World College of Technology and Management

Heat Transfer Lab

Experiment No. 1

Object: - To study the phenomena of critical thickness of insulation

Aim of insulating cylindrical pipes:-

Normal cylindrical pipes carrying hot fluid or cold fluid are insulated to decrease the rate of heat transfer from fluid to outside or from outside to inside fluid. For example pipe carrying steam in thermal power stations are insulated to decrease the rate of heat transfer from inside steam to outside atmosphere. Pipe carrying refrigerant in refrigeration systems are insulated to check the heat from outside atmosphere to inside refrigerant

Aim of insulating electric wires and cables

Electric wires and cables are insulated to increase the rate of heat transfer from its outer surface. This increase the current carrying capacity of electric wire and cables but increase or decrease in heat transfer from the outer surface depends upon the thickness of insulation

Critical thickness of insulation

Consider a thin wall metallic cylinder of length “L” inner radius ri carrying hot fluid at temperature ti which is higher than ambient temperature to. The cylindrical pipe is insulated with an insulating material of thickness (r-ri) and is of thermal conductivity k. hi and ho are convective heat transfer coefficients at inner and outer surface of the pipe.

Heat flowing from inside hot fluid to outside atmosphere is resisted by three resistances Rt1, Rt2, and Rt3

Where:-

Rt1 = resistance put forward by inside convective film =

Rt2 = resistance put forward by insulating material =

Rt3 = resistance put forward by outside convective film=

Assumptions :-

(1) Heat flow take place under steady state conditions.
(2) One dimensional heat flow take place in radial direction only
(3) The thermal resistance of metallic cylindrical wall is negligible
(4) Heat lost from outer surface by radiation is negligible

CRITICAL THICKNESS OF INSULATION

Heat flow (Q) =

$$\frac{ti-to}{1/2\pi ri\, lhi + ½\pi kl\, \log_e r/ri + 1/2\pi r\, l\, ho} \qquad (1)$$

The denominator represents the total thermal resistance to heat flow

In this equation (1) ri, hi, L, ho, K are constant and only variable parameter is r, indication the thickness of insulation (r-ri)

From this equation it can be noted that as value of r increases

(1) The thermal resistance of insulation material increases and heat transfer will decrease.
(2) The thermal resistance of outer connective film will decrease, and it will increase the heat transfer rate
(3) Thermal resistance of inside connective film remains constant. Hence addition of insulation can either increase or decrease the rate of heat transfer, depending upon the total resistance, which change with outer radius r.

The effect of thickness of insulation can be studied by differentiating the total resistance rt with respect to r and putting derivative equal to zero.

$Rt = 1/2\pi ri\, Lhi + 1/2\pi kl\, \log_e r/ri + 1/r\pi r\, l\, h\, o$

$dRt/dr = 0 + 1/2\pi klr - 1/2\pi\, lho\, r2 = 0$ (ii)

r=k/ho

The value of r is known as critical radius. For this value of r, the total resistance is either maximum or minimum.

To determine whether the foregoing result maximises or minimises the resistance, the second derivative needs to be calculated.

From the equation (ii)

$dRt/dr = 1/2\ \underline{\pi\ KLr - 1/2\ \pi\ Lho\ r^2}$

$d^2 Rt/ d\ r^{2=}\ -1/2\ \underline{\pi\ KL\ r^{2\,+}\ 2/ 2\ \pi\ Lho\ r^3}$

At r = k/ho

$d^2 Rt/ dr^{2\,=}\ ho^2/ 2\ \pi LK^3$ which is positive

The means at r=k/ho the resistance is minimum and heat transfer (Q) is maximum. Hence insulation radius r at which resistance to heat flow is minimum or heat transfer is maximum is known as critical radius (r_c)

Thus $r_{c\ =\ K/\ ho}$

The effect of insulation thickness can also be explained by the figure 1.1

This analysis gives two cases of practical interest

(1) When r < rc, the addition of insulation on bare pipe will increase rate of heat transfer and heat transfer will be maximum, which r = rc

It means in the range of (ri-rc) of insulation thickness, the outer convective resistance decreases to a higher extent as compared to increase in conduction resistance. Hence the total resistance decreases and heat transfer increases. This range of insulation is used for electric wires and cables.

(2) Further when r is more than rc or when the thickness of insulation is more than critical thickness of insulation, increase in conductive resistance is more than decrease is outside convective resistance, hence total resistance increases and heat transfer start decreasing. This range of insulation thickness is used for pipes carrying hot fluid to decrease the rate of heat transfer.

Answer the following question

(1) What do you mean by critical thickness of insulation?

(2) Why electric wires and cables are insulated?

(3) Why steam pipes, in thermal power stations are insulated?

(4) What is range of insulation thickness used for electric wires and cables?

(5) What is range of insulation thickness used for steam pipes?

(6) When r is less than ri, total resistance decrease, why?

(7) When r is more than ri, the total resistance increases. Why?

