EXPERIMENTS IN HEAT AND MASS TRANSFER

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DEPARTMENT OF MECHANICAL ENGINEERING

SUBJECT : HEAT AND MASS TRANSFER

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INDEX

PRACTICAL:-01

TO DETERMINE THERMAL CONDUCTIVITY OF THE METAL ROD

Introduction:-

Thermal conductivity is a physical property of the material denoting the ease with which a particular substance can accomplish the transmission of thermal energy by molecular motion.

Thermal conductivity of a material is found to depend on the chemical composition of the substance or substances 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 & pressure to which it is subjected, & whether or not it is a homogeneous material.

Thermal conductivity of metal:-

Metals	Thermal Conductivity Watt/M ^{o} K	State.
Pure Copper	390	20^{o}C
Brass	110	20^{o}C
Steel	40-50	20^{o}C
Stainless Steel	16-20	20^{o}C

Mechanism of the thermal conductivity of metals:-

Thermal energy may be conducted in solids by two modes:

1. Lattice vibrations
2. Transport by free electrons.

In good electrical conductors a rather large no 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 energy transfer is not as large as the electron transport & it is for this reason that good electrical conductor are almost always good heat conductors i.e Copper, Aluminum & 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 conductivity decreases with increase in the temperature.

Descriptions of apparatus:-

The experimental setup 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 fitted with the asbestos insulting powder. The temperature of the bar is measured at 8 different sections while the radial temperature distribution is measured by separate thermocouples at two different sections in the insulting shell.

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

Specifications:-

1. Length of the metal bar : 425 mm (Approx.)
2. Size of the metal bar(dia.) : 25 mm.
3. Test length of the bar. : 200 mm.

4.	No. of thermocouples mounted on bar	: 9.
5.	Heater coil.	: Band type.
6.	Digital temperature indicator. (Multi Channel)	: 0 - 1000 ^{o}.
7.	Dimmerstat	: 2 Amp.
8.	Volt meter	: 0 - 200 V.
9.	Ammeter	: 0 - 3 A.
10.	Measuring flask	: 1000 CC.
11.	Stop watch	: 1 No.
12.	Supporting structure	

Theory:-

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

After attaining the steady state.

1. Heat flowing out of section AA of bar(q_w).

$q_w = m\ C_p\ (\Delta T)$.

Where,

m = Mass flow rate of water (Kg/Sec).

C_p = Sp. Heat of water at constant pressure

ΔT = $T_{11} - T_{10}$.

2. Thermal conductivity of bar at section AA can be calculated as

$q_w = -K_{AA}[\,dt/dx]_{AA} \cdot A$

The value of (dt/dx) is obtained from experimentally. Obtained temperature distribution in the bar along its length at section AA.

A = Cross sectional area of bar.

3. Heat conducted through section BB of the bar.

q_{BB} = q_w + radial heat loss between section BB & AA

$$= q_w + \frac{2\pi KL(T_{14} - T_{15})}{\ln(r_o/r_i)} \times A$$

Where,

K = Thermal conductivity of insulation

L = Radial distance between r_o & r_i

r_o & r_i = radius of thermocouple mounted is shell.

4. Thermal Conductivity of bar at section BB

$$q_{BB} = -K_{BB}(dt/dx)_{BB} \times A$$

5. Heat conducted through section CC of the bar.

q_{CC} = q_{BB} + radial heat loss between section BB & CC

$$= q_{BB} + \frac{2\pi KL(T_{12} - T_{13})}{\ln(r_o/r_i)} \times A$$

Where,

K = Thermal conductivity of insulation

L = Radial distance between r_o & r_i

r_o & r_i = radius of thermocouple mounted is shell.

6. Thermal Conductivity of bar at section BB

$$q_{CC} = -K_{CC}(dt/dx)_{CC} \times A$$

Procedure:-

1. Start the electrical supply.

2. Adjust the temperature by means of rotating the knob for compensation of temperature equal to the room temperature (Normally, this is pre-adjusted).

3. Give input to the heater by slowly rotating the dimmerstat & adjust it to voltage = 80 V, 120 V etc.

4. Start the cooling water supply through the jacket & adjust 350 CC.

5. Go on changing the temperatures at some specified time intervals.

   5 minutes & continue this, till a satisfactory steady state conduction is ready.

6. Note the temperature readings 1 - 15.

7. Note the mean flow rate of the water in Kg/min & temperature rise in it.

   Plot the temperature distribution along the length of the metal bar using observed values For determining the slopes at BB & CC sections & about AA.

Observation table:-

Flow Rate cc/min	Temperatures On Bar									Water inlet Temp. T_{10}	Water Outlet Temp. T_{11}
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9		

Calculations:-

1. Mass of Water (m)

= cc/min

= Kg/s

2. Heat flow out of Bar (q_w)

$$q_w = m\, C_p\, (T_{11} - T_{10})$$

Where, $C_p = 4.186$ KJ/Kg ^{0}K.

= W.

3. Thermal Conductivity of a given Bar (K)

$$q_w = K \frac{dt}{dx} .A$$

Where,

A : $\pi/4\ (0.025)^2$

: 4.908×10^{-4}

dt : $T_9 - T_1$

dx : 0.175 m

K = W/m^{0}K.

Result table:-

Mass Flow Rate M Kg/sec	Heat Loss q_w Watt	Thermal Conductivity Watt/m ^{0}K

Conclusions:-

Marks: **Date:** **Faculty Sign:**

PRACTICAL:- 02

TO DETERMINE THERMAL CONDUCTIVITY OF THE INSULATING POWDER

Introduction:-

Thermal conductivity is one of the important properties of the materials and its knowledge is required for analyzing heat conduction problems.

Physical meaning of the thermal conductivity is how quickly it passes through a given materials, thus, the determination of this property is of considerable engineering significance, there are various methods of determination of thermal conductivity but it is suitable for finding out the thermal conductivities of the material in the powdered form.

Descriptions of apparatus:-

The apparatus consists of two thin walls concentric copper spheres. The inner sphere houses the heating coil, the insulating powder (Asbestos Powder, as lagging material) is packed between two shells. The powder supplied to the heating coil is by using a dimmerstat & is measured by Voltmeter & Ammeter.

Copper constant thermocouples are used to measure the temperatures, thermocouples 1 to 4 are embedded on inner sphere and thermocouples 5 to 10 are embedded on the outer shell. Position 1 to 10, are as shown on change over switch of temperature indicator. Under steady state condition, the temperatures 1 to 10 are rated and also the voltmeter and ammeter readings is recorded. These readings, in turn enables as to find out the thermal conductivity of the insulating powder packed between two shells like assume the insulating powder as are isotropic material and the value of thermal conductivity to be constant . The apparatus assume one dimensional radial heat conduction across the powdered layer and thermal conductivity can be determined as above under steady state condition.

Theory:-

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

Let,

r_i = Radius of inner sphere in meter

r_o = Radius of outer sphere in meter.

T_i = Average Temperature of inner sphere in ^oC

T_o = Average Temperature of outer sphere in ^oC

Where,

$$T_o = \frac{T_5 + T_6 + T_7 + T_8 + T_9 + T_{10}}{6}$$

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

Note that, T_1 to T_{10} denote, the temperature of thermocouples 1 to 10

From the experimental values of q , T_i and T_o the unknown thermal conductivity K can be determined as,

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

Specifications:-

1. Radius of Inner Copper Sphere r_i = 50 mm.
2. Radius of Outer Copper Sphere r_o = 100 mm.
3. Voltmeter = 0 to 300 V.

4.	Ammeter	=	0 to 3 A.
5.	Digital temperature Indicator	=	0 to1000^{o}C
6.	Thermocouples(Copper Constant)	=	10 Nos.
7.	Dimmerstat	=	0 to 2 Amp.
8.	Heating Coil (Mica Type)	=	400 watts.
9.	Insulating Powder	=	Asbestos.

Procedure:-

1. Start main switch of control panel.
2. Increase slowly the input to the heater by the dimmerstat, starting from 0 volt position.
3. Adjust input equal to 40 watts maximum with help of voltmeter and ammeter.
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 and not change in their readings with time.
6. Note down the readings in the observation table as given below,

Observations table:-

Sr. No.	1	2	3	4	5
Voltmeter Reading (V)					
Ammeter Reading (A)					
Inner Sphere					
1					
2					
3					
4					
Outer Sphere					
5					
6					
7					
8					
9 10					

Calculations:-

1. Heat input (q) :

$$q = V\,I \quad \text{.........(Watts)}$$

Where,

V = Input voltage.

I = Input Ampere.

2. Mean Temperature of Outer Sphere (T_O) :

$$T_o = \frac{T_5 + T_6 + T_7 + T_8 + T_9 + T_{10}}{6}$$

3. Mean Temperature of Inner sphere (T_i) :

$$T_i = \frac{T_1 + T_2 + T_3 + T_4}{4}$$

4. Thermal conductivity of insulating material :

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

Conclusions:-

Marks: **Date:** **Faculty Sign:**

PRACTICAL:- 03

HEAT TRANSFER THROUGH COMPSITE WALL APPARATUS

Descriptions of apparatus:-

The apparatus consists of a central heater sandwiched between two mica sheets. Three types of slabs are provided on both sides of heater which forms a composite structure. A small hand press frame is provided to ensure the perfect contact between the slabs. Auto transformer is provided for varying the input to the heater & 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 & calculation can be made accordingly.

