Department of

Mechanical Engineering

LAB MANUAL

HEAT TRANSFER LAB

B.Tech– VI Semester

KCT College OF ENGG AND TECH.

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INDEX

Experiment -1

AIM:-HEAT TRANSFER THROUGH COMPOSITE WALL DESCRIPTION:
The apparatus consists of a central heater sandwiched between two sheets. Three types of slabs are provided both sides of heater, which forms a composite structure. A small hand press frame is provided to ensure the perfect contact between the slabs. A dimmerstat is provided for varying the input to the heater and measurement of input is carried out by a voltmeter, ammeter.

Thermocouples are embedded between interfaces of the slabs, to read the temperature at the surface. The experiments can be conducted at various values of input and calculation can be made accordingly.

SPECIFICATIONS:

1. Slab assembly arranged symmetrically on both sides of heater.
2. Heater : Nochrome heater wound on mica former and insulation with control unit capacity 300 watt maximum.
3. Heater Control Unit : 0-230V. Ammeter 0-2Amps. Single phase dimmerstat (1No.).
4. Voltmeter 0-100-200V. Ammeter 0-2Amps.
5. Temperature Indicator (digital type): 0-200$_o$C. Service required – A. C. single phase 230 V. earthed electric supply.

EXPERIMENTS TO BE CARRIED OUT:

a) To determine total thermal resistance and thermal conductivity of composite wall.
b) To plot temperature gradient along composite wall structure.

PRECAUTIONS:

1. Keep dimmerstat to zero before start.
2. Increase the voltage slowly.
3. Keep all the assembly undisturbed.
4. Remove air gap between plates by moving hand press gently.
5. While removing the plates do not disturb the thermocouples.
6. Operate selector switch of temperature indicator gently.

PROCEDURE : Arrange the plates in proper fashion (symmetrical) on both sides of the heater plates.

1. See that plates are symmetrically arranged on both sides of the heater plates.
2. Operate the hand press properly to ensure perfect contact between the plates.
3. Close the box by cover sheet to achieve steady environmental conditions.
4. Start the supply of heater by varying the dimmerstat; adjust the input at the desired value.
5. Take readings of all the thermocouples at an interval of 10 minutes until fairly steady temperatures are achieved and rate of rise is negligible.
6. Note down the reading in observation table.

OBSERVATIONS :

COMPOSITE SLABS : 1. Wall thickness :
a. Cast iron =
b. Hylam =
c. Wood =
2. Slab diameter = 300mm.

	SET I	SET II	SET III
READINGS 1.Voltmeter V (Volts)			
2.Ammeter I (Amps)			
Heat supplied = 0.86 VI (in MKS units) = VI (SI units)			
Thermocouple Reading ^{0}C			
T1			
T2			
T3			
T4			
T5			
T6			
T7			
T8			

Mean Readings : $T_A = \frac{(T1 + T2)}{2}$

$T_B = \frac{(T3 + T4)}{2}$

$T_C = \frac{(T5 + T6)}{2}$

$T_D = \frac{(T7 + T8)}{2}$

CALCULATIONS :

Read the Heat supplied Q = V x I Watts (In S. I. Units) For calculating the thermal conductivity of composite walls, it is assumed that due to large diameter of the plates, heat flowing through central portion is unidirectional i. e. axial flow. Thus for calculation, central half diameter area where unidirectional flow is assumed is considered. Accordingly, thermocouples are fixed at close to center of the plates.

Now q = Heat flux = $\frac{Q}{A}$ [W / m_2]

Where A = $\pi / 4 \times d_2$ = half dia. of plates.

1. Total thermal resistance of composite slab

$$R\ total = \frac{(T_A - T_D)}{q}$$

2. Thermal conductivity of composite slab.

$$K_{composite} = \frac{q \times b}{(T_A - T_D)}$$

b = Total thickness of composite slab.

3. To plot thickness of slab material against temperature gradient.

Experiment- 2

AIM:-THERMAL CONDUCTIVITY OF INSULATING POWDER

DESCRIPTION:

The apparatus consists of two thin walled concentric copper spheres. The inner sphere houses the heating coil. The insulating powder (Asbestos powder – Lagging Material) is packed between the two shells. The powder supply to the heating oil is by using a dimmerstat and is measured by Voltmeter and Ammeter. Choromel Alumel thermocouples are use to measure the temperatures. Thermocouples (1) to (4) are embedded on inner sphere and (5) to (10) are as shown in the fig. Temperature readings in turn enable to find out the Thermal Conductivity of the insulating powder as an isotropic material and the value of Thermal Conductivity can be determined.