Experiment No. 2

Object: - The determine thermal conductivity of insulating powder

Apparatus:- The apparatus consists of two thin walled concentric copper spheres. The inner sphere houses heating coil. The insulating powder is packed between two shells. The power supply to the heating coil is by using a dimmerstat and is measured by volt meter and Ammeter. Chromel alumel thermo couples are used to measure the temperatures. Thermo couple (1) and (2) are embedded on inner sphere and (3) and (4) in outer sphere as shown in fig 2.1

Theory:-

Let

ri = radius of inner sphere in meters

ro = radius of outer sphere in meters

Ti = average temperature of inner sphere

To = Average temperature of outer sphere

Where

$$Ti = \frac{t1 + t2}{2}$$

$$To = \frac{t3+t4}{2}$$

Assuming the heat transfer from heating coil to insulation powder through copper metallic wall take place by conduction, then heat transfer.

$$Q = \frac{4\pi K(Ti-To)}{\frac{ro-ri}{ro\ ri}} = w = v\times 1$$

$$\text{OR} \quad K = \frac{Q(ro-ri)}{4\pi\ ri\ ro\ (Ti-To)}$$

Hence knowing the value T1, T0, V and I thermal conductivity K of insulating powder can be determined

Specification :-

(1) Radius of inner copper Sphere (R1) =50 mm
(2) Radius of outer copper sphere (Ro) = 100mm
(3) Voltmeter range :- 0-100-200V.
(4) Ammeter range :- 0-2 Amps.
(5) Temperature indicator range :- 0-300^{o} C
(6) Dimmerstat range :- 0-2 A, 0-230V.
(7) Heater coil :- strip heating element sandwiched between mica sheet- 200 watts.
(8) Chromel- Alumel thermocouples (1) and (2) are embedded on inner sphere and (3) and (4) are embedded in outer sphere to measure temperatures
(9) Insulating powder – plaster of paris commercially available powder and packed between two spheres

Experimental procedure

i. Start main switch of control panel
ii. Increase slowly the input to heater by dimmerstat starting from zero volt position
iii. Adjust input equal to 40 watts (max.) by voltmeter and ammeter. Wattage Q=v×1
iv. Keep this input to heating dement constant throughout the experiment.
v. Wait till fairly steady state condition is reached. This can be checked by reading and noting down the all the four temperatures at regular interval of time say 5 min.
vi. Note down the reading in observation table

Observation table

Sr. No	**Voltage V**	**Current Amps I**	**W=V×I =Q**	**t1** oC	**t2** oC	**t3** oC	**t4** oC	**T1** $\frac{t1+t2}{2}$ oC	**To** $\frac{t3+t4}{2}$ oC

Calculation

ri = radius of inner copper sphere = 50mm =0.05m

ro= radius of outer copper sphere = 100 mm= 0.1m

V= Voltage

I = Amperes

W= Q= V×I

T1 = **oC**

To = **o** C

$K = Q\,(r_o - r_i) / 4\pi\, r_i\, r_o\, (T_i - T_o)$

Result :- thermal conductivity of insulating powder = w/m-degree.

Experiment No.3

Object:-

(i) Determination of heat transfer coefficient and fin efficiency for fin in natural and forced convection, assuming that fin is insulated at tip

(ii) Draw temperature profile for fin in natural and forced convection**.**

Introduction:-

Fins or extended surface are used to increase the surface area and hence heat transfer from a surface to outside fluid. A fin may be of various profiles and shape i.e. straight fin, annular fin, pin fin etc.

A pin fin stick out from primary heat transfer surface. The temperature difference between fin surface and surrounding fluid decreases steadily, as one move out along the fin. If pin fin is long enough, the temperature difference between end of fin surface and outside fluid is very small, and heat transfer at tip of the fin is negligible. Hence analysis can be done by assuming that tip of pin fin is insulated.

Theory:-

Consider a pin fin of circular in cross section is connected at its base of heated wall and transferring heat to the surrounding.

Let:-

L = length of fin in meter

D = diameter of fin in meter

Ac = area of cross section = $\frac{\pi}{4} D^2 - m^2$

P = parameter of fin = π D- meter

K = conductivity of fin material w/m^0c

to = temperature at the base of fin ^0c

ta = temperature of outside fluid or ambient temperature $^0c = t_6$

h = convective heat transfer coefficient

$t_1, t_2, t_3, t_3, t_4, t_5$ - temperature at fin surface

t_1 = temperature at point 1

D_d = diameter of duct m

V_a = Velocity of air in duct in m/sec

γ_a = kinematic viscosity of air μ/ρ

μ_a = dynamic viscosity of air

ρ_a = density of air (outside fluid) at its temperature kg/m^3

Cp_a = sp. heat of air kj/kg^{0}c

k = conductivity of air w/m^{0}c

ρ_w = density of water

t_m = Average surface temperature of fin

$$= \frac{t_{1+} t_{2+} t_{3,} t_{3+} t_{4+} t_5}{5}$$

Determination of convective heat transfer coefficient

Q = heat added to fin = V×I

Where V = voltage in volts
I = current in amps

Q = h. As. $(t_m - t_a)$

Where

h = convective heat transfer coefficient
As = surface area of fin = π D.L

π × diameter of fin × length of fin

$$h = \frac{V.I}{As\,(t_m - t_a)}$$

Determination fin efficiency

Fin efficiency (η_f) for fin insulated at tip

$$= \frac{\sqrt{\left(\frac{k.Ac}{p.h}\right)} \tanh (mL)}{L}$$

$$\frac{\tanh (mL)}{mL}$$

Drawing of temperature profile

Draw temperature distribution curve in natural convection and forced connection by plotting a graph between temperature and distance on the fin surface.

