ETB-190

OPERATING INSTRUCTIONS

FOR

VERIFICATION OF STEFAN'S LAW OF RADIATION BY USING AN INCANDESCENT LAMP

OMEGA TYPE ETB-190

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OMEGA TYPE ETB-190 Experimental Training Board has been designed specifically for the verification of Stefan's law of radiation by using an incandescent lamp.

The board is absolutely self contained and requires no other apparatus. Practical experience on this board carries great educative value for Science and Engineering Students.

OBJECT

1. To verify the Stefan's law of radiation by using an incandescent lamp.

FEATURES

- The board consists of the following built-in parts :

1. 0-6V D.C. at 2A, I.C. regulated continuously variable and short circuit protected Power Supply with coarse and fine voltage control.
2. Digital panel meter 3½ digit 19.99 volt D.C.
3. Digital panel meter 3½ digit 1.999 Amp. D.C.
4. Incandescent lamp.
5. Mains ON/OFF switch and Fuse.

- The unit is operative on 230V ±10% at 50Hz A.C. Mains.
- Good Quality, reliable terminal / sockets are provided at appropriate places on panel for connections / observation of waveforms.

THEORY

The electrical current passes through a metal filament of an incandescent lamp and the emission results into continuous spectrum, a characteristic of filament temperature. Stefan-Boltzmann relation (1) relates such a radiant energy of radiator by following relation.

$$E = \sigma A \varepsilon T^4 \qquad \text{......} \quad (1)$$

A = Surface area of filament

ε = Emissivity

$\varepsilon = 1$ (for black body)

$\varepsilon < 1$ (for other bodies)

For a black body the radiant Energy per unit area per second is given by

$$E = \sigma T^4$$

However the power P (watt) in electrical filament circuit is the product of voltage drop V_t and current I_t and gives loss of electrical energy per second. Hence on presumption that whole of P is converted to E, we can write modified form of relation (1) in terms of P in the following order :

$$P = \sigma' T^4 \qquad \text{......} \quad (2)$$

Where σ' is a constant related to σ through the area of cross-section of the filament and radiation losses also note that the filament is not a black body.

In order to verify stefan's law in terms of eq. (2), we take logarithm of this equation and write

$$\log_{10} P = \log_{10} \sigma' + 4 \log_{10} T$$

or

$$\log_{10} P = 4 \log_{10} T + \log_{10} \sigma' \qquad \text{......} \quad (3)$$

Now this relation is subjected to test by plotting a linear relation by taking $\log_{10} P$ on y-axis and $\log_{10} T$ on x-axis. The slope of this relation should come out to be close to 4 and the intercept on y-axis should yield σ' of the order of σ.

Temperature **T** can be obtained by using Langmuir's Formula [eq^n 4] Here we calculate temperature for Tungsten filament. There are two eq^n i.e.

For particular temperature i.e.

$$\left(\frac{R_T}{R_0}\right) = \left(\frac{T}{T_0}\right)^{1.2} \qquad \text{......} \quad (4)$$

Where

R_T = Resistance of bulb filament at particular temperature (T)

R_0 = Resistance of bulb filament at 0°C temperature (T_0)

At room temperature (T_R)

$$\frac{R_R}{R_0} = \left(\frac{T_R}{T_0}\right)^{1.2} \qquad \ldots\ldots\ldots\ldots \quad (5)$$

Where R_R = Resistance of bulb filament at room temperature (T_R)

At Draper temperature (T_D)

$$\frac{R_D}{R_0} = \left(\frac{T_D}{T_0}\right)^{1.2} \qquad \ldots\ldots\ldots\ldots \quad (6)$$

R_D = Resistance of bulb filament at Draper point

T_D = 527°C = 800°K.

The Draper point is the temperature at which the filament of the bulb just glows with dull red colour.

The difficulty arises when we have to find the resistance of the filament at room temperature which requires that the filament SHOULD NOT GLOW and must remain cold (at the room temperature). Since this is a difficult work to realize in practice, we are modifying the method slightly.

In practice we find the resistance of the tungsten filament at the DRAPER POINT (≅ 527°C = 800°K) and utilize this resistance (R_D in the text) for all subsequent calculations.