Consider the transfer of heat by conduction through the wall of a hollow sphere formed by the insulating powdered layer packed between two thin copper spheres

Let, ri = Radius of inner sphere in meters.
ro = Radius of outer sphere in meters.
Ti = Average Temperature of the inner sphere in $_{o}$C
To = Average Temperature of the outer sphere in $_{o}$C

$$\text{Where, } Ti = \frac{T1 + T2 + T3 + T4}{4}$$

$$\text{and } To = \frac{T5 + T6 + T7 + T8 + T9 + T10}{6}$$

Note that T1 to T10 denote the temperature of thermocouples (1) to (10).

Form the experimental values of q, Ti and To the unknown thermal conductivity K cal be determined as …

$$K = \frac{q\,(ro - ri)}{4\,\pi\, ri \times ro\,(Ti + To)}$$

SPECIFICATIONS :

1. Radius of the inner copper sphere, ri = 50mm
2. Radius of the outer copper sphere, ro = 100mm
3. Voltmeter (0 – 100 – 200 V).
4. Ammeter (0 – 2 Amps.)
5. Temperature Indicator 0 – 300 $_{0}$C calibrated for chromel alumel.
6. Dimmerstat 0 – 2A, 0 – 230 V.
7. Heater coil - Strip Heating Element sandwiched between mica sheets – 200 watts.
8. Chromel Alumel Thermocouples – No. (1) to (4) embedded on inner sphere to measure Ti.
9. Chromel Alumel Thermocouples – No. (5) to (10) embedded on outer sphere to measure To.
10. Insulating Powder – Asbestos magnesia commercially available powder and packed between the two spheres.

EXPERIMENTAL PROCEDURE :

1. Start main switch of control panel.
2. Increase slowly the input to heater by the dimmerstat starting from zero volt

position.

3. Adjust input equal to 40 Watts Max. by Voltmeter and Ammeter. Wattage W = VI
4. See that this input remains constant throughout the experiment.
5. Wait till fairly steady state condition is reached. This can be checked by reading temperatures of thermocouples (1) to (10) and note changes in their readings with time.
6. Note down the readings in the observations table as given below :

OBSERVATION TABLE :

1. Voltmeter reading (V) = Volts.
2. Ammeter reading (I) = Amps.
3. Heater input (VI) = Watts.

INNER SPHERE :

Thermocouple No.	1	2	3	4	
	T1	T2	T3	T4	Mean Temp. Ti T1 + T2 + T3 + T4 Ti = ---------------------------- 4
Temp. $_0$C					

OUTER SPHERE :

Thermocouple No.	5	6	7	8	9	10	
	T5	T6	T7	T8	T9	T10	Mean Temp. Ti T5 T6 T7 T8 T9 T10 T5 + T6 +…..+ T10 Ti = --------------------------- 4
Temp. $_0$C							

CALCULATION :

W = V x I Watts.
Ti = Inner sphere mean temp. $_0$C
To = Outer sphere mean temp. $_0$C
ri = Radius of inner copper sphere = 50 mm.
ro = Radius of outer copper sphere = 100 mm.
Using Equation :
q = 0.86 W Kcal/hr (In MKS units)

$$K = \frac{0.86W\,(r_o - r_i)}{4\pi\, r_i \times r_o\,(T_i - T_o)}$$

$q = V \times I$ w / m – k (In SI units)

$$K = \frac{q\,(r_o - r_i)}{4\pi\, r_i \times r_o\,(T_i - T_o)}$$

PRECAUTIONS :

1. Keep dimmerstat to zero volt position before and after the experiment. Check this before switching ON the supply.
2. Handle the changeover switch of temperature indicator gently.

EXERCISE :

1. Note down the values of Thermal Conductivity of various insulating material from the literature.
2. Compare the value of K for insulating powder obtained experimentally with that reported in the literature.

Experiment-3

AIM:-THERMAL CONDUCTIVITY OF METAL ROD

INTRODUCTION :

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.

Table 1 lists the values of thermal conductivity for some common metal :

METAL THERMAL CONDUCTIVITY
kcal / hr – m - ^{0}c
STATE
SOLID’S
Pure Copper
Brass
Steel (0.5%C)
S. S.
330
95
46
14
20 degree
- - do - -
- - do - -
- - 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 transfer is not as large as the electrons transport and it is for this reason that good electrical conductors are almost always good heat conductor
viz. Copper, Aluminium 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. Fig. 1 shows the trend of vibration of thermal conductivity with temperature for some metals.