Specification

Diameter of duct = (D_d)=150mm

Diameter of fin(D) = 12mm = 0.012m

Diameter of orifice = 18mm = 0.018m

Length of fin = 150mm = 0.15m

Coefficient of discharge for orifice meter (Cd) = 0.64

Power of centrifugal blower = 1 HP

Thermal conductivity of fin material i.e. brass (k) = 110w/m^{0}k

Temperature indicator = 0-300^{0}c

Dimmer stat for heat input control

= 230V, 2amps

Voltmeter = 0-100/200V

Ammeter = 0-2amps

Experimental procedure

(1) Start heating the fin by switching on the heater element and adjust the current to supply say 80 watts (increase slowly from 0 to onward). Note down the thermo couple reading 1 to 5.
(2) When the steady state is reached, record the final readings of t_1, t_2, t_3 , t_4 , t_5 and t_5 and record temp t_6
(3) Repeat the experiment with 100 watts and 120 watts

Forced correction

(1) Start heating of fin by switching on the heater and adjust the dimmer stat voltage equal to 100 watts.
(2) Start the blower and adjust the difference level in the manometer with help of gate valve.
(3) Note the readings t_0, t_1, t_2 , t_3 t_4 t_5, t_6 and t_6 in steady state conditions
(4) Repeat the experiment with different watts and manometer readings.

Precautions:-

(1) See the dimmer stat and be ensure that it is at zero position before switching on the heater.
(2) Operate the charge over switch of temperature indicator gently.
(3) Be sure that steady state is reached before taking final reading.

Observation Table

(1) Natural correction.

V Volt	I Amp	Q VI Watts	Fin temperature					Ambient Temp $t_6\ ^0c$	Manometer Readings (H) in mm
			$T_1\ ^0c$	$T_2\ ^0c$	$T_3\ ^0c$	$T_4\ ^0c$	$T_5\ ^0c$		

Observation Table

(2) Forced Convection

V Volt	I Amp	Q VI Watts	Fin temperature					Ambient Temp t_6 ^0c	Manometer Readings (H) in mm
			t_1 ^0c	t_2 ^0c	t_3 ^0c	t_4 ^0c	t_5 ^0c		

Calculations:-

Results

Natural Convection

(1) Heat transfer coefficient (h) = w/m^0c
(2) Fin efficiency = %

Forced Convection

(1) Heat transfer coefficient (h) = w/$m^{2}\,{}^{0}c$
(2) Fin efficiency = %

Determination of heat transfer coefficient

(Alternative Approach)

For natural convection conditions

Nu (Nusselt number) = $1.1\,(G_{r\,a} P_{r\,a})^{1/6}$ if $10^{-1} < G_r P_r < 10^4$

Nu = $0.53\,(G_r P_r)^{1/4}$ if $10^4 < G_r P_r < 10^9$

Nu = $0.13\,(G_r P_r)^{1/4}$ if $10^9 < G_r P_r < 10^{12}$

For forced convection conditions

Nu = $0.615\,(R_e)^{0.466}$ if $40 < R_e < 4000$

$Nu = 0.174 (R_e)^{0.618}$ if $4000 < R_e < 40,000$

Where

$Nu = \frac{h D}{Ka}$

Reynolds No $(R_e)_a$ $\frac{Va.D}{\frac{\mu_a}{\rho_a}}$

Grashoff No $((G_r)_a = \frac{g.\beta.D.^3\Delta T}{\gamma_a}$

Where $\gamma_a = \frac{\mu_a}{\rho_a}$

Prandtl Number $Pr_a = \frac{\mu_a C_{Pa}}{K_a}$

Where:-

g = Acceleration due to gravity = $9.81 \ m/sec^2$

β = Coefficient of thermal expansion = $\frac{1}{tm_f + 273}$

$A_m = \frac{t_1, + t_2 +, t_3 + t_4 + t_5}{5}$

$\Delta T = t_m - t_6$

$tmt = \frac{t_m + t_6}{2}$

Va = velocity of air in duct

ρ_a, $C_{P\,a}$, K_a, μ_a, Pr are the properties of air at ambient temp t_6 which can taken from table given at the end of book by D.S. Kumar

Determination Velocity or air (Va)

Volume flow rate of air $Q_a = Cd. \frac{\pi d^2}{4} \sqrt{\frac{2g\ H\ Pw}{\rho_a}}$

Where H = difference of level in manometer in meter

ρ_w = density of water = 1000kg/m^3

ρ_a = density of air

Cd = 0.64

D = dia of orifice

Velocity of air (Va) at t_6 = $\frac{Qa}{\text{Duct area of cross section}}$

$$= \frac{Qa}{\frac{\pi}{4} D_d^2}$$

Calculate

This velocity is used to determine Reynolds Number

Quality of heat transfer-

$Q = \sqrt{h. Ac\ Pk}\ (t_1 - t_a)\ \tanh mL$ $m = \sqrt{(Ph)/ KAc}$

Experiment No.4

Object: - To determined convective heat transfer coefficient for vertical cylinder in free convection.

Introduction: - Natural convection phenomenon for a vertical cylinder due to temperature difference between the surface of cylinder and surrounding air is known as free convection.

