EXPERIMENT 4

EMISSIVITY MEASUREMENT

INTRODUCTION:

All substances at all temperature emit thermal radiation. Thermal radiation is an electromagnetic wave and does not require any material medium for propagation. All bodies can emit radiation and have also the capacity to absorb all or part of the radiation coming from the surroundings towards it.

An idealised black surface is one which absorbs all the incident radiation with reflectivity and transmissivity equal to zero. The radiant energy emitted per unit time per unit area from the surface of the body is called the emissive power and is usually denoted by **e**. The emissivity of a surface is defined as the ratio of the emissive power of the surface to the emissive power of the hypothetical black surface at same temperature. It is denoted by ε.

Thus $\varepsilon = \frac{e}{e_b}$

For a black body absorptivity = 1, and by the knowledge of Kirchoff's Law emissivity of the blackbody also becomes unity.

Emissivity being a property of the surface depends on the nature of the surface and temperature.

It is obvious from the Stefan-Boltzmann Law that the prediction of the emissive power of a surface requires knowledge about the value of its emissivity and therefore much experimental research in radiation has been concentrated on measuring the value of emissivity as a function of surface temperature. The present experimental set up is designed and fabricated to measure the property of emissivity of a test plate surface at various temperatures.

Table-1 gives approximate values of emissivity for some common materials for ready references.

Table-1

		Temperature	Emissivity
Metal	Polished copper, Steel, Stainless Steel, Nickel.	20^{o}C	0.15 Increase with temperature
	Aluminium(oxidized)	90-540^{o}C	0.2 to 0.33
Non-metals	Brick, Wood, Marble, Water.	20-100^{o}C	0.8 to 1

APPARATUS:

The experimental set up consists of two circular Aluminium plates identical in size and provided with heating coils at the bottom. The plates are mounted on an asbestos cement sheet and are kept in an enclosure so as to provide undistributed natural convection surroundings.

The heat input to the heater is varied by separated dimmerstats and is measured by using an ammeter and a voltmeter/wattmeter with the help of double pole double-throw switches. The temperature of the plates is measured by thermocouples. Separated wires are connected to diametrically opposite points to get the average surface temperatures of the plates. Another thermocouples is kept in the enclosure to read the ambient temperature of enclosure.

Plate-1 is blackened by a thick layer of lamp black to form the idealised black surface whereas the plate-2 is the test plate whose emissivity to be determined.

The heater inputs to the two plates are dissipated from the plates by conduction, convection and radiation. The experimental set up is designed in such a way that under steady state condition the heat dissipation by conduction and convection is same for both the plates.

When their surface temperatures are the same and the difference in the heater input readings is because of the difference in radiation characteristics due to their different surface emissivity. The schematic arrangement of the set up is shown in fig . 2.

THEORY:

Under steady state conditions.

Let W_1 = Heater input to black plate, watts = $V_1 . I_1$

$W2$ = Heater input to test plate, watts = $V_2 . I_2$

A = Area of plates ($\frac{\pi}{4} d^2$)

T_S = Temperature of black plate, in Kelvin

T_D = Ambient temperature, in Kelvin

D = Diameter of Aluminium Discs

ε b = Emissivity of black plate

(To be assumed equal to unity)

ε = Emissivity of non-black test plate.

σ =Stefan-boltzmann constant.

By using Stefan-Boltzmann law:

$W_1 - W_2 = (\varepsilon_b - \varepsilon).A.\sigma.(T^4_S - T^4_D)/0.86$

PROCEDURE:

1. Give power supply to temperature indicator (230 v single phase) and adjust the reading in it equal to room temperature by rotating the compensation knob (Normally this is pre- adjusted)
2. Select the proper range of voltage on wattmeter/ voltmeter and Ammeter.
3. Gradually increase the power input to the heater of the black plate and adjust it to some value 30,50,75 watts and adjust the power input to the test plate to a slightly less value than the black plate 27,35,55 watts etc.
4. Check the temperatures of the two plates at small time intervals and adjust the power input of the test plate only by means of the dimmerstat such that the two plates are maintained at the same temperature.
5. This will require some trial and error and one has to wait sufficiently long (more than one hour or so) to obtain the steady state condition.
6. After attaining the steady state record the reading of