APPARATUS:

The experimental set up consists of the 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 { Fig. 2 (1) to (4) } while the radial temperature distribution is measured by separate thermocouples at two different sections in the insulating shell.

The heater is provided with a dimmerstat for controlling the heat input. Water under constant heat condition is circulated through the jacket and its flow rate and temperature rise are noted.

SPECIFICATION:

1. Length of the metal bar (total) : 410 mm
2. Size of the metal bar (diameter) : 25 mm
3. Test length of the bar : 200mm
4. No. of thermocouple mounted on the Bar (Positions are shown fig. 2) : 9
5. No. of thermocouples in the insulation shell (shown in fig. 2) : 2
6. Heater coil (Bald type) : Nichrome.
7. Water jacket diameter : 80mm
8. Temperature indicator, 13 channel : 200 Degree.
9. Dimmerstat for heater coil : 2A / 230 V.
10. Voltmeter 0 to 300 volts.
11. Ammeter 0 to 2 Amps.
12. Measuring flask for water flow rate.
13. Stop clock.

THEORY :

The heater will heat the bar at its end and heat will be conducted through the bar to other end.

After attaining the steady state Heat flowing out of bar.

Heat flowing out of bar = Heat gained by water

$Q_w = m_w \times Cp_w \times (T_{out} - T_{in}) = m_w Cp_w(\_T_w) = m_w Cp_w(T_{out} - T_{in})$

Where, m_w : Mass flow rate of the cooling water In Kg / hr

Cp : Specific Heat of water (Given 1)

T : $(T_{out} - T_{in})$ for water

Thermal Conductivity of Bar

1. Heat Conducted through the Bar (Q)

$$Q = Qw + \frac{2\pi KL (To - T I)}{\text{Log } e \{ro / ri\}}$$

Where, Qw : Heat conducted through water

K : Thermal conductivity of Asbestos powder is 0.3 Kcal / hr – mdegree

ro & ri : Radial distance of thermocouple in insulating shell.

2. Thermal conductivity of Bar (K)

Q = K {dt / dx} x A

Where, dt : Change in temperature. (T1 – T9)

dx : Length across temperature. (0.2)
A : Area of the bar (π / 4 x d2).
π / 4 x (0.025)2 = 4.9 x 10_{-4} m_2

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 dimmerstat 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 350cc 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 13.
7. Note the mass flow rate of water in Kg/minute and temperature rise in it.

Observation Table :

Sr. No. Mass Flow Rate in Kg/Min Temperature in Degree Centigrade
T1, T2, T3, T4,………………………T13
1.
2.
3.
4.
5.

Observations:

Mass flow rate of water (m) : Kg/min
Water inlet temperature (T12) : Degree Centigrade
Water outlet temperature (T13) : Degree Centigrade
Rod Temperature (T1 to T9) : Degree Centigrade
Radial distance of Thermocouples (ro) : 40mm
in insulating shell. (ri) : 25mm
Specific heat of water (Cp) : 1 Kcal/Kg$_0$K = 4.186 KJ/KgK
Thermal conductivity of Asbestos powder (K) : 0.3 Kcal/hr-m-$_0$C
0.3 x 4.18 KJ/KgK
Length of bar (L) : 200mm
Demeter of bar (d) : 50mm
Area of the bar (A) : 4.9 x 10 $_{-4}$ m_2

Plot the temperature distribution along the length of the bar using observed values.

Calculations:

1. Heat flowing out of bar. Qbar = Qw

Qw = m x Cp x (_Tw) (Kcal/hr)
Where, m : Mass flow rate of the cooling water In Kg/hr
Cp :Specific Heat of water (Given 1)

_Tw : (Tout – Tin) for water
2. Heat conducted through the Bar (Q)
2n KL (T10 – T11)
Q = Qw + ----------------------------- (Kcal / Hr)
Log e {ro / ri}
Where, Qw : Heat conducted through water
K : Thermal conductivity of Asbestos powder is
0.3 Kcal/ hr-m-degree.
ro & ri : Radial distance of thermocouple in insulating shell.
3. Thermal conductivity of Bar (K)
Q = K {dt/dx} x A (Kcal/Hr-m-^{0}C)
Where, dt : Change in temperature. (T1 – T9)
dx : Length Across temperature. (0.2)
A : Area of the bar (n/4 x d^2).
n/4 x $(0.025)^2$ = 4.9 x 10^{-4} m^2