Apparatus: - The apparatus consist of a brass tube fitted in a circular duct in a vertical position. The duct is open at top and bottom and forms enclosure which serve the purpose of undisturbed surroundings.

A heating element is kept in vertical brass tube which heats the tube surface. Heat is transferred from heated tube surface to surrounding air by free convection.

Five thermo couples have been installed on different locations on tube surface to measure the temperatures at these locations. One thermo couple has been installed in the surrounding air of heated tube in the duct to measure its temperature. The heat input to the heater is measured by digital ammeter and voltmeter and can varied by dimmerstat.

Theory: - Let

V= voltage an electric power supplied to heating element.

I= Magnitude of current in amps supplied to heating element.

W= wattage of power supplied to heating dement.

Assume heat supplied to heating element is transfer to surrounding air.

Hence W=Q = heat supplied to air

For convective heat transfer

$Q= h\ As\ (t_m-t_6)$

Where h =convective heat transfer coefficient to be determined.

As = surface area of brass tube

$= \pi D_i L$

Where Di = Diameter of brass tube

L = length brass tube

t_m = mean temperature of brass tube surface

t_6 = temperature of surrounding air in the duct.

Alternative approach: - Assuming the flow in duct is laminar in nature.

Nussult number (Nu) = $0.59(Gr.\ Pr)^{0.25}$

Where Gr = grashoff number = $\frac{L^3 p^2 \beta g (\Delta T)}{\mu^2}$

Pr = Prandtl number = $\frac{\mu C_p}{k}$

Where

D1 = diameter of brass tube

p = density of air at tm_f

μ = dynamic viscosity of air at tm_f

K = thermal conductivity of air at tm_f

Cp = Specific heat of air at tm_f

$\Delta T = t_m - t_6$

g = Acceleration due to gravity = 9.81

β = thermal coefficient of expansion = $\frac{L}{tm_f + 273}$

$$t_m = \frac{t_1 + t_2 + t_3 + t_4 + t_5}{5}$$

t_6 = temp of surrounding air

$$tm_f = \frac{t_m + t_6}{2}$$

Note: - All properties of air p, μ, k, Cp and Pr are taken at mean film temperature tm_f.

$$\text{Nussult number (Nu)} = \frac{hl}{k}$$

$$h = \frac{Nu.k}{l}$$

hence h convective heat transfer coefficient can be determined

Specification

Diameter a brass tube = 38mm
Length brass tube = 350mm
Voltmeter = 0- 220V
Ammeter = 0 -2.5Amps.

Experimental procedure:-

(1) Switch on the supply and adjust the dimmer stat to supply about 100 watts.

(2) Wait till the steady state is reached

(3) Note down all the six temperature readings

(4) Repeat the experiment with approximately 120 watts and 140 watts.

μ

Observation Table

Set No	**Voltage V volts**	**Current I Amps**	**W=Q V×I Watts**	t_1 0C	t_2 0C	t_3 0C	t_4 0C	t_5 0C	t_6 0C	t_m 0C	tm_f 0C

Set No 1											
Set No 2											
Set No 3											

Calculation

Result

Answer the following questions

(1) What do you mean by heat transfer in free convection?

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(2) Free convection heat flow depends upon all of the following except

(a) Density

(b) Coefficients of viscosity

(c) Gravitational force

(d) Velocity

(3) The free convection heat transfer is significantly affected by (a) Reynolds number (b) Grashoff number (c) Prandtl number (d) Stanton number

(4) Consider natural convection heat transfer between a vertical tube surface and fluid surrounding. For dimensional analysis of the problem, the characteristic length corresponds to (a) Length of the tube (b) Diameter of tube (c) parameter of tube (d) Either length or diameter of the tube.

(5) The Nusselt number in natural convection heat transfer is a function of prandtl number and (a) Biot Number (b) Grashoff number (c) Reynolds number**.**

(6) The ratio of heat transfer by convection to that by conduction is called

(a) Nusselt Number (b) Biot Number (c) Reynolds Number

(7) The ratio of kinematic viscosity to thermal diffusivity is known as (a) Prandtl Number (b) Nusselt Number (c) Peclet Number

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(8) Prandtl Number will be lowest for-

(a) Water (b) Liquid metal (c) Aqueous solution (d) Lubricating oil

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(9) Convective heat transfer coefficient in laminar flow over a flat plate-

(a) Increase with distance

(b) Increases of a higher viscosity fluid used

(c) Increases if denser fluid is used

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(10) In free convection heat transfer, transition from laminar to turbulent flow is governed by-

(a) Reynolds Number to Grashoff Number

(b) Reynolds Number and Grashoff Number

(c) Grashoff Number and prandtl Number

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Experiment No. 5

Object:- To determine convective heat transfer coefficient for a horizontal pipe in forced convection.

Apparatus:- The apparatus consist of horizontal lest section attached with blower. The test section is surrounded by nichrome wire heater. Four temperature sensors embedded on the test section and two temperature sensors are placed in the air stream at the entrance and exit of the test section to measure air temperatures.

The test pipe is connected to the delivery side of the blower with the orifice to measure air flow rate through test section. Input to the heater is given through a dimmer stat and measured by voltmeter and ammeter.

It is to be noted that is this case, that only part of the total heat supplied to heating element is utilized to heat the air in test section.