Specifications:-

1. Wall assembly arranged symmetrically on both sides of heater.
2. **Heater:** Nichrome heater wound on mica former & insulation with control unit capacity 400 W maximum.
3. **Heater Control Unit:** 0 - 230 V., 0 - 2 Amps. single phase Auto transformer (1 No.)
4. Voltmeter 0 - 100 - 200 V. Ammeter 0 - 2 Amps.
5. Temperature Indicator (digital type) 0 - 200 ^{0}C. Service required - A.C. Single phase 230 V. earthed electric supply.

Experiments to be carried out:-

a. To determine total thermal resistance & thermal conductivity of composite wall.

b. To plot temperature gradient along composite wall structure.

Precautions:-

1. Keep Auto transformer 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:-

1. Arrange the plates in proper fashion (Symmetrical) on both sides of the heater plates.
2. See that plates are symmetrically arranged on both sides of the heater.
3. Operate the hand press properly to ensure perfect contact between the plates.
4. Close the box by cover sheet to achieve steady environmental conditions.
5. Start the supply of heater. By varying the Auto transformer, adjust the input at the desired value.
6. Take readings of all the thermocouples at an interval of 10 min until fairly steady temperature are achieved & rate of rise is negligible.
7. Note down the readings in observation table.

Observations:-

Composite Slabs :

1. Wall Thickness

   A. Mild Steel : 25 mm
   B. Bakelite : 19 mm

   C. Wood : 12 mm

2. Wall Diameter : 200 mm

Observation table:-

	SET I	SET II
Readings 1. Voltmeter (V) in (V)		
2. Ammeter (I) in (A)		
Temperature Reading ^{0}C		
T_1		
T_2		
T_3		
T_4		
T_5		
T_6		
T_7		
T_8		

Calculations:-

1. Mean Temperatures

a) Mean Temp. before 1st wall (T_A)

$$T_A = \frac{(T_1 + T_2)}{2}$$

b) Mean Temp. After 1st wall or mean Temp. Before 2nd wall (T_B)

$$T_B = \frac{(T_3 + T_4)}{2}$$

c) Mean Temp. after 2nd wall or mean Temp. before 3rd wall (T_C)

$$T_C = \frac{(T_5 + T_6)}{2}$$

d) Mean Temp. After 3rd wall (T_D)

$$T_D = \frac{(T_7 + T_8)}{2}$$

2. Heat Supplied (Q)

$$Q = V \times I = \_\_\_\_\_\_\_\_ \text{(Watt)}$$

Where,

V = Supplied Voltmeter reading (V)

I = Supplied Ammeter reading (A)

3. Effective Area (Heat Transfer Area)

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 uni-directional i.e. axial flow. Thus for calculations, central half diameter area where unidirectional flow is assumed is considered. Accordingly, thermocouples are fixed at close to center of the plates.

$$A = \frac{\pi}{4} d^2 \qquad \_\_\_\_\_ \text{ (} m^2 \text{)}$$

Where, d = half dia. of plate or wall

4. Heat Flux (q)

$$Q = \frac{Q}{A} = \_\_\_\_\_\_ \qquad \text{(} W/m^2 \text{)}$$

5. Total thermal resistance in composite wall (R)

$$R_{total} = \frac{T_A - T_D}{q} = \_\_\_\_\_\_ \; ({}^0 k/w/m^2)$$

6. Thermal conductivity in composite wall (k)

$$K_{composite} = \frac{q \times b}{(T_A - T_D)} = \_\_\_\_\_\_\_ \; (w/m\,{}^0 k)$$

Where, b = Total Thickness of composite wall

7. Plot thickness of wall against Temp. gradient references.

Conclusions:-

Marks: **Date:** **Faculty Sign:**

PRACTICAL:-04

TO DETERMINE THERMAL CONDUCTIVITY OF LIQUID GUARDED HOT PLATE

Descriptions of apparatus:-

The apparatus is designed & fabricated according to the guarded hot plate principal. The guarded hot plate method has been recognized by scientists & engineers in U.S.A., West Germany, Scandinavian Countries., U.S.S.R. & India as mots dependable & reproducible for the measurement of thermal conductivity of insulting material. It is a steady state absolute method suitable for material which can be laid flat between two parallel plates & can be adopted for loose fill materials which can be filled between such plates

Principle of guarded hot plate method:-

A sketch of the apparatus ideas shown in fig.1. The essential parts - the hot plate, the cold plates, the heater assembly, thermocouples & the specimens in position are shown in the same fig.

For the measurement of thermal conductivity (k) what is required is to have a 1 dimensional heat flow through the flat specimen, an arrangement for maintaining its faces at constant temperature & some metering method to measure the heat flow through a known area. To eliminate the distortion caused by edge losses in unidirectional heat flow, the central plate is surrounded by guard ring which is separately heated. Temperature are measured by celebrated thermocouples either attached to the plates or to the specimens at the hot & cold faces

$$W_1 = -K \; dT / dX \; X \; A \quad m$$

$$W_1 \qquad S \; X \; 10^{-3}$$

$$K = \qquad\qquad \text{Watts/m-}\ {}^{o}K \;\; ......(1)$$

Am T_h - T_C

Where, K = Thermal Conductivity of sample watts/m- ^oK

q = Heat flow rate in the specimen, watts

A = Mean area for heat flow , m^2.

T_h = Hot plate temperature ^oC.

T_C = Cold plate temperature, ^oC.

S = Spacer thickness = 3mm.

Apparatus:-

This apparatus is designed & fabricated with IS 3346-1966 as a guide line, having the following specification.

Specifications:-

1. Central Heater.

   Nichrome strip type sandwiched between mica sheets.

2. Guarded Heater Ring.

   Nichrome strip type sandwiched between mica sheets.

3. Dimmerstat 2 Nos. = 0-2 Amp., 0-240 V.
4. Voltmeter - 0-100/200 V.
5. Ammeter - 0-2 Amp.
6. Thermocouples : 6 Nos. chromel alumel.
7. Insulation Box 375 mm x 375 mm x 375 mm Approx.
8. Temperature Indicator : 0 - 200 ^{o} C.

Descriptions of apparatus:-

The heater plate is surrounded by a heating ring for stabilizing the temperature of the primary heater & prevents heat loss readily around its edges. The primary & guard heater are made up of mice sheets in which is wound closely spaced Nichrome wire & packed with upper & lower mica sheets. These heaters together form flat together with upper & lower copper plate & rings from the heater plate assembly.

Two thermocouples are used to measure the hot face temperature at the upper & lower central heater assembly copper plates. Two more thermocouples are used to check balance in both the heater inputs.

Specimens are held between the heater & cooling unit on each side of the apparatus. Thermocouples No. 5 & 6 measure the temperature of the upper cooling plate & lower cooling plate respectively.(Fig 1.)

The heater plate assembly together with cooling plates & specimen hold in position by 3 vertical stands & nuts on a base plate are as shown in the assembly drawing (Fig. 3).

The cooling chamber is a composite assembly of grooved aluminum casting & aluminum cover with entry & exit adapters for water inlet & outlet.

The central guard heater arrangement is shown automatically.

Test procedure:-

1. Level the outer box on laboratory table by properly fixing the levelling screws and check nuts.
2. Fix the supporting studs inside the box.
3. Fix up the cooling jacket assembly along with the cooling plate and circumferential ring.
4. Fix up the proper thickness spacers in position in cooling plate assembly.
5. Introduce measured quantity of liquid in the liquid space on the cooling plate with the help of syringe.

6. Observe the liquid level in the cavity and make minor level adjustments if necessary with the help of level screws. Liquid should assume a uniform level in the cavity.
7. Introduce main heater assembly and ensure that it properly rests on the spacers in the liquid cavity.
8. Fix up the top guard heater assembly in position.this has to be done carefully so as to take out the heater terminals and thermocouples wires properly from the slots provided.
9. Properly connect the heater terminals.
10. Start the cooling water supply after providing the necessary piping connections for inlet and outlet.
11. Check any leakage in the cooling water circuit.
12. Fill the loose fill bags in the box and fix up the top cover.

Precautions:-

1. Keep dimmerstat to zero voltage position before start.
2. Increase the voltage gradually.
3. Start the cooling circuit before switching on the heaters & adjust the flow rate so that practically there is no temperature rise in the circulation fluid.
4. Keep the heater plate undisturbed & adjust the cooling plates after keeping the samples with the help of nuts gently.
5. Keep the loose till insulation (glass wool) packets gently & remove them slowly so that they do not disturb the thermocouples terminals & heater wires.