W_1, W_2, T_S and T_D

Where $W_1 = V_1 I_1$ and $W_2 = V_2 I_2$

7. The same procedure is repeated for various plate surface temperatures in increasing order.

PRECAUTIONS:

1. Use stabilized A.C. single phase supply (preferably).
2. Always keep the dimmerstats at zero position before start.
3. Use the proper voltage range on voltmeters.
4. Gradually increase the heater inputs.
5. See that the black plate is having a layer of lamp black uniformly.

NOTE:

There is possibility of getting absurd results if the supply voltage is fluctuating or if the input is not adjusted till the satisfactory steady state condition is reached.

SPECIFICATIONS:

1. Test plate = 160 mm. Ø
2. Black plate = 160 mm. Ø
3. Heater for (1) Nichrome strip wound on mica sheet and sandwitch between two mica sheets.

   Heater for (2) , same as above

4. Dimmerstat for (1) 0- 2A, 0 -260 V
5. Dimmerstat for (2) 0-2A, 0-260 V
6. Wattmeter for (1) 0- 2A, 0 – 37, 5/75-150 V or

Voltmeter 0- 100- 200 V, Ammeter -0- 2A

7. Enclosure size 58 cm x 30 cm 30 cm approx. With one side of Perspex.
8. Thermocouples - [Iron – constantan (3 NOS.)]
9. Temperature Indicator 0- 300^0c with compensation for room – temperature which is to be adjusted initially.
10. D.P.D.T. Switch.

RESULTS AND DISCUSSIONS:

BY using the expression

W_1-W_2 = (ε_b- ε).A.σ.($T^4{}_S$- $T^4{}_D$)/0.86

and assuming that ε_b= 1(for the black plate)

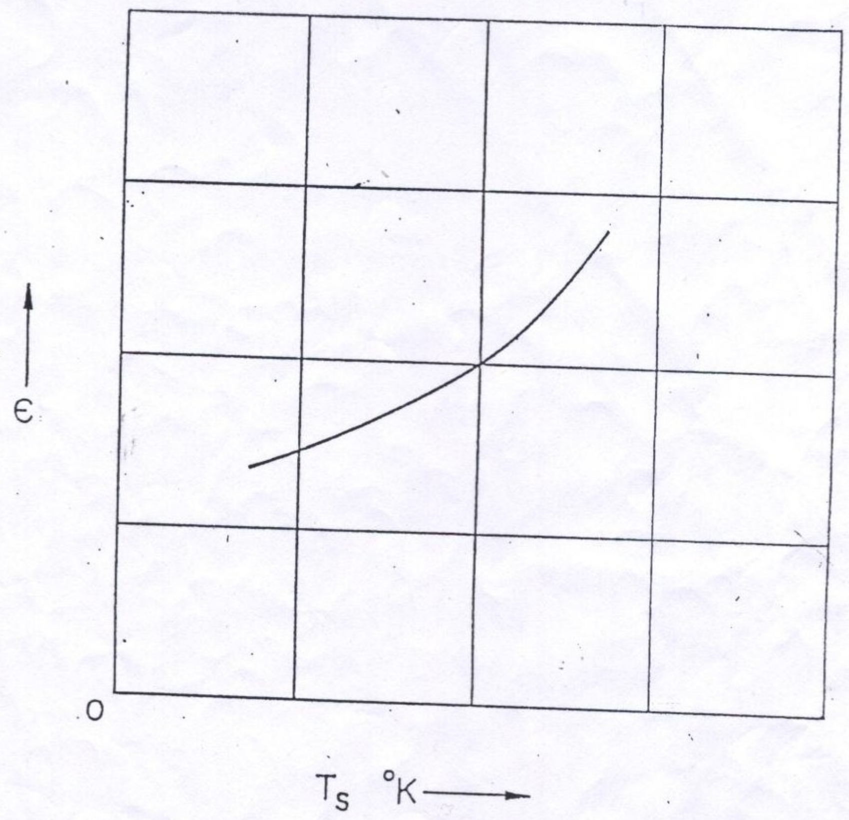
The emissivity of the test plate can be calculated at various surface temperature of the plate

With increase in temperature, the test surface becomes somewhat dull and therefore it's emissivity increases with increase of surface temperature.