References :

1. Engineering Heat Transfer ---------------------- Gputa & Prakash
2. Experimental method for Engineers ------------ Tata Mc Grew Hill Company

Experiment-4

AIM:-HEAT TRANSFER FROM A PIN-FIN APPARATUS

INTRODUCTION:

Extended surfaces of fins are used to increase the heat transfer rate from a surface to a fluid wherever it is not possible to increase the value of the surface heat transfer coefficient or the temperature difference between the surface and the fluid. The use of this is variety of shapes (refer fig. 1). Circumferential fins around the cylinder of a motor cycle engine and fins attached to condenser tubes of a refrigerator are a few familiar examples.

It is obvious that a fin surface sticks out from the primary heat transfer surface. The temperature difference with surrounding fluid will steadily diminish as one moves out along the fin. The design of the fins therefore required a knowledge of the temperature distribution in the fin. The main objective of this experimental set up is to study temperature distribution in a simple pin fin.

APPARATUS:

A brass fin of circular cross section in fitted across a long rectangular duct. The other end of the duct is connected to the suction side of a blower and the air flows past the fin perpendicular to the axis. One end of the fin projects outside the duct and is heated by a heater. Temperature at five points along the length of the fin. The air flow rate is measured by an orifice meter fitted on the delivery side of the blower. Schematic diagram of the set up is shown in fig. 2, while the details of the pin fin are as per fig. 3.

SPECIFICATIONS:

1. Duct size = 150mm x 100mm.
2. Diameter of the fin = 12.7mm.
3. Diameter of the orifice = 18mm.
4. Diameter of the delivery pipe = 42mm.
5. Coefficient of discharge (or orifice meter) Cd = 0.64.
6. Centrifugal Blower 1 HP single-phase motor.
7. No. of thermocouples on fin = 5.

(1) to (5) as shown in fig. 3 and indicated on temperature indicator.

8. Thermocouple (6) reads ambient temperature inside of the duct.
9. Thermal conductivity of fin material (Brass) = 110w/m $_0$C.
10. Temperature indicator = 0 – 300 $_0$C with compensation of ambient temperature up to 50$_0$C.
11. Dimmerstat for heat input control 230V, 2 Amps.
12. Heater suitable for mounting at the fin end outside the duct = 400 watts (Band type).
13. Voltmeter = 0 – 100/200 V.
14. Ammeter = 0 – 2 Amps.

THEORY:

Consider the fin connected at its bast to a heated wall and transferring heat to the surroundings. (Refer fig. 4)

Let, A = Cross section area of the fin.

C = Circumference of the fin.
L = Length of the fin.
T_1 = Temp. of the fin at the beginning.
T_f = Duct fluid temperatures.
∅ = (T – T_f) = Rise in temperature.
The heat is conducted along the rod and also lost to the surrounding fluid by convection.
Let, h = Heat Transfer coefficient.
K = Thermal conductivity of the fin material.
Applying the first law of thermodynamics to a controlled volume along the length of the fin at X, the resulting equation of heat balance appears as:
d_2 ∅ h. c
--------- - --------- ∅ = 0 ……………..(1)
d x_2 K. A
and the general solution of equation (1) is
∅ = C_1. e_{mx} + C_2. e_{-mx} …………………………..(2)
h. c
Where, m = -----------
K. A
With the boundary conditions of ∅ = $∅_1$ at x = 0
Where, $∅_1$ = T_1 – T_F and assuming the fin tip to be insulated.
d∅
------ = 0 at x = L results in obtaining eq_n (2) in the form:
dx
∅ T – T_F Cosh m (L – x)
----- x ----------- = --------------------- ……………(3)
$∅_1$ T_1 – T_F Cosh mL
This is the equation for the temperature distribution along the length of the fin. It is seen from the equation that for a fin of given geometry with uniform cross section, the temperature at any point can be calculated by knowing the values of T_1, T_F and X. Temperature T_1 and T_F will be known for a given situation and the value of h depends on whether the heat is lost to the surrounding by free convection or forced convection and can be obtained by using the correlation as given below:
1. For free convection condition,
Nu = 1.1 $(Gr. Pr)_{1/6}$ . . 10_{-1} < Gr. Pr. < 10_4 }
Nu = 0.53 $(Gr. Pr)_{1/4}$ . . 10_4 < Gr. Pr. < 10_9 } 4
Nu = 0.13 $(Gr. Pr)_{1/4}$ . . 10_9 < Gr. Pr. < 10_{12}}
2. For forced convection,
Nu = 0.615 $(R_e)_{0.466}$ . . 40 < R_e < 4000
Nu = 0.174 $(R_e)_{0.618}$ . . 4000 < R_e < 40000
h. D
Where, Nu = ---------
A_{Air}
_ VD
R_e = --------- = Reynold's Number.
ν
g. β. D_3 _T

G_r = ----------------- = Grashoff Number.