Procedure for changing the liquid and disassembling procedure:-

1 Remove the top guard heater assembly carefully along with the thermocouple and heater connections.

2 Remove the main heater assembly.

3 Clean the main heater plate bottom surface with cotton waste using some cleansing agent line acetone.

4 Remove the liquid using syringe after slightly tilting the box.

5 After removing the major quantity, remove the remaining layer of liquid using cotton waste.

6 Clean the cavity surface by using cleaning agent like acetone.

7 Cleaning is done repeatively till the cavity surface is trace free of the liquid.

Observations:-

1 Main heater diameter = 110mm.

2 liquid space diameter = 115mm.

3 Mean diameter of (1) & (2) = 112.5mm.

4 Mean area for heat flow (A_m) = $\pi / 4 \ (11.25^2 \text{ X } 10^{-4}) \ m^2$

$= 99.40 \text{ X } 10^{-4} \ m^2$

5. Spacer thickness (s) = 3mm.

Observation table:-

Heater	Voltage in Volts (V)	Current in Amps (I)	Wattage in Watts (VI) W_1=	Heat input Watts X 0.86 (Kcal/hr) Q_1=
Main				
Guard Ring				
Top Guard				

Temperature measurement:-

Location	Temperature ^{0} C
Central Surface Plate Temperature	T_1 =
	T_2 =

Guard Surface Plate Temperature	T_3 =	
	T_4 =	
Cooling Water Plates Temperature	T_5 =	
	T_6 =	

Calculation:-

1. Main Heater Input = $V_1 \times I_1 = W_1 = q$

   (inner Heater)

2. Guard Heater Input = $V_2 \times I_2 = W_2$

   (outer Heater)

3. Average Temperature of hot plate :

$$T_h = \frac{T_1 + T_2}{2} \quad {}^oC.$$

4. Average Temperature of Cold Plate :

$$T_c = \frac{T_5 + T_6}{2} \quad {}^oC.$$

5. $W_1 = -K \quad dT / dX \times Am$

$$K = \frac{W_1}{Am} \quad \frac{S \times 10^{-3}}{T_h - T_C} \qquad \text{Watts/m-} \ {}^oK \ ......(1)$$

Where, K = Thermal Conductivity of sample watts/m- ${}^oK$

q = Heat flow rate in the specimen, watts

A = Mean area for heat flow , m^2.

T_h = Hot plate temperature ${}^oC$.

T_C = Cold plate temperature, ${}^oC$.

S = Spacer thickness = 3mm.

Conclusion:-

Marks: **Date:** **Faculty Sign:**

PRACTICAL: 05

TO DETERMINE CRITICAL RADIUS OF INSULATING MATERIAL

Introduction:-

Thermal conductivity is one of the important properties of the materials and its knowledge is required for analyzing heat conduction problems.

Physical meaning of the thermal conductivity is how quickly it passes through a given materials, thus, the determination of this property is of considerable engineering significance, there are various methods of determination of thermal conductivity but it is suitable for finding out the thermal conductivities of the material in the powdered form.

Description of apparatus:-

The apparatus consists of one metal cylinder in which heater is fitted . The insulating material (asbestos belt) as lagging material is covered around the cylinder. Again the total assembly is insulated by glass wool & alluminium foil. The heat supplied to inner cylinder through heating coil by using a by a dimmerstat & is measured by Voltmeter & Ammeter.

Cromial alumel thermocouples are used to measure the temperatures, thermocouples 1 to 5 are embedded on metal cylinder and thermocouples 6 to 10 are embedded on the external side of insulating material. Position 1 to 10, are as shown on change over switch of temperature indicator. Under steady state condition, the temperatures 1 to 10 are rated and also the voltmeter and ammeter readings is recorded. These readings, in turn enables as to find out the thermal conductivity of the insulating powder packed between two shells like assume the insulating powder as are isotropic material and the value of thermal conductivity to be constant . The apparatus assume one dimensional radial heat conduction across the powdered layer and thermal conductivity can be determined as above under steady state condition.

Theory:-

In a number of cases it is require the rate of heat flow . For Ex.

1. Pipe line carrying steam: - When the steam flows from the boiler to the turbine through a pipe heat loss take place from steam to atm. This reduces the steam temp. & hence ,the work output from turbine.
2. The pipe line carrying liquid refrigerant : In this case heat flows into the cold refrigerant before it enters the evaporator. Thus some of the refrigerant gets vaporized ultimately reducing the refrigeration effect

let,

r = Radius of cylinder = 0.13 mtr

T_a = Average temperature of cylinder ^oC

T_b = Average Temperature of insulating material at external side ^oC

Where,

$$T_a = \frac{T_1 + T_2 + T_3 + T_4 + T_5}{5}$$

$$T_b = \frac{T_6 + T_7 + T_8 + T_9 + T_{10}}{5}$$

Note that T_1 to T_{10} denote, the temperature of thermocouples 1 to 10

From the experimental values of q, T_a and T_b the unknown thermal conductivity K can be determined as,

$$K = \frac{q}{\pi DL\,(T_a - T_b)}$$

Specifications:-

1.	Radius of Cylinder r	=	13 mm.
2.	Radius of Insulation	=	25 mm.
3.	Voltmeter	=	0 to 300 V.
4.	Ammeter	=	0 to 3 A.
5.	Digital temperature Indicator	=	0 to1000^{o}C
6.	Thermocouples(Copper Constant)	=	10 Nos.
7.	Dimmerstat	=	0 to 2 Amp.
8.	Heating Coil (Mica Type)	=	400 watts.
9.	Insulating Material	=	Asbestos.

Procedure:-

1. Start main switch of control panel.
2. Increase slowly the input to the heater by the dimmerstat, starting from 0 volt position.
3. Adjust input equal to 40 watts maximum with help of voltmeter and ammeter.
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 and not change in their readings with time.
6. Note down the readings in the observation table as given below,

Observation table:-

Sr. No.	1	2	3	4	5
Voltmeter Reading (V)					
Ammeter Reading (A)					
Cylinder temp.					
1					
2					
3					
4					
5					
Temp. of insulating material at external side					
6					
7					
8					
9					
10					

Calculation:-

1. Heat input (q) :

   $q = V\,I$ ....(Watts)

   Where, V = Input voltage.

   I = Input Ampere.

2. Mean Temperature of Cylinder (T_a) :

$$T_a = \frac{T_1 + T_2 + T_3 + T_4 + T_5}{5}$$

3. Mean Temperature of Insulating Material at external side (T_b):

$$T_b = \frac{T_6 + T_7 + T_8 + T_9 + T_{10}}{}$$

4. Heat Transfer Co-efficient of Insulating Material :

   $q_h = \pi DL\ (T_a - T_b)$

5. Critical Radius of Insulating Material

   $R = K/h$

   Where, R = Critical radius

   h = Heat Transfer Co-efficient.

   K = Thermal conductivity of Material(0.2 Watt/mtr^0 K) (Asbestos)

Result Table:-

	1	2	3	4
T_i				
T_o				
q				

Conclusions:-

Marks: **Date:** **Faculty Sign:**

PRACTICAL: 06

CRITICAL HEAT FLUX APPARATUS

Introduction:-

The mode of heat transfer with change of phase finds wide application,

1. Cooling of Nuclear Reactors and rocket motors
2. Steam power plants(Boilers & Condensers)
3. Refrigerating and air conditioning Systems (Evaporators and Condensers)
4. Melting of metals in furnaces.
5. Refineries and sugar mills(Heat Exchangers)
6. Process Heating & Cooling etc.

These process entail the following feachers,

1. As a consequence of phase change in there process, the heat transfer to from the fluid can occurs without influencing the fluid temperature.
2. The heat transfer co-efficient and rates due to latent heat associates with phase change are generally much higher compared with the normal convention process (Without phase change)
3. High rate of heat transfer is achieved with small temperature difference .

The phenomena associated with boiling and condensation are much more complex (Than the normal convection process) Due to the following being vary significant

1. Latent heat effects
2. Surface tension

Description of apparatus:-

This unit made by DATACONE for laboratory purpose, it consists of a glass water bath with an immersed heating coil in it. Two electrodes are fixed to the lid of water bath while, the ends of these electrodes produced in to the water. A Thin nichrome wire is connected between the ends of the electrodes. The electrodes are connected to the mains through a auto transformer. A Voltmeter and an Ammeter are provided to measure the volt and current supplied to the electrode.

Technical specification:-

1. Diameter of nicrome wire (d) :- 36 Gauge = 0.19 mm
2. Length of nicrom Wire (L) :- 100 mm.
3. Heater Capacity :- 1000 Watt
4. Auto Transformer :- 230 V. 8 Amp.
5. Glass Water Bath :- 200 mm dia.