Digital temperature indicator is provided to measure temperature of pipe wall at four locations and temperature of air at two locations. Air flow is measured with the help of orifice meter and water manometer fitted on the board.

Theory:-

Heat transfer coefficient (h) = $\frac{Qa}{A(ts - ta)}$

Let – t_1, t_2, t_3, t_4 are temp of test section of four different locations

ts = Mean surface temp of test section = $\frac{t_1+t_2+t_3+t_4}{4}$

t_5, t_6 are temperatures of at inlet and exit section of test pipe.

t_a = mean temp of air = $\frac{t_5+t_6}{2}$

A = surface area of lest pipe – π DiL

Qa = heat transferred to air from the surface of test section

$mc_{pa}\ (t_6 - t_5)$

m= mass flow rate of air

CPa= specific heat or air mean temperature of air (ta)

m= volume flow rate of air × density of air mean temp or air

m= $V \times \rho_a$

V= volume flow a rate of air = $C_d \times \frac{\pi}{4} d^2 \sqrt{2gH.\rho w/\rho_a}$ m^3/hr)

Where Cd = coefficient of discharge = 0.6

d = diameter of orifice

g = 9.81

ρw = density of water = 1000 kg/m^3

H= manometer reading in meter

Specification:-

Inner dia test section (D1) = 28mm

Outer dia test section (D_0) = 32mm

Length of the test section = 40 cms.

Blower = 1 Hp

Diameter of orifice (d) = 20mm

Dimmerstat range = 2Amp, 220 V

Procedure

(i) Start the blower and adjust the flow of by means of gate valve to some desired difference in manometer level.

(ii) Start heating of the test section with the help of dimmer stat and adjust desired heat input with the help of voltmeter and Ammeter (do not exceed 90 watts)

(iii) Note the reading of wall temperature sensors (t_1, t_2, t_3, t_4, t_5, t_6) until the steady state condition is reached. (wait at least 45min for first set of reading, and 15min for consecutive readings)

(iv) Note down the heat input

Sr. No	Voltage V Volts	Current I Amps.	V×I Watts	t_1 ^0C	t_2 ^0C	t_3 ^0C	t_4 ^0C	t_5 ^0C	t_6 ^0C	t_a $\frac{t_5 + t_6}{2}$	ts ^0C	Manometer Reading

										^{0}C		

Calculations.

Result: - convective heat transfer coefficient in forced convection= w/m^2 per degree.

Answer the following questions

(1) Which of the following heat flow situations pertains to free or natural convection
(a) Cooling of internal combustion engine
(b) Flow of water inside the condenser tubes
(c) Cooling of billets in atmosphere

(2) Mark the system where heat transfer is by forced convection.
(a) Chilling effect of cold wind on warm body
(b) Fluid passing through the tubes of condenser and other heat exchange equipment
(c) Heat from a hot placement to surrounding atmosphere

(3) Forced convection in liquid bath is caused by
(a) Density difference brought about temperature gradients
(b) Molecular energy interaction
(c) Intense stirring by an external agency

(4) A finned tube hot water radiator with a fan blowing over it is kept in rooms during winter. The major portion of the heat transfer from the radiator is due to
(a) Conduction
(b) Convection to air
(c) Combined conduction and radiation

(5) A body cooling from $80^0{}_C$ to $70^0{}_C$, takes 10 minutes, when left exposed to environmental conditions. If the body is cool further from 70 to $60^0{}_{C,}$ under the same external conditions. It will take
(a) Same time of 10min.
(b) More than 10min.
(c) Less than 10min

(6) A sphere, a cube and circular plate, all made some material and having same mass, are initially heated to a temperature of 250 $^0{}_C$ .When left in air at room temperature, which one will cool at fastest rate
(a) Sphere
(b) Cube
(c) Circular plate

(7) The convective coefficient for boiling and condensation usually lie in the range
(a) 30-300
(b) 300-10,000
(c) 2500 to 10,000 w/m^2k

Experiment No. 6

Object: - To determine emissivity of non black lest plate surface.

Apparatus: - Apparatus consist of one Black Plate one non black lest plate mounted in an endoser made of transparent acrylic cover. Black plate and non black test plate are made of aluminum are fitted with individual heaters to heat them.

Thermo couples have installed to measure temps of black plate (t_1) test plate (t_2) and enclose (t_3). A dimmer stat has provided to supply electric power to the heating dements of Black plate and non black test plate. Manitude of power supplied to both the plates can be measured by their voltmeter and Ammeter. A digital thermometer with selector has been provided to note down the temperatures $T_{1,}$ $T_{2,}$ $T_{3.}$

Theory: - Under the steady state conditions

Let-

W_1 = Heater input to black plate

= $V_1 \times I_1$ watts.

W_2 = Heater input to test plate

= V_2 I_2 watts.