Dividing eq^n (5) by eq^n (6)

$$\frac{R_R}{R_D} = \left(\frac{T_R}{T_D}\right)^{1.2} \qquad \ldots\ldots\ldots\ldots \quad (7)$$

$$\boxed{R_R = R_D\left(\frac{T_R}{800}\right)^{1.2}} \qquad \ldots\ldots\ldots\ldots \quad (8)$$

Dividing eq^n (4) by eq^n (5)

$$\frac{R_T}{R_R} = \left(\frac{T}{T_R}\right)^{1.2}$$

$$\frac{T}{T_R} = \left(\frac{R_T}{R_R}\right)^{1/1.2}$$

$$\boxed{T = T_R\left(\frac{R_T}{R_R}\right)^{0.833}} \qquad \ldots\ldots\ldots\ldots \quad (9)$$

OBJECT:-TO VERIFY THE STEFAN'S LAW OF RADIATION BY USING AN INCANDESCENT LAMP.

PROCEDURE

1. Connect the lamp 6V, 10W to D.C. Power Supply (0-6V, 2Amp.).
2. Connect main to A.C. main socket having 230V ± 10% at 50Hz.
3. Starting with a low current raise it till filament just shows a glow (keeping the bulb in a covered enclosure help judging the state).
4. Note down V_D and I_D at Draper point (when bulb shows just glow) and calculate R_D

$$R_D = \frac{V_D}{I_D}$$

Where

V_D = voltage at Draper point

I_D = current at draper point

R_D = Resistance of bulb filament at Draper point

5. We can find out room temperature by thermometer

   Room temperature $T_R = t°C = (273 + t°C)°K$

6. Now we calculate R_R by following eq.

$$R_R = R_D \left(\frac{T_R}{800}\right)^{1.2}$$

7. Increase the voltage in steps and note down the value of voltage V_T and current I_T and calculate R_T at different temperature

$$R_T = \frac{V_T}{I_T}$$

8. We can calculate T by following eq.

$$T = T_R \left(\frac{R_T}{R_R}\right)^{0.833}$$

9. Now at each setting of voltage V_T and current I_T to the lamp calculate different temperatures (T) of the filament and power supply ($P = V_T \times I_T$).
10. Take $\log_{10} P$ and $\log_{10} T$
11. Plot a graph by taking log T an X axis and $\log_{10} P$ on Y axis as a straight line.
12. Determine the slope of line and note that it is about 4. Also determine intercept on y-axis as $\log_{10}\sigma$ and take its antilogarithm to find the value of σ in M.K.S. units. You will see that the value of σ differ than the value of σ (5.76×10^{-8} watt $m^{-2} k^{-4}$). It is due to the surface area of filament, emissivity (ε) and radiation losses.

OBSERVATION

Bulb : 6V , 10W

Room Temp : --------°C, T_R = 273 + --- °C = ----- °K

Bulb Resistance at Draper point $R_D = \dfrac{V_D \text{ (Draper voltage)}}{I_D \text{ (Draper current)}}$

OBSERVATION TABLE

Sr. No.	V_T (volt)	I_T (Amp)	$R_T = \frac{V_T}{I_T}$	$P = V_T\ I_T$	$\log_{10} P$	$T = T_R\left(\frac{R_T}{R_R}\right)^{0.833}$	$\log_{10} T$
1.							
2.							
3.							
4.							
5.							
6.							

$$\text{Slope} = \frac{\Delta \log_{10} P}{\Delta \log_{10} T} = \text{————} = \text{------------------}$$

Intercept on Y- axis = log σ' = --------------

σ' = antilog ----------------- = ----------------

Note :

1. Value of σ' is different than the value of σ (5.76×10^{-8} watt m^{-2} K^{-4}). It is due to the surface area of filament, emissivity (ε) and radiation losses.
2. The importance of the resistance R_R of the bulb filament with the help of due DRAPER POINT has already been emphasized on page no. 3 of the THEORY.

PRECAUTIONS

1. Special care is needed during V_D measurement. The V leads must be soldered to the bulb base directly. So that the resistance of the contacts of bulb terminals & socket does not occur in R_D. Also the lead wires must be thick.
2. Resistance at particular temperature R_T to be found by each setting of voltage and current of D.C. Power Supply but the value of R_R and T_R should be same.

BOOK REFERENCES

1. A LABORATORY MANUAL OF PHYSICS : BY D.P.KHANDELWAL
2. APPLIED ELECTRONICS : BY PARKER
3. INTRODUCTION TO PHYSICS : BY KITAIGORODSKY.

ACCESSORIES : Nil

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