This fact could be verified by performing the experiments at various values of T_S and can be plotted in a graph as shown in F i g . 3.

REFERENCES:

1. A test book Heat Transfer by Dr . s. p. sukhabmo.
2. Experimental methods for Engineering by J. P. Holman McGraw- Hill company.



Variation of ϵ against T_s

Fig. 3

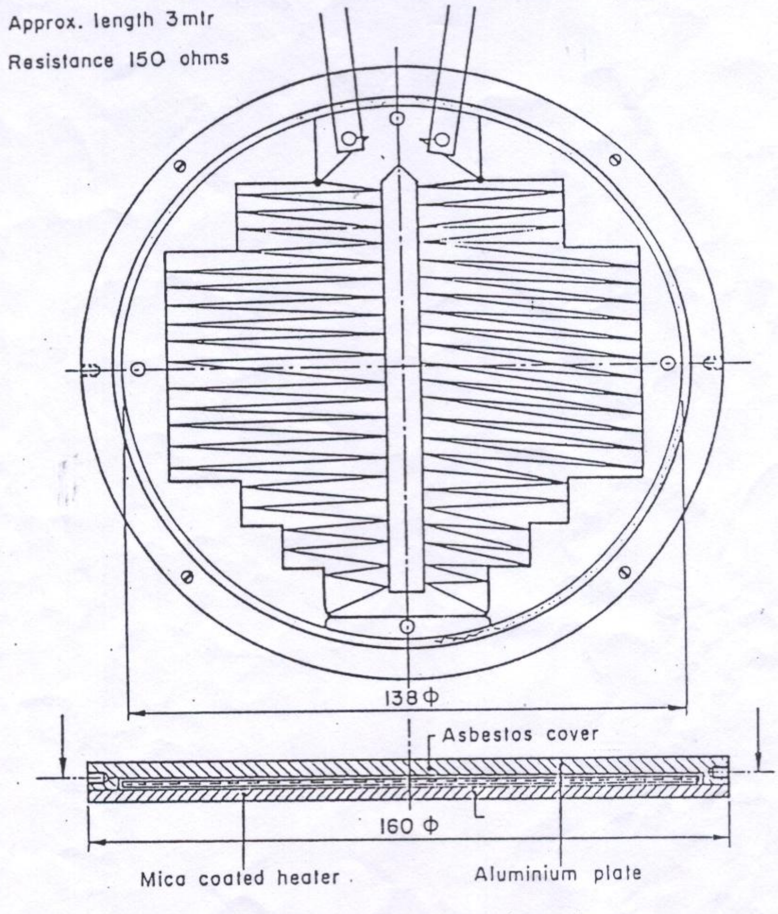
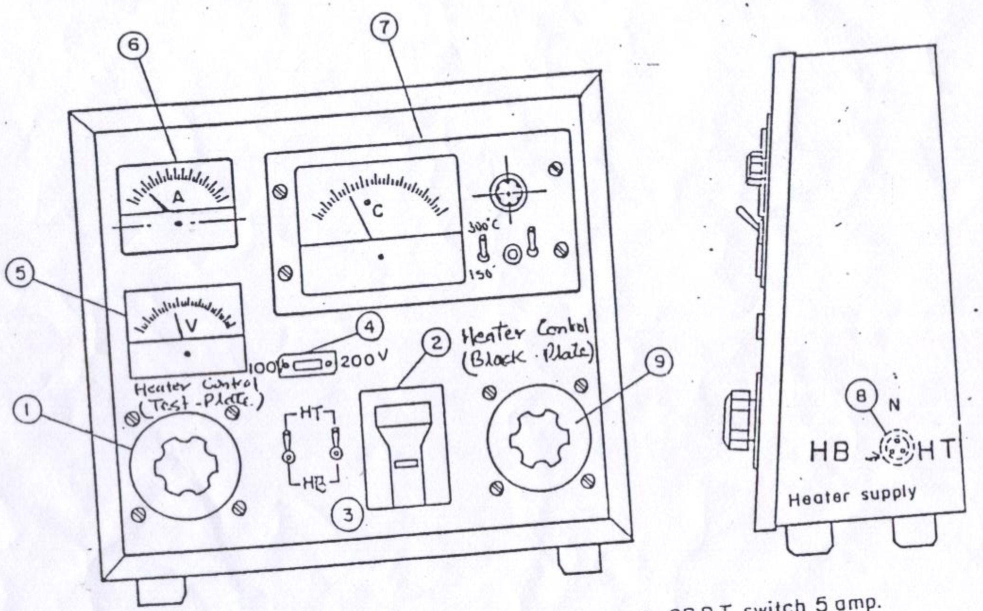
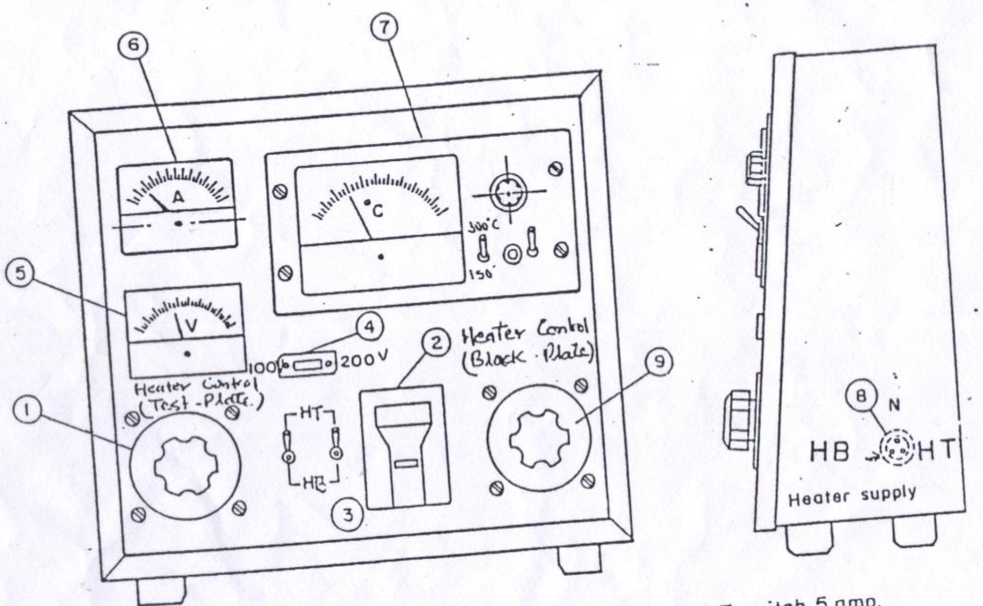


Fig.4 Electrical heater assembly diagram.