ν2

Cp . ⌠

P_r = ------------- = Prandt 1 Number

K_{Air}

All the properties are to be evaluated at the mean film temperature. The mean film temperature is to arithmetic average of the fin temperature and air temperature.

Nomenclature:

_ = Density of air, Kg / m$_3$

D = Diameter of pin-fin, m

⌠ = Dynamic viscosity, N.sec/m$_2$

C_p = Specific heat, KJ/Kg.k

ν = Kinematic viscosity, m2/Sec

K = Thermal conductivity of air, W/m $_0$C

g = Acceleration due to gravity, 9.81m/sec$_2$

Tm = Average fin temperature

(T1 + T2 + T4 + T5)

= -----------------------------

5

_T = T_m – T_F

T_m + T_F

T_{mF} = --------------

2

β = Coefficient of thermal expansion

1

= ----------------

T_{mF} + 273

ν = Velocity of air in the duct.

The velocity of air can be obtained by calculating the volume flow rate through the duct.

π _W m$_3$

Q = Cd ------- x d_2 x 2g (H. ---------) ---------

4 _$_a$ Sec

Where, H = Difference of levels in manometer, M

_W = Density of water 1000 Kg/m$_3$

_$_a$ = Density of air at T_f

Cd = 0.64

d = Diameter of the orifice = 18mm.

Q

Velocity of air at T_f = --------------------- = m/sec

Duct c/s Area

Use this velocity in the calculation of $R_{e.}$

The rate of heat transfer from the fin can be calculated as,

Q = h. c. k. A x (T1 – Tf) tanh mL ………………(6)

And the effectiveness of the fin can also be calculated as,

$$\_ = \frac{\tanh mL}{mL} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

EXPERIMENTAL PROCEDURE:

To study the temperature distribution along the length of a pin fin natural and forced convection, the procedure is as under

(I) NATURAL CONVECTION:

1. Start heating the fin by switching ON the heater element and adjust the voltage on dimmerstat to say 80 volt (Increase slowly from 0 to onwards)
2. Note down the thermocouple reading 1 to 5.
3. When steady state is reached, record the final readings 1 to 5 and also record the ambient temperature reading 6.
4. Repeat the same experiment with voltage 100 volts and 120 volts.

PRECAUTIONS:

1. See that throughout the experiment, the blower is OFF.

(II) FORCED CONVECTION:

1. Start heating the fin by switching ON the heater and adjust dimmerstat voltage equal to 100 volts.
2. Start the blower and adjust the difference of level in the manometer with the help of gate valve.
3. Note down the thermocouple readings (1) to (5) at a time interval of 5 minutes.
4. When the steady state is reached, record the final reading (1) to (5) and also record the ambient temperature reading (6).
5. Repeat the same experiment with different manometer readings.

PRECAUTIONS:

1. See that the dimmerstat is at zero position before switching ON the heater.
2. Operate the changeover switch of temperature indicator, gently.
3. Be sure that the steady state is reached before taking the final reading.

OBSERVATION TABLE:

I) NATURAL CONVECTION:

Fin Temperatures Sr. Ambient Temp.
No.
V
Volts
I
Amps T_1 ($_0$C) T_2 ($_0$C) T_2 ($_0$C) T_4 ($_0$C) T_5 ($_0$C) $T_6 = T_f$ ($_0$C)

II) FORCED CONVECTION:

Sr. Fin Temperatures Ambient Temp
No
V
Volts
I
Amps
Manometer
reading

(Cm.)
T_1
($_0$C)
T_2
($_0$C)
T_2
($_0$C)
T_4
($_0$C)
T_5
($_0$C)
$T_6 = T_f$ ($_0$C)

RESULTS FROM EXPERIMENTS:

I) NATURAL CONVECTION:

1. Plot the temperature distribution along the length of the fin from readings (refer fig. 5)
2. Calculate Gr and Pr and obtain Nu form equation (4) and finally get the value of 'h' in natural convection.
3. Calculate the value of 'm' and obtain the temperature at various locations along the length of the fin by using equation (3) and plot them (refer fig. 5)
4. Calculate the value of heat transfer rate from the fin effectiveness by using equation (6) and equation (7).
5. Repeat the same procedure for all other sets.