Experimental procedure:-

1. Put sufficient water in water bath (i.e. half of bath).
2. Cut the sufficient length of Nichrome wire i.e. 150mm.
3. Fix wire between electrodes and immerse it in water bath.
4. Switch ON the water heater supply till the water attains the required temperature.
5. Switch Off the water heater supply and Switch ON the wire supply(Auto transformer position should be ZERO before start the button).
6. With the help of auto transformer increase the supply of nichrome wire gradually.
7. Observe and note the Voltmeter & Ammeter reading at the instance when the nichrome wire brakes or melt.
8. Simultaneously Note down the temperature of water in water bath.
9. Repeat the procedure for different bath temperatures.
10. Calculate the critical heat flux at different bath temperatures.
11. Plot the graph of Critical Heat Flux Vs Bath Temperature.

Observation table:-

Sr. No.	Bath Temp. in (T) ^oC	Ammeter Reading (I) in Amp.

Calculation:-

1. Surface Area Of Wire (A)

   $$A = \pi \, d \, L$$

   Where,

   d = Diameter of wire

   L = Length of wire

2. Critical Heat Flux

   $$= V\,I/A$$

   Where,

I = Ammeter Reading

A = Surface Area

V = Voltmeter Reading(Unity)

Calculations:-

Conclusion:-

Marks: **Date:** **Faculty Sign:**

PRACTICAL : 07

HEAT TRANSFER THROUGH NATURAL (OR FREE) CONVECTION

Introduction:-

In contrast to the forced convection, Natural convection phenomena are due to the temperature the difference between the surface & the fluid & are not created by any external agency. Natural convection flow patterns for some commonly observed situations are shown in fig.

The present experimental set up is designed & fabricated to study the natural convection phenomenon from a vertical cylinder in terms of the variation of local heat transfer coefficient & its compression with the valve obtain by using an appropriate correlation.

Description of apparatus:-

The apparatus consists of a brass tube fitted in a duct in vertical fashion. The duct is open at the top & bottom & forms an enclosure & serves the purpose of un-distributed surrounding. One side of the duct is made up of Perspex for visualization. An electric heating element is kept in the vertical tube which intern heats the surrounding air by natural convection. The temperature of the vertical tube is measured by seven thermocouples. The heat input to the heater is measured by a dimmerstat.

The vertical cylinder with the thermocouple, position are in fig. while the possible flow pattern & also the variation of local heat transfer coefficient is shown in fig. 3. The tube surface is polished to minimise the reduction losses.

Specifications:-

1. Dia. of the tube (d) : 38 mm.
2. Length of tube (L) : 500 mm.
3. Duct size 20 mm. x 20 mm. x 0.75 length.
4. No. of thermocouples : 7.& are shown as (1) to (7) & as (1) to (7) & are marked on temperature indicator switch.
5. Thermocouple No. 8 reads the ambient temperature, & is kept in the duct.
6. Temperature Indicator: 0 - 300 ^{o} C Multi Channel. type Calibrated for Co/Constant, thermocouples with compensation of ambient from 0 - 50 ^{o} C.
7. Ammeter.
8. Voltmeter 0 - 300 V.
9. Dimmerstat 2 Amp. 260 V.

Experiment:-

To determine the surface heat transfer coefficient for a vertical tube loosing heat by natural convection.

Theory:-

When a hot body is kept in a still atmosphere, heat is transferred to the surrounding fluid layer in contact with the hot body gets heated.

Rises up due to the decrease in its density & the cold fluid rushes in to take place. The process is continues & the heat transfer particles. The heat transfer coefficient is given by:

$$h = q/A_S \cdot (T_S - T_a) \qquad \text{......... (1).}$$

Where :

h : Average surface heat transfer coefficient. (Kcal/hr-m^2 - ^{o}C)

q : Heat transfer rate (Kcal - hr)

A_S : Area of the heat transferring surface coefficient. ndL.

T_S : Average surface temperature (^{o} C).

$$\frac{(T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7)}{7}$$

T_a : Ambient temperature in the duct (^{o} C). T_8.

The surface heat transfer coefficient, of a system transferring heat by natural convection depends on the shape. dimensions & orientation of the fluid & the temperature difference between heat transferring surface & the fluid. The dependence of 'h' on all the above mentioned parameters is generally dimensional groups, as follows :

$$\frac{h.L.}{K} = A \left[\frac{g.L^3 \ \beta \ . \ \Delta T}{\nu^2} \ . \ \frac{Cp \ . \ \chi}{K} \right]^n \qquad \text{........(2)}$$

Where, $\frac{h.L}{K}$ is called the nusselt number.

$g.L^3 \, . \, \beta \, . \, T/\nu^2$ is called the grashoof Number.

Cp r The Prandtl number.

K

A & n are constants depending on the shape & orientation of the heat transferring surface.

Where , L : A characteristics dimension of the surface.

K : Thermal Conductivity of fluid.

ν: Kinematics Viscosity of fluid.

Cp: Specific heat of fluid.

X : Dynamic Viscosity for fluid.

β : Coefficient of Volumetric expansion for fluid.

g : Acceleration due to gravity.

$\Delta T : T_S - T_a$

For Gases:

$$\beta = \frac{1}{T_f + 273} \quad ({}^0k)^{-1}$$

Where :

$$T_f = \frac{(T_S + T_a)}{2}$$

For a vertical cylinder losing heat by natural convection, the constants A & n of equation (2) have been determined & the following empirical correlations obtained.

$$\frac{h.L}{K} = 0.59\ (Gr\ .\ pr)^{0.25} \text{ for } 10^4 < Gr.pr < 10^9 \quad .....(3).$$

$$\frac{h.L}{K} = 0.13\ (Gr\ .\ pr)^{1/3} \text{ for } 10^9 < Gr.pr < 10^{12} \quad .....(4).$$

L : Length of the cylinder.

All properties of the fluid are determined at the mean film temperature. (T_f).

Procedure:-

1. Put on the supply & adjust the dimmerstat to obtain the require heat input.(Say 40W, 60W, 70W etc).
2. Wait till the steady state is reached. Which is confirmed from temperature readings? (T_1 to T_7)
3. Measure surface temperature at the various points T_1 to t T_7.
4. Note the ambient temperature T_8.
5. Repeat the experiment at different heat inputs. (Do not exceed 80 W.)

Observation:-

O.D. Cylinder D = 38 mm.

Length of Cylinder L = 500 mm.

Input to Heater = VI Watts.

Where, V = Volts.

I = Amps.

Observation table:-

Sr. no.	V Volts	I Amp.	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_S	T_8	q
1												
2												
3												
4												

Calculation:-

1. Calculate the value of average surface heat transfer coefficient, neglecting end losses using equation (1).

T_S = T_1 to T_7

$$h = \frac{q}{A_S\ (T_S - T_a)}$$

q = VI

A_S = Area of the heat transfer coefficient.

= π dL

= π x 0.038 x 0.5

= 0.0596 m^2.

2. Calculate & plot (fig 4) the variation of loacl heat transfer coefficient along the length of the tube

$\Delta T = T_S - T_a =$ ^0C

Mean Temp.

$$T_f = \frac{T_S + T_a}{2} = \quad {}^oC.$$

Properties of Air at T_f= ^0C.

i. K = W/mK

ii. g = 9.81 m/sec^2.

iii. ν = m^2/sec

iv. Pr =

v. $\beta = \frac{1}{} =$ K^{-1}

$$T_f + 273$$

vi. $$G_R = \frac{g L3 \beta \Delta T}{\nu^2}$$

For a vertical cylinder losing heat by natural convection, the constants **A** & **n** of equation (2) have been determined & the following empirical correlations obtained.

$$\frac{h.L}{K} = 0.59 \, (Gr \,.\, pr)^{0.25} \text{ for } 10^4 < Gr.pr < 10^9 \quad .....(3).$$

$$\frac{h.L}{K} = 0.13 \, (Gr \,.\, pr)^{1/3} \text{ for } 10^9 < Gr.pr < 10^{12} \quad .....(4).$$

L : Length of the cylinder.

All properties of the fluid are determined at the mean film temperature(T_f).

Precaution:-

1. Keep dimmerstat to zero V position & increase it slowly.
2. Operate the change over switch of temperature indicator gently from one position to other i.e. from 1 to 8 position.
3. Never exceed 80 Watts

Results & Discussion:

Some typical results are shown in Fig. 4. for different heater inputs. The heat transfer coefficient is having a maximum value at the beginning as excepted because of the just starting of the building of the boundary layer & it decreases as excepted in the upward direction due to thickening of layer & which is laminate one. This trend is maintained up to half of the lengths (approx.) &

beyond that there is little variation in the value of local heat transfer coefficient because of the transition & turbulent boundary layers. The last point shows somewhat increase in the value of which is attributed to end loss causing a temperature drop.The comparison of average heat transfer coefficient is also made with predicted values are somewhat less than experimental values due to the heat loss by reduction.