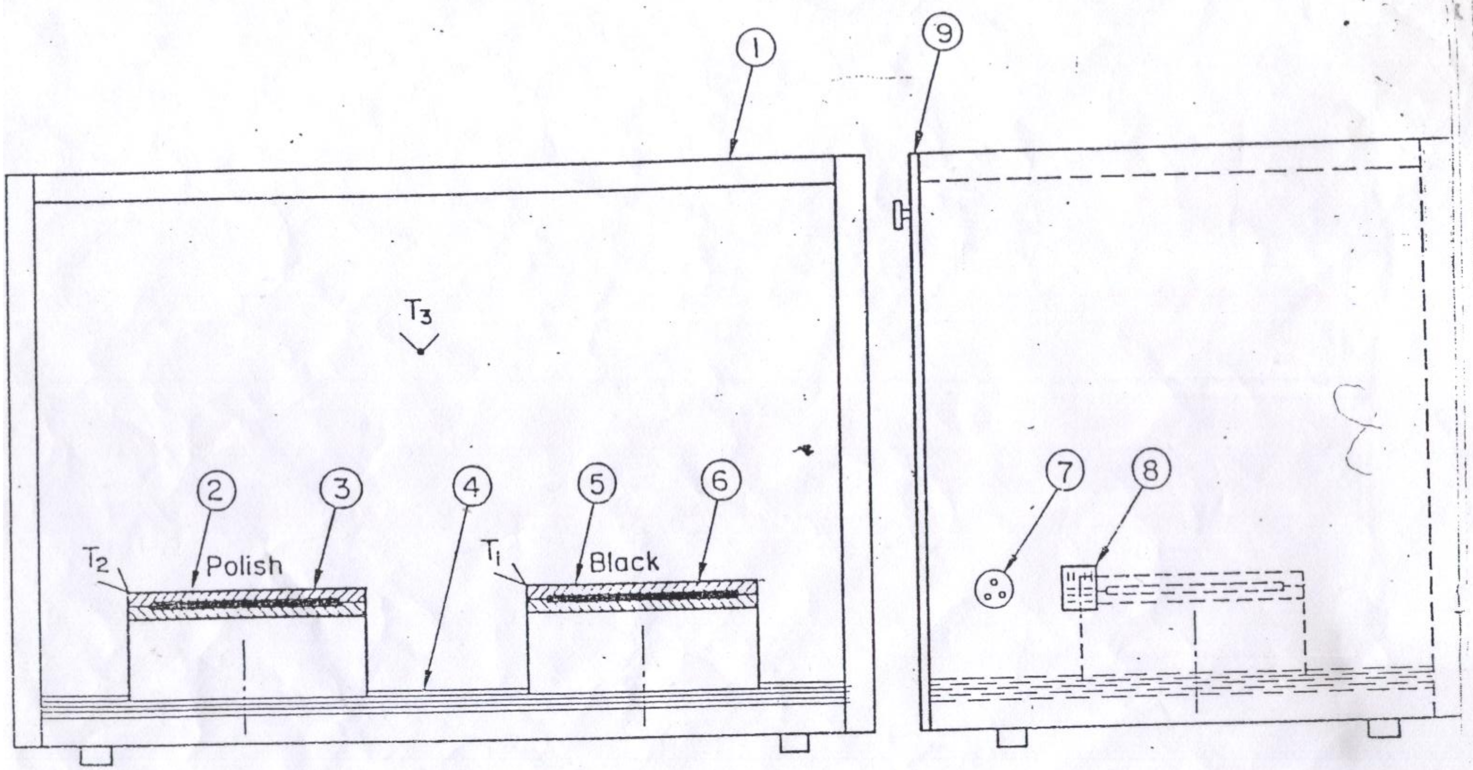
1 Dimmer state 2. Main switch 3 D.P.D.T switch 6 amp 4. SP.D.T switch 5 amp.
(Inner heater)
5 Voltmeter 6. Ammeter 0-2 Amp 7. Temprature Indicator 8. Power socket
9. Dimmer state (Black plate)

HB - Black plate heater power HT - Test plate heater power



1 Dimmer state (Inner heater) 2. Main switch 3 D.P.D.T switch 6 amp 4. SP.D.T switch 5 amp.
5 Voltmeter 6. Ammeter 0-2 Amp 7. Temprature Indicator 8. Power socket
9. Dimmer state (Black plate)

HB - Black plate heater power HT - Test plate heater power



1-Enclosure, 2-Test plate, 3-Test plate heater, 4-Asbestos sheet, 5-Black plate, 6-Black plate heater

7-Heater socket, 8-Thermocouple socket, 9-Acrylic cover, T_1 to T_3 Thermocouple positions

Schematic diagram for emissivity measurement apparatus