II) FORCED CONVECTION:

1. plot the temperature distribution along the length of the fin from observed readings (refer fig. 6)
2. Calculate the value of 'm' and obtain the temperature at various locations along the length of fin by using equation (3) and plot them. (Refer fig. 6)
3. Calculate Re and Pr and obtain Nu from equation (5).
4. Calculate the value of heat transfer rate from the fin and fin effectiveness by using equation (6) and equation (7).
5. Repeat the same procedure for all other sets of observations.

CONCLUSION:

(I) Comment on the observed temperature distribution and calculation by using the theory. It is expected that observed temperature should be slightly less than their corresponding calculated values by radiation.

(II) The insulated tip boundary condition can be visualized on the plot of calculated temperature.

APPENDIX – I

In MKS Units In SI Units
K_{Brass} = 95 Kcal/hr. m$_0$C 110 w/m-$_0$C
K_{Steel} = 40 Kcal/hr. m$_0$C 46.5 w/m-$_0$C
K_{Brass} = 200 Kcal/hr. m$_0$C 232.6 w/m-$_0$C

Experiment-5

AIM:-EMISSIVITY MEASUREMENT APPARATUS

INTRODUCTION:

All substances at all temperature 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 a pare of the radiation coming from the surrounding towards it.

An idealized black surface is one, which absorbs all the incident radiation with reflectivity and transmissivity equal to zero. The radiant energy per unit time per unit area from the surface of the body is called, as the emissivity of the surface is the ratio of the emissive power of the surface to the emissive power of a black surface at the same temperature. It is noted by E.

e
Thus E = + ----------
E_b

For black body absorptivity = 1 and by the knowledge of Kirchoff's Law emissivity of the black body 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's Law that the prediction of emissive power of a surface requires knowledge about the values of its emissivity and therefore much experimental research in radiation has been concentrated on measuring the values of emissivity as function of surface temperature. The present experimental set up is designed and fabricated to measure the property of emissivity of the lest test plate surface
at various temperatures.

Table 1 gives approximate values of emissivity for some common materials for reference.

TABLE – 1

MATERIAL TEMPERATURE EMISSIVITY
Metals Polished copper, Steel,
Stainless Steel, Nickel
Alluminium (Oxidised)
20$_0$C
90 - 540$_0$C
0.15 increases with
temperatures
0.20 to 0.33
Non- Metals Brick, Wood, Marble,
water
20 – 100$_0$C 0.80 to 1

APPARATUS:

1) Two aluminium plates identical in all dimension, one coated with lamp black
2) Heater
3) Heating coils.
4) Voltmeter

5) Dimmerstat
6) Thermocouples
7) Temperature indicator.

THEORYUnder
steady state conditions:
Let - W1 = Heater input black plate.
Watts = V1 I1
W2 = Heater input to test plate.
Watts = V2 I2
2nd$_2$
A = Area of plates = ----------- m$_2$
4
d = Diam. Of plate = 160mm
T_b = Temperature of black plate $_0$K
T_a = Ambient temperature $_0$K
E_b = Emissivity of black plate.
(To be assumed equal to unity.)
E = Emissivity of non-black test plate
σ = Stefan Boltzmann constant.
MKS = 4.876 x 10$_{-8}$ Kcal/ hr-m$_2$ – $_0$K$_4$ (In MKS units)
SI = 5.67 x 10$_{-8}$ w/m$_2$ K$_4$ (In SI units)
By using the Stefan Boltzmann Law:
(W_1 – W_2) = (E_b – E) σ A (T_s
$_4$ – T_d
$_4$)/0.86
In SI Units
(W_1 – W_2) = (E_b – E) σ A (T_s
$_4$ – T_d
$_4$)

PROCEDURE:

1. Gradually increase the input to the heater to black plate and adjust it to some value viz. 30, 50, 75 watts and adjust the heater input to test plate slightly less than the black plate 27, 35, 55 watts etc.
2. Check the temperature of the two plates with small time intervals and adjust the input of test plate only, by the dimmerstat so that the two plates will be maintained at the same temperature.
3. This will required some trial and error and one has to wait sufficiently (more than one hour or so) to obtain the steady state condition.
4. After attaining the steady state condition record the temperatures. Voltmeter and Ammeter readings for both the plates.
5. The same procedure is repeated for various surface temperature in increasing order.