Calculation:-

Characteristics of air:-

T ^{0}C	ς Kgm/m^3 2	C_p Kcal/Kgm- ^{0}C 3	4 x 10 ^{6} Kgm/ms 4	K Kcal/nr-m ^{0}C	Pr	ν x 10 ^{6} m^2/sec
0	1.293	0.240	17.1675	0.0210	0.707	13.28
10	1.247	0.240	17.658	0.0216	0.705	14.16
20	1.305	0.240	18.1195	0.0223	0.700	15.00
30	1.165	0.240	18.639	0.0230	0.701	16.00
40	1.128	0.240	19.1295	0.0237	0.699	16.96
50	1.093	0.240	19.620	0.0243	0.698	17.95
60	1.060	0.240	20.110	0.0249	0.696	18.97
70	1.029	0.241	20.601	0.0255	0.694	20.02

80	1.000	0.241	21.0915	0.0262	0.692	21.09
90	0.972	0.241	21.483	0.0269	0.690	22.10
100	0.946	0.241	21.876	0.0276	0.688	23.13
120	0.896	0.241	22.857	0.0287	0.686	28.45
140	0.854	0.242	23.740	0.0300	0.684	27.80
160	0.815	0.243	24.525	0.0313	0.682	30.09
180	0.779	0.244	25.310	0.0325	0.681	32.49
200	0.746	0.245	25.966	0.0338	0.680	34.85
250	0.674	0.248	27.370	0.0367	0.677	40.61
300	0.615	0.250	29.724	0.0396	0.674	48.33
350	0.566	0.253	31.392	0.0432	0.676	55.46
400	0.524	0.255	33.060	0.0448	0.678	63.09
500	0.456	0.261	36.199	0.0494	0.687	79.38
600	0.404	0.266	39.142	0.0535	0.699	96.89
700	0.362	0.271	41.790	0.0577	0.706	115.40
800	0.329	0.275	44.341	0.0617	0.713	134.80
900	0.301	0.280	46.695	0.0656	0.717	155.10
1000	0.227	0.283	49.050	0.0694	0.719	177.10

Temp 0C	Density Kg/m3	Kinematic Viscosity V x 106 m2 /s	Prandil Number Pr	Thermal Diffusivity m2/nr	Specific Heat Cp J/Kg K	Thermal Conductivity K x 103	Coefficient of Viscosity x 106 N3/m2 or Kg/m
-50	**1.584**	**9.23**	**0.728**	**45.7**	**1013**	**20.35**	**14.61**
-40	**1.515**	**10.04**	**0.728**	**49.6**	**1013**	**21.17**	**15.20**
-30	**1.453**	**10.80**	**0.723**	**53.7**	**1013**	**21.98**	**15.69**
-20	**1.395**	**11.61**	**0.716**	**68.3**	**1009**	**22.79**	**16.18**
-10	**1.342**	**12.43**	**0.712**	**52.8**	**1009**	**23.61**	**16.67**
0	**1.293**	**13.28**	**0.707**	**67.7**	**1005**	**24.42**	**17.16**
10	**1.247**	**14.16**	**0.705**	**72.2**	**1005**	**25.12**	**17.65**
20	**1.205**	**15.06**	**0.703**	**77.1**	**1005**	**25.93**	**18.14**
30	**1.165**	**16.00**	**0.701**	**82.3**	**1005**	**26.75**	**18.63**

40	**1.128**	**16.69**	**0.699**	**87.5**	**1005**	**27.56**	**19.12**
50	**1.093**	**17.95**	**0.698**	**92.6**	**1005**	**28.26**	**19.61**
60	**1.060**	**18.97**	**0.696**	**97.9**	**1005**	**28.96**	**20.10**
70	**1.029**	**20.02**	**0.694**	**102.8**	**1009**	**29.66**	**20.59**
80	**1.000**	**21.09**	**0.692**	**108.7**	**1009**	**30.47**	**21.08**
90	**0.972**	**22.10**	**0.690**	**114.8**	**1009**	**31.28**	**21.48**
100	**0.946**	**23.13**	**0.688**	**121.1**	**1009**	**32.10**	**21.87**
120	**0.898**	**25.45**	**0.686**	**132.6**	**1009**	**33.38**	**22.85**
140	**0.854**	**27.80**	**0.684**	**145.2**	**1013**	**34.89**	**23.73**
160	**0.815**	**30.09**	**0.682**	**158.0**	**1017**	**36.40**	**24.52**
180	**0.779**	**32.49**	**0.681**	**171.0**	**1022**	**37.80**	**25.30**
200	**0.746**	**34.85**	**0.680**	**184.9**	**1026**	**39.31**	**25.99**
250	**0.674**	**40.61**	**0.677**	**210.6**	**1038**	**42.68**	**27.36**
300	**0.615**	**48.20**	**0.674**	**257.6**	**1047**	**46.05**	**29.71**
350	**0.566**	**55.46**	**0.676**	**294.7**	**1059**	**49.08**	**31.38**
400	**0.524**	**63.09**	**0.678**	**335.2**	**1067**	**52.10**	**33.05**
500	**0.456**	**79.38**	**0.687**	**415.1**	**1093**	**57.45**	**36.19**
600	**0.404**	**96.99**	**0.699**	**499.0**	**1114**	**62.22**	**39.13**
700	**0.362**	**115.40**	**0.706**	**588.2**	**1135**	**66.87**	**41.78**
800	**0.329**	**1347.80**	**0.713**	**682.0**	**1156**	**71.76**	**44.33**

Marks: **Date:** **Faculty Sign:**

PRACTICAL:- 08

HEAT TRANSFER THROUGH FORCED CONVECTION

Introduction:-

1. Average surface heat transfer coefficient for a pipe losing heat by forced convection to air flowing through it can be obtained for different air flow & heat flow rates.
2. Reynold's number & Nusselt number for each experimental condition . Plot these values on Log - log graph. Plot on the same graph the Dittus-Boelter correlation.
3. To plot & comment on the surface temperature distribution along the length of pipe.

Description of apparatus:-

The apparatus consists of Blower unit fitted with a test pipe. The test section is surrounded by Nichrome band heater. Four thermocouples are embedded on the test section the thermocouples are placed in the air stream at the entrance & exit of the test section to measure the temperature. Test pipe is connected to the delivery side of the blower along with an orifice to measure flow of air through pipe. Input to the heater is given through a dimmerstat & measured by meters. It is to be noted that only a part of the total heat supplied is utilized in heating the air. A temperature indicator with cold junction compensation is provided to measure temperature of pipe wall at various points in the test section. Air flow is measured with the help of orifice meter & the water manometer fitted on the board.

Specification:-

1.	Pipe Dia. (Do)	:	33 mm.
	Pipe Dia. (Di)	:	26 mm.
2.	Length of Test Section (L)	:	400 mm.
3.	Blower		
4.	Orifice Dia. (d)	:	16 mm.
5.	Dimmerstat	:	0 - 2 Amp, 260 V AC.
6.	Temperature Indicator:		Range 0 - 300 ^{o}C, Calibrated for Cr/Al thermocouple
7.	Voltmeter	:	0 -200 V. AC.
8.	Ammeter	:	0 - 2 Amp.
9.	Heater	:	Nichrome wire, Band type 400 W.

Precaution:-

1. Keep the dimmerstat at zero position before switching ON the power supply.
2. Start the blower unit first.
3. Increase the voltmeter gradually.
4. Do Not stop the blower in between the testing period.
5. Do not disturb thermocouples while testing.
6. Operate selector switch of Temperature Indicator gently.
7. Do not exceed 200 W.

Procedure:-

1. Start the blower & adjust the flow by means of gate valve to some desired difference in manometer level.

2. Start the heating of test section with help of dimmerstat & adjust desired input with the help of Voltmeter & Ammeter

3. Take readings of all thermocouples at an interval of 10 min until steady is reached.

4. Note the heater input.

Observation:-

1. Outer dia. of the pipe (Do) : mm.
2. Inner Dia. of test pipe (Di) : mm.
3. Length of test section (L) : mm.
4. Dia. of the orifice (d) : mm.

Observation table:-

Sr. No.	Voltage V Volts	Current A Amp	**Temperatures**						Manometer Reading H = cm of water
			T_1	T_2	T_3	T_4	T_5	T_6	
1.									
2.									
3.									