A = Area of plate ………m^2

d = diameter of plate

T_1 = temperature of Black plate

T_2 = temperature of non black test plate

T_3 = temperature of air in enclosure

E_l = Emissivity of black plate
(to be assumed equal to unity)

E = emissivity of non Black test plate

$= \frac{\text{emissive power of non black body}}{\text{emissive power of black body}}$

Q = Stefan Boltzmann constant

= 5.67×10^{-8} w/m^2 k ^{4}

By using stefen Boltzmann Law

$W_{l-} W_2 = (W_6 - E) \quad A (T_l{}^4 - T_l{}^4)$

Specifications:-

1. Test diameter = 140mm
2. Black plate diameter = 140mm
3. Heater Black plate – nichrome strip wound on mica sheet and saved witched between two mica sheets
4. Heater for non black test plate – as above having
   Capacity of 200 watts in each case
5. Dimmer stat for black plate and test plate 0-2A , 0-260V
6. Voltmeter 0-100-200V, Ammeter 0-2 Amps
7. Enclosure size 580mm × 300mm with are side of perpex sheet
8. Thermo couples = chromel- Alumel – 3No
9. Temperature indicator –0-300^{0}C

Procedure

1. Gradually increase the input to the heater of black plate and adjust it to some value VIZ 30,50,75 watts etc and adjust the heat input to lest plate slightly less than black plate say 27,35,55 watts.
2. Check the temperature of two plates with small time intervals and adjust the input to lest plate only by dimmer stat so that two plate will be maintained at the same temperatures.

   Note: - for the same temperature of black plate and non black plate, heat input it black plate (W_l) will be more than heat input to test plate (W_2). This is due to that fact black plate is better absorber as well as better emitter of heat radiations as compared to non black plate.

3. Bring the temperatures of two plates at the same level by trial and error method and get the steady state condition (A bout one hour required) to get steady state conditions.
4. After altering steady state conditions, record the temperatures $T_{1,}$ $T_{2,}$ and T_3 reading on voltmeters and Ammeters.
5. Procedure is repeated for different temperatures of black plate.

<u>Observation Table</u>

Sr. No	BLACK PLATE			TEST PLATE			T_3 ^0C
	V_1 Volt	A_1 Amps	T_1 ^0C	V_2 Volt	A_2 Amps	T_2 ^0C	

Calculations:-

Result:-

Answer the following questions

(1) Define the emissivity of non black body

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(2) Define emissive power

____

(3) A perfect black body
   (a) Absorb all the incident radiation
   (b) Allows all the incident radiations to pass through it
   (c) Reflect all the incident radiations

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(4) A body which partly absorb and partly reflects but does not allow any radiation to pass through it
   (a) Opaque   (b) grey   (c) Specular

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(5) For a grey surface
   (a) emissivity is constant
   (b) emissivity equal to reflectivity

(c) emissivity equal to transmissivity

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(6) the emissivity is likely to be higher in case of
(a) rubber (b) paper (c) carbon

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(7) Four identical pieces of copper painted with different colours of paints were heated to the same temperature and they left in the environment to cool. Which of the following paints will give fast cooling
(a) whit (b) rough (c) Black (d) shining

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(8) Absorptivity of a body is equal to its emissivity
(a) For a polished body
(b) Under thermal equilibrium conditions
(c) At shorter wave length

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(9) For an ideal reflector, the energy distribution at higher temperatures is at

(a) Shorter wave length
(b) Longer wave length
(c) Remains the same at all wave length

(10) Gases has poor

(a) Absorptivity (b) Reflectivity (c) Transmissivity

Experiment No.7.

Object: - To determine Stefan Boltzmann constant

Apparatus: - The Apparatus consist of flanged copper hemisphere fixed on a flat non conducting plate. This hemisphere is enclosed in a metallic water jacket used to heat the copper hemisphere.

Water is heated initially in a geyser and poured in to metallic water jacket.

A test disc which is mounted on a insulating backlite sleeve, which can be fitted in a hemisphere through a hole, drilled in the centre of base plate.

There are three temperature sensors $T_{1,}$ T_2 and T_3 to measure temperatures.

T_1 indicate the temperature of water in geyser

T_2 indicate the temperature of inner surface of hemisphere.

T_3 indicate the temperature of test-disc inserted in hemisphere.

The inner surface of hemisphere and surface test disc are blackened with lamp black, to make their absorptivity to be approximately unity.

Theory: - Stefan Boltzmann law states that thermal radiation heat flux (per unit area) of a black surface is proportional to fourth power of its absolute temperature

OR $\frac{Q}{A} \propto T^4$

OR $\frac{Q}{A} = \sigma\, T^4$

Where σ = Stefan Boltzmann constant

Let

E_1 = Radiant energy received by test- disc from hemispherical enclosure

$E_1 = \sigma\, A_D\, T^4$

Where A_D = area of cross test disc

$= \frac{\pi}{H} D^2$

Where D = diameter of test disc

Let E_2 radiant energy emitted by test disc to enclosure

Assuming the emissivity of test disc surface to be unity net heat retain by test- disc.

$E_1 - E_2$ = $\Delta D\,(T^4 - T^4_3)$

Let m = mass of test-disc

S = specific heat test-disc

Then = $m \times s \left(\frac{dT}{dt}\right)_{t=0} = \sigma A_D (T^4 - T^4_3)$

Where = $\left(\frac{dT}{dt}\right)_{t=0}$ = rate of rise of temperature of test-disc

It measured at t=0, before heat is start conducting from enclosure to test-disc to have any significant effect. This is obtained from the plot of temperature rise of test-disc with reference to time and obtaining its slope at t=0. This will be required value of $\left(\frac{dT}{dt}\right)_{t=0}$ Hence σ can be calculated.