PRECAUTION:

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 VOLTMETER.

4. Gradually increase the heater inputs.
5. See that the black plate is having a layer of lamp black uniformly.

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

SPECIFICATIONS:

1. Test Plate = Ø 165mm
2. Black Plate = Ø 165mm Material Alluminium.
3. Heater for (1) Nichrome strip wound on mica sheet and sandwiched between two mica sheets.
4. Heater for (2) as above capacity of heater = 200 watts each approx.
5. Dimmerstat for (1) 0 – 2A, 0 – 260V
6. Dimmerstat for (2) 0 – 2A, 0 – 260V
7. Voltmeter 0 – 100 – 200V, Ammeter 0 – 2 Amp.
8. Enclosure size 580mm x 300mm x 300mm approximately with one side of perpex sheet.
9. Thermocouples – Choromel Alumel – (3Nos).
10. Temperature indicator 0 – 300$_0$C.
11. D. P. D. T. Switch.

OBSERVATION TABLE:

BLACK PLATE TEST Sr. PLATE ENCLOSURE TEMP.
No. V1 I1 T_b V_2 I_2 T_s T_a $_0$C

For SI Unit:

$(W_b – W_s) = (E_b – E_s)\ \sigma\ A\ (T_s^4 – T_b^4)$

CALCULATIONS:

$qb = \sigma A\ E_b\ (T_s^4 – T_D^4)$

$qb = \sigma E\ A\ (T_s^4 – T_D^4)$

Where,

qb = heat input to disc coated with lamp black watt.

In SI Unit qb = $V_1 I_1$ Watts = W_b x 0.86 $V_1 I_1 = W_b$

q_s = heat input to Specimen disc. (Kcal / hr) = W_s = 0.86

In SI unit $q_s = V_2 I_2$ Watts

= Stefan Boltzmann Constant = 4.876 x 10^{-8} Kcal/hr $m^2\ {}^0K^4$

In SI unit $\sigma = 5.67 \times 10^{-8}$ W/M^2 K^4

E = Emissivity of specimen to be determined (absorption)

In SI unit $(W_b – W_s) = (E_b – E)\ \sigma.A\ (T_s^4 – T_a^4)$

This fact could be verified by performing the experiments at various values of T_s and E can be plotted in a graph in a graph as shown in fig. 4.

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Experiment-6

AIM:-STEFAN BOLTZMANN APPARATUS

INTRODUCTION:

The most commonly used law of thermal radiation is the Stefan Boltzmann Law which States that thermal radiation heat flux or emissive power of a black surface is proportional
To the fourth power of absolute temperature of the surface and is given by:

Q
------- = eb = σ T_4 (kcal / hr.m_2. k_4) and SI unit (W/m_2k_4 where 1W = 1J/S)
A

The constant of proportionality σ is called the Stefan Boltzmann Constant and has the value of :
4.876 x 10_{-8} (kcal / hr.m_2. k_4) and SI unit K_4 (5.67 x 10 $_{-8}$ W/m_2k_4)
The Stefan Boltzmann law can be derive by integrating the planks law over the entire spectrum of wave length, through historically it is worth nothing that the Stefan Boltzmann law was independently developed before planks law.
The object of this experimental set up is to measure the value of this constant fairly close,
by an easy arrangement.

APPARATUS:

The apparatus, as illustrated in (fig 1) is centered on a flanged copper hemisphere B fixed
on a flat non-conducting plate A. The outer surface of B is enclosed in a metal water jacket used to heat B to some suitable constant temperature. The hemispherical of B is chosen solely on the grounds that is simplifies the task of water between B & C
Four chromel alumel thermocouple are attached to various points on surface of B to measure its mean temperature.
The disk D, which is mounted in an insulating bakelite sleeve S is fitted in hole drilled in the centered of based plate A. the of S is conveniently supported for underside of A. A chromel alumel thermocouple is used to measured the temperature of D (T5).
Thermocouple is mounted on the disk to study the rise of its temperature.
When the disk is inserted at the temperature T5 (T5 $\geq$T ie the temperature of the enclosure), the response of the temperature change of this with time is used to calculate the Stefan Boltzmann constant.