Calculation:-

1. The rate at which air getting heated is calculated as :

$$q_a = m\ cp\ \Delta T$$

Where, m = Mass flow of air kg/sec

ΔT = Temp. rise in air

= $T_6 - T_1$ ^{0}K

Cp = Specific heat of air -------- kJ/kg ^{0}k

Mass flow of air (m)

$$m = Q \times \rho a$$

Where , ρ_a = density of air to be evaluated at ($T_1 + T_2$)/2 kg/m^3

Q = Volume flow rate of air

$$= Cd \times \frac{\pi}{4} \times d^2 \sqrt{\frac{2g \times H \times \varsigma w}{\varsigma a}}$$

--------m^3/ s

Where,

d = Dia of orificemter ---------m

cd = Co-efficient of discharge

= 0.64

H = Diff.of water level in manometer------m

ρ w = Density of water

= 1000 kg/m^3

ρ a = Density of air at

$T_1 + T_2$

mean bulk Temp ------ kg/m^3

2

g = Gravitational Acceleration

= 0.81 m/s^2

2. Surface Heat Transfer Co-efficient (h_a)

$$h_a = \frac{q_a}{A\,(T_s - T_a)} = \text{--------Watt/ } m^2\,k$$

Where, q_a = heat rate at which air is getting heated

= V x I --------- Watt

A = Test section Area -------- m^2

= $\pi\ D_i\ L$

T_a = Average Temp. of air -------- ^oK

$$= \frac{T_1 + T_6}{2}$$

T_s = Average surface Temp. ------- ^{0} K

$$= \frac{T_2 + T_3 + T_4 + T_5}{4}$$

3. Reynold's Number (Dimension less Number) (Re)

$V\,D_i$

$$Re = \frac{\qquad}{\upsilon} =$$

Where,

V = Velocity of air -----------m/s

$$= \frac{4\,Q}{\pi \quad D_i}$$

Where, υ = Kinematic viscosity to be evaluated at average bulk Temp

$$\frac{T_1 + T_6}{2} \qquad \text{-----------}m^2/s$$

4. Nusselt Number (Nu)

$$Nu = \frac{h_a \; D_i}{K} =$$

Where,

h_a = Surface heat Transfer

Co-efficient -------- watt/m$^{2\,0}$ k

D_i = Inner dia of pipe

K = Thermal conductivity of air to be evaluated at average bulk temp.

$$\frac{T_1 + T_6}{2} \qquad \text{--------}\ w/m\,^0k$$

5. **Plot the values of Nu Vs Re on a log-log paper.**
6. **Prandtl Number (Pr)**

   Pr = Prandtl number to be evaluated at a average

   bulk temp. $\frac{T_1 + T_6}{2}$

7. **The appropriate correlation for turbulent flow through closed conduits is Dittus-Boelter Correlation**

   $$Nu = 0.023 \ Re^{0.8} \times Pr^{0.4}$$

8. **Draw this correlation on the same graph & compare the two.**

Calculation:-

Conclusions:-

Marks: **Date:** **Faculty Sign:**

PRACTICAL NO: 09

EXPERIMENT ON PARALLEL FLOW AND COUNTER FLOW HEAT EXCHANGER

Introduction:-

Heat exchanges are devices in which heat is transferred from one fluid to another. The necessity for doing this arises in a multitude of industrial application. Common examples of heat exchanger are :

The indicator of a car, the consider at the back of a domestic refrigerator of steam boiler of a thermal power plant heat exchangers are analised in the categories :

1. Transfer type.
2. Storage type.
3. Direct contact type.

A transfer type of heat exchanger is one in which both fluids pass simultaneously through the device & heat is transfer through operating valves.

In practice most of the heat exchangers used are transfer tube ones. The transfer tube exchanger further according to flow arrangement as :

1. Parallel flow in which fluids flow in the same direction.
2. Counter flow in which they flow in opposed direction.
3. Cross flow in which they flow at right angle to each other.

A simple example of transfer tube heat exchanger can be in the form of a tube in tube type arrangement. One fluid flowing through the inner tube & the other through the anulus surrounding it. The heat transfer takes place across the walls of the inner tube.

Description of apparatus:-

The apparatus consists of a tube in tube type concentric tube heat exchanger.

The hot fluid is hot water which is obtained from on electrical geyser & it flows through the inner tube. While the cold fluid is cold water, flowing through anules. The hot water flows in one direction & the flow rate of which is collected by means of a wall. The cold water can be admitted at one end enabline the heat exchanger to run as a parallel flow apparatus or a counter flow apparatus this is done by wall operations.

The main of this experiment is to study & compare

1. Temperature distribution in parallel flow & counter flow heat exchanger.
2. Heat transfer rates in parallel flow & counter flow.
3. Overall heat transfer coefficient in parallel & counter flow.
4. To obtained the effectiveness in both cases.

The experiments are conducted by keeping identical flow rates while running the unit as parallel & counter flow. The temperature measured by digital temp. indicator & the flow rates by a rotameter. The readings are recorded when steady state is recorded. The outer tube is provided with adequate thermocouples insulation to minimize the heat losses.

Specifications:-

1. Inner tube material : G.I.

Internal dia. of inner tube	= di	=	26 mm.
Outer dia. of inner tube	= do	=	34 mm.
Length of inner tube	= Li	=	1.2 m.
Thickness of inner tube	= ti	=	4 mm.

2. Outer tube material : G.I.

Internal dia. of outer tube	= Di	=	68 mm.
Outer dia. of outer tube	= Do	=	76 mm.
Length of outer tube	= Lo	=	1.2 m.
Thickness of outer tube	= to	=	4 mm.

3. Specific heat of water = 4.186 Kw/Kg^{o}K

Procedure:-

1. Start the flow on the hot water side
2. Start the flow through annulus & the exchanger as parallel flow unit.
3. Put ON the geyser.
4. Adjust the flow rate on hot water side between the rate of 1.5 - 4 LPM.
5. Adjust the flow rate on cold water side between range of 3 - 8 LPM.
6. Keeping the flow rate some wait till the steady state conditions are reached
7. Record the temperature on hot water & cold water side & also the flow rates
8. Repeat the experiment with a counter under identical flow conditions.

Calculations:-

1. Heat transfer rate for hot water

$$q_h = m_h \, Cp_h \, (Th_i - Th_o)$$

2. Heat transfer rate for cold water

$q_c = m_c\, Cp_c\, (Tc_o - Tc_i)$

3. Average heat transfer rate (q)

$$q = \frac{q_h + q_c}{2}$$

4. Logarithmic mean temperature difference

$$\Delta T_m = \frac{\Delta T_i - \Delta T_o}{\ln(\Delta T_i / \Delta T_o)}$$

Where,

$T_i = Th_i - Tc_i$

$T_o = Th_o - Tc_o$

5. Over all heat transfer coefficient

$$q = U \times A \times \Delta T_m$$

Where,

U based on $A_i = \pi\, d_i\, L$

U based on $A_o = \pi d_o\, L$

6. Compare the value of ΔT_m & q in parallel & counter flow.

   Note that if experiment is conducted very carefully then the superiority of counter flow in terms of higher value of ΔT_m of excess value of q for self flow condition can be revealed.

   The value of over all heat transfer coefficient U is more or less same for both the runs.

7. Effectiveness of the heat exchanger

$$= \frac{m_c \cdot Cp_c\, (Tc_o - Tc_i)}{m_h \cdot Cp_h\, (Th_i - Th_o)}$$

Calculations:-

Conclusions:-

Marks: **Date:** **Faculty Sign:**

PRACTICAL NO:- 10

EXPERIMENT ON PLATE TYPE HEAT EXCHANGER

Introduction:-

The plate type heat exchanger have become more popular for process heat transfer. Extremely high rate of heat transfer ,compactness ,flexibility in design and operation ,ease of cleaning and low liquid hold up are some of the advantages of plate heat exchangers which make it suitable for processing heat sensitive material in brewing and dairy industries.

Theory:-

This type is well suited to liquid liquid duties in turbulent flow . it is also suitable for central cooling of fresh , non corrosive and non fouling water by means of readily available cheap and blackish water. Condensation of vapours at moderate pressure (0.5 to 4 atm) is also economically handled by plate heat exchangers .The maximum rate of heat transfer is obtained when the fluids moving in adjacent spaces are in counter current conditions.

Procedure:-

1) Give supply to the heaters.
2) Wait for some time till water become heated for certain degree of temperature rise.
3) Start the hot water and cold water flow through the heat exchanger.
4) Measure the temperature T_1 , T_2 ,T_3, T_4 .

Observation:-

1) T_1 = Hot water outlet temperature.

2) T_2 = Cold water outlet temperature.
3) T_3 = Cold water inlet temperature.
4) T_4 = Hot water inlet temperature.
5) m_c = flow rate of cold water.
6) mh = flow rate of hot water.

Observation table:-

Sr. No.	T_{hi} (T_4)	T_{ho} (T_1)	T_{ci} (T_3)	T_{co} (T_2)

Calculation:-

$$q = (m\, C_p\, \Delta T)\ \text{hot or cold}$$

$$\text{Effectiveness}\ \epsilon = \frac{\text{Actual heat transfer}}{\text{Maximum possible heat transfer}}$$

$$\epsilon = \frac{(m\, C_p\, \Delta T)\ \text{hot or cold}}{(m\, C_p)\,(T_{hi} - T_{ci})}$$

Conclusions:-

Marks: **Date:** **Faculty Sign:**

PRACTICAL:-11

TO DETERMINE STEFAN BOLTZMAN CONSTANT

Introduction:-

The most commonly used law of thermal radiation is the Stefan Boltzman law, which states that thermal radiation heat flux or emissive power Q iliac surface is proportional to the fourth power of absolute temperature of the surface & is given by .

$$\frac{Q}{A} = e_b = 6\, T^4 \text{ Watt/m } {}^oK^4 \, .$$

The constant of proportionality 6 is called the Stefan Boltzman constant, & has a value of 5.67 x 10^{-8} w/m^2 K^4 & in S.I unit 4.876 x 10^{-8} Kcal/hr. m^2 K^4 .