Specifications

Diameter of flanged hemisphere = 200mm

Thickness of water jacket around hemisphere = 2.0mm

Dia of test-disc = 25mm

Mass of test-disc = 5grams

T_1, T_2, T_3 = temperature of water in geyser, temp flanged hemisphere and temp of test-disc

Procedure

(1) Heat the water in tank (geyser) by immersion heater up to temperature of about 90 ^{0}c

(2) Test disc is removed before pouring hot water in to jacket around flange hemisphere

(3) Hot water is poured in the water jacket

(4) Hemisphere enclosure and water jacket will come to some uniform temperature

(5) The enclosure will soon come to thermal equilibrium conditions.

(6) Test disc is attached in enclosure

(7) Now temperature of test disc will increase. Note down its temperature after an each interval of 30 seconds.

(8) Plot a graph between temperature of test disc and time. Get the value of $\left(\frac{dT}{dt}\right)_{t=0}$ from this plot

(9) Calculate value of Stefan Boltzmann constant.

Observation Table

Sr. NO	**Temp. of water in gyser** T_1 ^0K	Temp. of heat Spherical enclosure T_1 ^0K	T $\frac{T_1+T_2}{2}$ ^0K	Temp. of test disc T_3 ^0K	$\frac{dT}{dt}$ from graph	

Graph for $\left(\frac{dT}{dt}\right)$

Sr. No	**Time**	**Temp. of disc** $T_3\ {}^0C$	**Temp. of disc** $T_3\ {}^0K$	
	30			
	60			
	90			
	120			
	150			
	180			
	210			
	240			
	270			
	300			

Calculations

Result

Answer the following questions

(1) Define Stefan Boltzmann Law

(2) Thermal radiations occur in the portion of electrometric spectrum between the wave lengths.

(a) 10^{-2} to 10^{-4} micron

(b) 10^{-1} to 10^{-2} micron

(c) 0.1 to 10^{2} micron

(d) 10^{2} micron on wave

(3) The sun with an effective surface temperature of 5600^{0}K, emit most of its radiations in the spectrum of frequency range.

(a) 0.1 to 4 micron (b) 1 to 10 micron (c) 0.01-0.1 micron

(d) At all wave length

(4) Solar radiation 15mainly scattered or transmitted but ……….by the atmosphere, because

(a) in the visible spectrum, for which atmosphere has very low absorptivity

(b) Solar radiation is very intense

(c) Most of the solar radiation is scattered and little remains for absorption

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(5) Heat transfer by radiation is encountered least in

(a) Boiler furnace (b) insulated pipe (c) electric …….(d) nuclear reactor

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(6) With an increase in wave length, the monodromatic emissive power of black body

(a) Increases (b) decreases (c) increases, reaches maximum and then decrease (d) decrease, reaches a minimum and then increase

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(7) The low governing the distribution of radiant energy over wave length for a black body at fixed temperature is referred to as

(a) Planck's Law (b) wion Low (c) Kirchhoff's Low (d) Lambert's Law

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(8) Stefan Boltzmann constant has units of

(a) Kj/m^2-hr-k^4 (b) Kj/ m-hr- k^4 (c) Kj/hr- k^4 (d) Kj/ m^2 k^4

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(9) When of the following parameters does not appear the formation of Stefan Boltzmann law

(a) Absorplivity (b) emissivity (c) radiating area (d) radiation flux

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(10) The intensity of solar radiation on earth is

(a) 1kw/m^2 (b) 2kw/ m^2 (c) 5kw/m^2 (b) 2kw/ m^2 (d) 10kw/ m^2

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Experiment No.8

Aim: - To determine logarithmic mean temperature difference in counter flow and parallel flow arrangement of heat exchanger.

Apparatus: - it consists of a gyster to supply hot water to heat exchanger. It is concentric heat exchanger. Water is made to flow in the inner pipe and cold water in the annulus outer pipe.

Values are provided to flow the cold water in the parallel flow and counter flow arrangement.

Fig-I show fluids flowing in parallel direction and while fig-II show couter arrangement

Let

th_1 ( ) = Inlet temp of hot fluid

th_2 ( ) = out let temp of hot fluid

tc_1 ( ) = Inlet temp of cold fluid

tc_2 ( ) = outlet temp of cold fluid

Q_1 = terminal temp difference at inlet side

Q_2 = terminal temp difference at outlet side

Log mean temp difference (LMTD)- Qm

$$Qm = \frac{Q_1 - Q_2}{\text{Logo} \frac{Q_1}{Q_2}}$$

Procedure: - (i) supply cold water gyster and make the immersion heater on.

(ii) Regulate the supply of cold water to

Observation:-

Sr. No		(A) Parallel flow arrangemnet				
1.	th_1	th_2	tc_1	tc_2	Q_1	Q_2	$Qm = \frac{Q_1 - Q_2}{Logo \frac{Q1}{Q_2}}$
2.							
3.							
4.							

Sr. No		(B)Parallel flow arrangemnet				
1.	th_1	th_2	tc_1	tc_2	Q_1	Q_2	$Qm = \frac{Q_1 - Q_2}{Logo \frac{Q1}{Q_2}}$
2.							
3.							
4.							