SPECIFICATIONS:

1. Hemispherical enclosure = 200mm.
2. Suitable sized water jacket for hemisphere.
3. Base plate, bakelite diameter = 240mm.
4. Sleeve size, diameter = 44mm
5. Fixing arrangement for sleeve (fig. 1) =
6. Test disc diameter = 25mm
7. Mass of test disc = 0.005Kg.
8. Specific heat, S of the test disc = 0.1 kcal/Kg. $_0$C
(Ref. Mech. Engg. Hand book for copper 0.41868Kj/Kg.- $_0$C In SI unit)
9. No. of thermocouples mounted on B = 4
10. No. of thermocouples mounted on D = 1

11. Temperature indicator digital 0.1_0C L. C. $0\text{-}200_0C$ with built in cold junction compensation and a timer set for 5 Sec. To display temperature rise of the disc.
12. Immersion water heater of suitable capacity = 1.5KW
13. Tank for hot water.

The surface of B and A forming the enclosure are blackened by using lamp black to make
their absorptivities to be approximately unity. The copper surface of the disc D is also blackened.

EXPERIMENTAL PROCEDURE:

1. The water in the tank is heated by immersion heater up to a temperature of about 90_0C.
2. The disc D is removed before pouring the hot water in the jacket.
3. The hot water is poured in the water jacket.
4. The hemispherical enclosure B and A will come to some uniform temperature T in short time after filling the hot water in jacket. The thermal inertial of hot water is quite adequate to presence significant cooling in the time required to conduct the experiment.
5. The enclosure will soon come to thermal equilibrium conditions.
6. The disc D is now inserted in A at a time when its temperature is say T5 (to be sensed by separate thermocouple).

The radiation energy falling on D from enclosure is given by:

$E = A_D (T)_4 \sigma$ ………………………..(1)

Where A_D = Area of the disc – D in m_2

The emissivity of the disc D is assumed to be unity (Black disc). The radiant energy disc D is emitting into the enclosure will be:

$E1 = A_D (T)_5$

$_4 \sigma$ ………………………..(2)

Net heat in put to disc D per unit time is given by (1) – (2):

$E – E1 = \sigma A_D (T_4 - T_5$

$_4)$………………..(3)

If the disc D has mass m and specific heat S then a short time after D is inserted in A.

m. s. (dT / dt) t = $\sigma A_D (T_4 - T_5$

$_4)$

m. s. (dT / dt) t = 0

σ = --------------------------- W

$A_D (T_4 - T_5$

$_4)$

In this equation (dT / dt) t = 0 denotes the rate of rise temperature of the disc D at the instant when its temperature is T5 and will vary with T5. It is clearly best measured at time t = 0 before heat conducted from A to D begins to have any significant effect. This is obtained from plot of temperature rise of D with respect to time and obtaining its slope at t = 0 when Temperature = T5. This will be the required value of dT / dt at t = 0 (fig. 2). The thermocouple mounted on disc is to be used for this purpose.

Note that the disc D with its insulating sleeve S, is placed quickly in position and start the

timer and record the temperature at fixed time intervals. The whole process is completed
in about 30 seconds of time.
Longer D is left in position; the greater is the probability of errors due to heat conduction from A to D.
The experiment is repeated for obtaining better result.
1. Mass of the test disc (m) = 0.005Kg.
2. Specific heat of disc material (s) = 0.1 Kcal / Kg - ^{0}C (Copper disc) – MKS Unit
= 0.41868 KJ / Kg – ^{0}C – SI Unit
Thermocouple No. Temperature ^{0}C
T1
T2
T3
T4
T1 + T2 + T3 + T4
3. Average temperature in ^{0}C = ------------------------
4
Average temperature in ^{0}K (T) = ^{0}K
4. Temperature of disc D at the instant when it is inserted (T5)
T5 = in ^{0}C =
T5 = in ^{0}K =
5. Temperature time response of the disc.
Use the Disc thermocouple on T. I. and note down T5 at the time interval of 5 sec.
With –
Time (Sec.) t Temperature (T5) ^{0}C
5
10
Plot the graph of dT against t as shown in fig. 2.
6. Obtain slope from the graph –
(dT / dt) at t = 0 = ^{0}C/sec
= ^{0}C/Hr
7. Value of σ can be obtain by using (3)
m. s. (dT / dt) t = 0
σ = --------------------------- Kcal/ hr ^{0}K^4 m^2 (M K S)
A$_D$ (T^4 – T5^4)
m. s. (dT / dt) t = 0
= ----------------------------- w /m^2 ^{0}K^4 (S I Units)
A$_D$ (T^4 – T5^4) x 0.86