The Stefan Boltzman law, can be derived by integrating the Planck's law over the entire spectrum of wavelengths from O to ∞ through historically, it is worth noting that, the Stefan Boltsman law, was independently developed before planch's law. The object of this experimental set up is to measure the value of this constant fairly dose by on easy coveragement.

Description of apparatus:-

The apparatus as shown in fig. , is centered on a flanged copper hemisphere 'B', fixed on a flat non-conducting plate 'A' the outer surface 'B' is enclosed in a metallic water jacket used to heat 'B' to some suitable constant temperature. The hemispherical shape of 'B' is chosen solely on the grounds that, it simplifies the task of changing the water between 'B' & 'C'.

Four Alumel-Chromel thermocouples are attached to various points on surface of 'B' to measure its mean temperature to be read by a temperature indicator.

The disc 'D', which is mounted in an insulating Bakelite sleeve 'S' is fitted in a hole drilled in the center of base plate 'A'. The lose of 'S', is conveniently supported from under side of 'A' & chromel alumel thermocouple is used to measure the temperature of 'D' (T_S). A thermocouple is mounted on the disc to study the rise of its temperature.

When the disc is inserted at the temperature T_5, ($T_5 > T$ i.e the temperature of the enclosure) the response of temperature change of the disc with time is used to calculate the Stefan Boltzman constant.

Specifications:-

1. Hemispherical enclosure dia. : 200 mm.
2. Suitable sized water jacket for hemisphere.
3. Fixing arrangement for sleeve.
4. Test disc dia. : 25 mm.
7. Mass of test disc : 0.005 Kg.

   'S' : Specific heat of the disc for copper from the table

   0.1 Kcal/Kg. ^oC (Ref : Mech Engg. Hand Book)

   0.41868 Kj/Kg ^oC (In S.I. Unit)

8. Number of thermocouples mounted on ' B': 4
9. Number of thermocouples mounted on 'D': 1
10. Temperature indicator : Digital 1^oC least count

0- 200^{o}C with built in cold junction

11. Immersion water heater of suitable capacity : 1.5 Kw.

12. Hot water tank.

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

Procedure:-

1. The water is heated in the tank by the immersion heater upto a temperature of about 90^{o} C.
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' & 'A' will come to some uniform temperature T in short time after filling the hot water in the jacket. The inertia of hot water is quite adequate to present significant cooling in the time required to conduct 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 'T_5' (To be sensed by a separate thermocouple)

   The radiation energy falling on 'D' from the enclosure is given by

   $$E = A_D \, . \, T^4 . \, 6 \qquad \text{..................} \ 1$$

   Where , A_D = Area of disc.

   T = Average temperature of the enclosure recorded by the thermocouples.

   The emissivity of the disc 'D' is assumed to be unity (black disc)

   The radiant energy disc 'D' emitting into the enclosure will be,

$E_1 = A_D \,.\, T_5^4\, 6.$ 2

Net heat input to Disc 'D' per unit time is given by equation 1 & 2.

i.e $E - E_1 = 6\, A_D\, (T^4 - T_5^4).$ 3

of the disc 'D' mass 'm', & specific heat 'S', then a art time after 'D' is metered in 'A'.

$$m.s \left[\frac{dT}{dt} \right] = 6\, A_D\, (T^4 - TS^4)$$

OR

$$6 = \frac{m.s\, (dT/dt)\, t = 0}{A_D\, (T^4 - TS^4)}$$

In the equation (dT / dt) denoted the rate of rise of temperature, of

t = 0 the Disc 'D' at the instant, when its temperature id 'T_5' & will very with 'T_5' it is clearly best measured at time t = 0 before heat conducted from 'A' to 'D', begin to take any significant effect.

This is obtained from heat of temperature rise of 'D' with respect to time & obtaining its slope at t = 0.

When temperature = T_5

This will be the required valve (dT/dt) at t = 0.

The thermocouple mounted on disc is to be used for this purpose.

Note that, the disc 'D' with its insulting above sleeve 'S', is placed quickly in position & start the time & 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 'A' to 'D'.

The Experiment is repeated for obtaining better results.

1. Mass of the test disc (m) : 0.005 Kg.
2. Specific heat of the disc for material (S)

   = 0.1 Kcal/Kg. ^{o}C (Copper disc). (In MKS Units)

   = 0.41868 Kj/Kg ^{o}C (In S.I. Unit)

Observation table:-

Thermocouple	**Temperature in ^{O}C** 1	2
T_1		
T_2		
T_3		
T_4		

3. Average Temperature in ^{o}C = $\dfrac{T_1 + T_2 + T_3 + T_4}{4}$

   Average Temperature in ^{o}K (T) = $^{o}K^4$

4. Temperature of disc D at the instant when it is inserted (T_5).

   T_5 = in ^{o}C =

   T_5 = in ^{o}K =

5. Temperature time response of the disc.

   Use the disc Thermocouple on T.I. & note down T_5 at the time interval of 10 sec. with

Time (Sec) t	**Temperature r**
00	
10	
20	

30	
40	
50	
60	
70	
80	
90	
100	
110	
120	

Plot the graph of ‘dT’ against ‘t’

6. Obtain the slope from the graph (dT/dt) at t = 0.
7. The value of 6 can be obtained by using equation

$$m.s \left[\frac{dT}{dt} \right] = A_D \, (T^4 - TS^4)$$

$$6 = \frac{m.s \, (dT/dt) \, t = 0}{A_D \, (T^4 - TS^4)} \quad \text{Kcal / hr . } K^4 . \, m^2 \text{ (MKS Unit)}$$

$$6 = \frac{m.s \, (dT/dt) \, t = 0}{A_D \, (T^4 - TS^4) \, . \, 0.86} \quad w / m^2 . \, K^4 \text{ (S.I Unit)}$$

Calculation:-

Conclusions:

Marks: **Date:** **Faculty Sign:**

PRACTICAL: 12

TO DETERMINE EMMISIVITY OF A TEST PLATE

Introduction:-

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

An idealized black surface is one which absorbs all the incident radiation with reflectivity & transmissivity equal to zero. The radiant energy per unit time area from the surface of the body is called as the emissive power & is usually denoted by e. 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.

$$\text{Thus, } E = \frac{e}{eb}$$

For black body absorbvity = 1 & by the knowledge of Kirchoff's Law emissivity of the black body becomes unity.

Emissivity begin a property of the surface depends on the nature of the surface & temperature.

It is obvious from the Stefan Boltzman's Law that the prediction of emissive power of a surface requires knowledge about the values of it's emissivity & therefore much experimental research in redaction has been concentrated on measuring the values of emissivity as function of surface temperature. The present experimental set up is designed & fabricated to measure the property of emissivity of the test plate surface at various temperature.

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

Table 1

	Material	Temperature	Emissivity
Metals	Polished Copper Steel, Stainless Steel, Nickel, Aluminum (Oxidised)	20^{o} $90 - 540\ ^{o}C$	0.15 increases with temperatures 0.20 to 0.33
Non-Metal	Brick, Wood, Marble, Water.	$20 - 100\ ^{o}C$	0.80 to 1

Description of apparatus:-

The experimental set up consists of two circular Aluminum plates identical in size & is provided with heating coils sandwiched. The plates are mounted on brackets & are kept in an enclosure so as to provide undisturbed natural convection surroundings.

The heat input to the heater is varied by separate dimmerstats & is measuring by using an ammeter & a voltmeter with the help of double throw switch (fig 1.). The temperatures of the plates are measured by thermocouples. Separate wires are connected to diametrically opposite points to get the average surface temperature of the plates. Another thermocouple is kept in the enclosure to read the ambient temperature of enclosure.

Plate (1) is blackened by a thick layer of lamp black to from the idealised black surface where as the plate (2) is the test plate whose emissivity is to be determined.

The heater inputs to the two plates are dissipated from the plates by conduction, convection & radiation. The experimental set up is designed in such a way that under steady state conditions the heat dissipation by conduction & convection is same & the difference in the heater input readings is because of the difference in radiation characteristics due to their different emissivities. 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, $W = V_1 I_1$

W_2 = Heater input to test plate, $W = V_2 I_2$.

A = Area of plates = $\dfrac{\pi d^2}{4.}$ m^2

d = Diameter of the plate = 155 mm.

$T_1 = T_s$ = Temperature of black plate ^oK.

$T_3 = T_D$ = Ambient Temperature ^oK

E_b = Emissivity of black plate.

(to be assumed equal to unity).

E = Emissivity of non-black test plate.

σ = Stefan Boltzman Constant.

MKS = 4.876×10^{-8} Kcal/hr - m^2 - $^oK^4$

(In MKS units)

SI = 5.67×10^{-8} $w/m^2 K^4$ (In S.I. units)

By using Stefan Boltzman Law :

$$(W_1 - W_2) = (E_b - E)\, \sigma\, .\, A\, (T_S^4 - T_D^4)$$

Procedure:-

1. Gradually increase the input to the heater to black plate & adjust it to some value viz. 30, 50, 75 W. and adjust the heater input to test plate slightly less than the black plate 27,35, 55 W etc.