Result:-

1. Gyser such that temp hot water from gyster becomes constant
2. Supply cold water in annulus pipe at a certain rate.
3. Measure all the four temperature in steady state condition
4. Repeat the procedure for some other rate of cold water and note down readings for 3 different rate of cooling water
5. Now the make the cold water the flow in counter direction to the direction of hot water.
6. Repeat the procedure to get all the four temperatures

Experiment No. 9

Object: - To determine thermal conductivity of Liquid

Apparatus: - The apparatus consist of hot plate and cold plate. The inner surface of the plate are separated by a layer of sample liquid whose conducting is to be determined. Hot plate is fixed with two thermocouple (T1 and T2) at two different locations at its inner surface is contact the is used temperature of hot plate (Th) in steady state condition. Cold water is supplied to the cold plate to take away the heat transferred through the sample liquid.

Heat is supplied to hot plate by an……. Heater which can be varied by dimmer stat and can be noted down by voltmeter and Ammeter cold water is supplied to cold plate at high vdocity to keep temperature rise of cold water (T_4-T_3) to minimum average of these two temperatures (T_3 & T_4) is taken as of cold body (Tc)

The gap between hot plate and cold plate form the liquid cell, in which liquid sample is filled. The depth of the liquid in the direction of heat flow must be small to ensure the absence of convection currents and liquid sample of high viscosity and density shall further ensure the absence of convection and heat transfer can safely be assumed to take place by conduction alone.

Theory:-

The conductivity of sample liquid is determined from the Fourier's law of heart conduction

$$Q = V \times I = \frac{K.\ An\ (Th-Tc)}{\Delta x}$$

Where:-

Q = V×I = heat supplied to hot plate –watts

K = thermal conductivity of sample liquid – w/mk

Tn = Mean temperature of hot body = $\frac{T_1+T_2}{2}$ ^0C

Tc = Mean temperature of cold body = $\frac{T_3+T_4}{2}$ ^0C

An = Heat transfer over $\frac{\pi}{H} d^2$ m^2

d= diameter of hot plate - m^2

Δx = thickness of sample liquid –m

Specifications:-

Diameter of hot plate (d) = 170mm

Depth of sample liquid (Δx) = 15mm

Heating coil rating = 400 watts

Sample liquid = glycerol

Procedure:-

(1) Fill the liquid cell with sample liquid (Glycerol) through the inlet port. Liquid filling should be continued to complete removal of air and also liquid glycerol come out of the outlet port. Close the outlet port followed by inlet port
(2) Allow the cold water to flow from inlet to outlet
(3) Start the electric heater of hot plate. Adjust the wattage hot plate heater in the range of 10 to 30 watts.
(4) Adjust the cold water flow rate such that there is no appreciable in its temperature. Temperature rise in cold water should be minimum
(5) Go-on recording the temperature should be minimum plate till the steady state condition is reached (may be after 30-60min). In the steady state condition there is no appreciable change in the temperature of hot plate and cold plate (temperature variation should not be more than 10.1^0C
(6) Not down reading of voltmeter and Ammeter
(7) Procedure may be repeated with different input to the heating element.

(8) Stop electric supply to the heater and continue with supply of cold water, till there decrease in the temperature of hot plate (may be another 30-40min)

Observation Table

Sr. No	**V Volts**	**I Amps**	**W=Q =V×I Watts**	**Th_1** ^0C	**Th_2** ^0C	**Th=** $\frac{Th_1 + Th_2}{2}$ ^0C	**Tc_3** ^0C	**Tc_4** ^0C	**Tc** $\frac{Tc_3 + Tc_4}{2}$ ^0C

Calculation:-

Result:-

Thermal conductivity of sample liquid =

Answer the Following question

(1) With the rise in temperature of gases, its thermal conductivity

(a) Decrease (B) Increase

(2) A gas with higher molecular weight has thermal conductivity more Or less compared with gas having lower molecular weight for most of the (Except Water)

(3) With the rise in temperature liquid, its thermal conductivity
(a) Increase (b) decreases

(4) With the increases in density of material, its thermal conductivity
(a) Increases (b) decreases (c) remains constant

(5) As temperature of ice on snow decreases, its thermal conductivity
(a) Increases (b) decreases (c) remains constant

(6) What material structure has higher thermal conductivity
(a) Crystalline structure (b) Amorphous structure

(7) What do you mean by " Super conductivity state of metals"

(8) What do you mean by " Super Conductor"

(9) A composite slab has two layers of different materials with thermal conductivity K1 and K2. Each conductivity of the slab would be

(a) K_1+K_2 (b) $\frac{K_1+K_2}{KK_2}$ (c) $2\frac{K_1K_2}{K_1+K_2}$

(10) Which of the following forms of water have highest value of thermal conductivity

(a) Boiling water (b) Steam (c) solid ice (d) melting ice

Super Conductivity state of metal

With the decrease in temperature, thermal and electrical conductivities of metal increases, but increase in electrical a absolute zero tem. (-273^0C) This correspond to super conductivity state of material.

Super Conductor

As the temperature of metals decreases, its thermal conductivity increases. At very low temperature, the thermal conductivity of metal is very high. So metals having very high thermal conductivity are known as super conductors. For Example thermal conductivity of aluminum reaches a value of 200 w/-m deg at 10^0K (-263^0C) and this is 100 times as large as the value that occurs at room temperature.