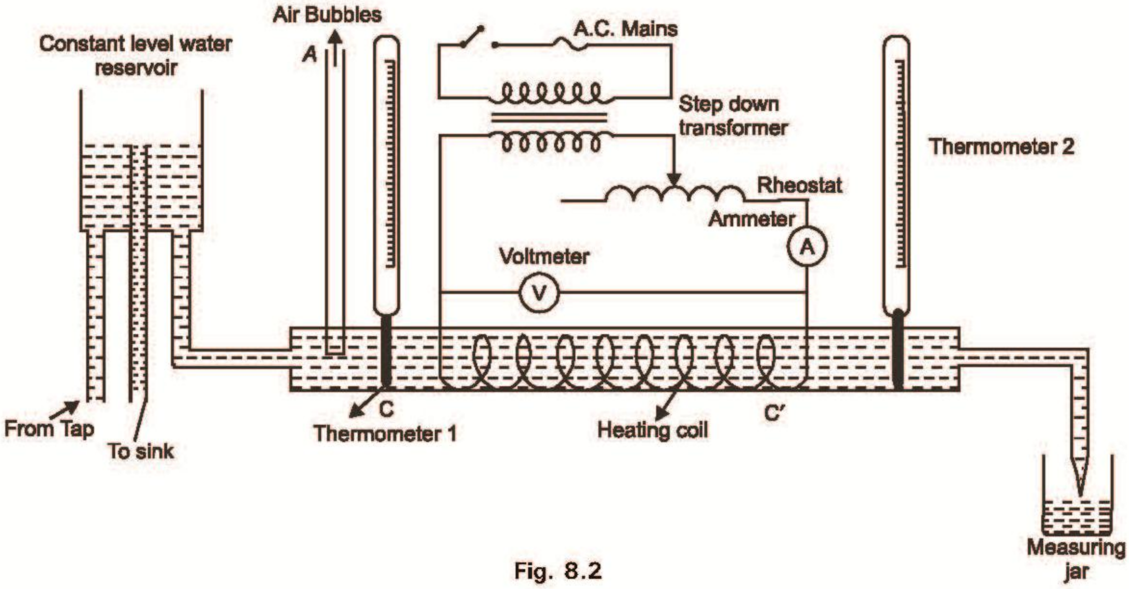

Fig. 8.2

3. Switch on the current and regulate the rheostat so that the current passing is about 2 amperes.
4. As soon as the temperature of the heated water going out becomes steady. Note the temperature of the two thermometers. Note the ammeter and the voltmeter readings.
5. Measure the rate of flow of water at this moment with the help of measuring Jar.
6. Change the rate of flow of water by varying the height of the reservoir and vary the electric current until the two thermometers again indicate their previous readings. Note the new readings of the ammeter and the voltmeter and measure the new rate of flow of water.

Observation:

Temperature of the cold water (inlet end) = θ_1 _ _ _ _ _ °C

Temperature of the hot water (exit end) = θ_2 = _ _ _ _ _ °C

	E (in volts)	*C (in amps)*	*Amount of flow of water per minute unit*			
			I	II	III	Mean
I Case						
II Case						

Result: The value of *J* is found to be = ergs/cal. (C.G.S. units)

= Joule/cal. (M.K. S. units)

Precautions:

1. The rate of flow of water in the tube should be uniform. To ensure this a number of measurements for the rate of out flow of water should be made.
2. Heating of the water should be uniform throughout tube.
3. Thermometers should be very sensitive.