2. Check the temperature of the two plates with small time intervals & 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 require some trial & error & one has to wait sufficiently (more then 1 Hour or so) to obtain the steady state condition.

4. After attaining the steady state condition record the temperature, Voltmeter & Ammeter readings for both the plates.

5. The same procedure is repeated for various surface temperature in increasing order.

Precaution:-

1. Use stabilized AC Single phase supply (preferably).
2. Always keep the dimmerstat at zero position before start.
3. Use 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 the supply voltage is fluctuating or if the input is not adjusted till the satisfactory steady state condition reached.

Specification:-

1. Dia. Of Test Plate (d) = 160 mm

_ Material Aluminum.

2. Dia. Of Black Plate(d) = 160mm __

3. Heater for (1) Nichrome strip wound on mica sheet & sandwiched between two mica sheets.

4. Heater for (2) as above. Capacity of heater = 200 W each Approx.

5. Dimmerstat for (1) 0 to 2 A, 0 to 260 V.

6. Dimmerstat for (2) 0 to 2 A, 0 to 260 V.

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

8. Enclosure size 580 mm x 300 mm x 300 mm. Approx.

9. Thermocouples : Chromel Alumel : 3 Nos.

10. Temperature Indicator 0 - 300 ^{o} C.

11. D.P. D.T. Switch.

Observation table:-

Sr. No	Black Plate			Test Plate			ENCLOSURE TEMP
	V_1	I_1	T_1	V_2	I_2	T_2	T_3 ^{o}C
1							
2							
3							

For SI Unit :

$(W_1 - W_2) = (E_b - E)\, \sigma \,.\, A\, (T_S^4 - T_D^4)$

Derivation:-

$W_1 = \sigma\, A\, E_b\, (T_1^4 – T_3^4)$ …………………… 1

$W_2 = \sigma\, A\, E\, (T_2^4 – T_3^4)$ …………………… 2

Where,

a. W_1 = Heat input to Body coated with lamp black

$= V_1 I_1$ Watts In S.I. Units

$= V_1 I_1 \times 0.86$ Kcal In M.K.S Units

Where,

V_1 = Voltage input to black body.

I_1 = Current input to black body.

b. W_2 = Heat input to Test Body :

$= V_2 I_2$ Watts In S.I. Units

$= V_2 I_2 \times 0.86$ Kcal In M.K.S Units

Where,

V_2 = Voltage input to Test body.

I_2 = Current input to Test body.

c. σ = Stefan Boltzman Constant

$= 5.67 \times 10^{-8}$ W/M^2 K^4. In S.I. Units

$= 4.876 \times 10^{-8}$ Kcal/hr m^2 $^oK^4$. In M.K.S. Units

d. A = Area of disc (m^2).

T_1 = Surface temperature of Black Body. ^oK

T_2 = Surface temperature of Test Body. ^oK

T_3 = Ambient temperature of enclosure ^oK

E = Emissivity of Test Body to be determine (absorbing)

E_b = Emissivity of Black Body

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

With increase in temperature, the test surface becomes somewhat dull & therefore its emissivity increases with increase of surface temperature.

e. From Eq. 1 & 2, we get

$(W_1 - W_2) = (E_b - E)\, \sigma \,.\, A\, (T_S^4 - T_D^4)$

Conclusions:-

Marks: **Date:** **Faculty Sign:**

PRACTICAL:- 13

EXPERIMENT ON 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 & the fluid. The use of this is very common & they are fabricated in a variety of shapes. Fig:1. circumferential fins around the cylinder of a motor cycle engine & 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 temperature distribution is the fin. The main object of this experimental set up is to study the temperature distribution in a simple pun fin.

Description of apparatus:-

A brass fin of circular cross section is fitted across a long rectangular duct. The other end of heater is connected to the suction side of blower a the air flows fast through the fin perpendicular to its axis. One end of the fin products out side the duct & is heated by the heater. Temperature at five points along the length of the fin are measured by Chromel Allumel Thermocouples connected along the length of the fin. The air flow rate is measured by Orifice meter fitted on the delivery side of blower. Schematic diagram of setup is shown in fig. 2. While the details of the pin fin as shown in fig. 3.

Specification:-

1. Duct size : 150 mm. x 100 mm.
2. Dia. of the Fin : 12.7 mm.
3. Dia. of the Orifice : 32 mm.
4. Dia of delivery pipe : 50 mm.
5. Coefficient of discharge C_d : 0.64 mm.
6. Centrifugal Blower : single phase motor.
7. No. of thermocouples on fin : 5
   1 to 5 as shown in fig. 3.
8. Thermocouple (6). reads ambient temperature inside of the duct.
9. Thermal Conductivity of fin material (Brass) :
   95 Kcal/hr-m- ^{o}C. (In MKS Units)
   110 W/m ^{o}C. (In SI Units)
10. Temperature indicator : 0 - 300 ^{o} C.
    with compensation of ambient temp. upto 50 ^{o} C.
11. Dimmerstat for heat input control 230 V 2 Amps.
12. Heater suitable for mounting at the fin end outside the duct :
    400 W (Band type).
13. Voltmeter : 0 - 100 / 200 V.
14. Ammeter : 0 - 2 Amps.

Theory:-

Consider the fin connected to its base to a heated wall & transferring heat to the surrounding (Fig. 4).

Let,

A = Cross Sectional area of the fin.

C = Circumference of the fin.

L = Length of the fin.

T_i = Average Temperature of the fin

T_F = Duct fluid temperature.

$ø = (T_i - T_F)$ = Rise in temperature.

The heat is conducted along the rod & 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 :

$$\frac{d^2 ø}{d x^2} - \frac{h.C}{K.A} , ø = 0. \quad ....(1).$$

and the general solution of equation (1) is -

$$ø = C_1 . e^{mx} + C_2 . e^{-mx} \quad ....(2).$$

Where,

$$m = \sqrt{\frac{h.c}{K.A}}$$

with the boundary conditions of $ø = ø_1$ at $x = 0$.

Where,

$\varnothing_1 = T_l - T_F$ & assuming the fin tip to be insulated.

$\frac{d\varnothing}{dx} = 0$ at x = L results in obtaining equation (2)

in the form :

$$\frac{\varnothing}{\varnothing} \quad \frac{T - T_F}{T_l - T_F} = \frac{\text{Cosh } m (L - x)}{\text{Cosh } mL} \quad ......(3)$$

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 if T_l , T_F & X. Temperature T_1 & T_F will be known for a given situation & the value of h depends on whether the heat is lost to the surrounding by free convection or forced convection & can be obtained by using the correlation as given below :

1. For free convection condition :

$Nu = 1.1 (G_r.P_r)^{1/6}$ ....$10^{-1} < Gr.Pr. < 10^4$

$Nu = 0.53 (G_r.P_r)^{1/4}$ ....$10^{4} < Gr.Pr. < 10^9$

$Nu = 0.13 (G_r.P_r)^{1/4}$ ....$10^{9} < Gr.Pr. < 10^{12}$

2. For forced convection,

$Nu = 0.165 (R_e)^{0.466}$ .... $40 < R_e < 4000$.

$Nu = 0.174 (R_e)^{0.618}$ .... $4000 < R_e < 40000$.

Where,

$$Nu = \frac{h.D}{k_{Air}}.$$

$$R_e = \frac{\rho VD}{\mu} \quad \text{OR} \quad \frac{VD}{\nu} = \text{Reynold's Number.}$$

$$G_r = \frac{g \cdot \beta \cdot L^3 \cdot \Delta T}{\nu^2}$$ = Grashoff Number.

$$P_r = \frac{C_p \cdot \mu}{K_{Air}}$$ = Prandtl Number.

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

Nomenclature:-

ρ = Density of air, Kg/m^3.

D = Diameter of pin fin, m.

μ = Dynamic Viscosity, $kgf.sec./m^2$. (In MKS Units)

$N.sec./m^2$. (In SI Units).

C_p = Specific heat, Kcal/Kg./ ^oC. (In MKS Units).

KJ/Kg.k (In SI Units).

ν = Kinematic Viscosity, m^2/sec.

K = Thermal conductivity of air, Kcal/hr.m ^oC

(In MKS Units).W/m ^oC.(In SI Units).

g = Acceleration due to gravity, 9.81 m/sec^2.

T_m = Average fin temperature

$$= \frac{(T_1 + T_2 + T_3 + T_4 + T_5)}{5}$$

$\Delta T = T_m - T_f$.

$$T_{mF} = \frac{T_m + T_f}{2}$$

β = Mean temperature

$$= \frac{1}{}$$

$T_{mf} + 273$

V = Velocity of air in the duct.

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

$$Q = C_d \times \frac{\pi d^2}{4} \times \sqrt{2g\left(\frac{H.\ell w}{\ell a}\right)} \quad m^3/Sec$$

Where,

H = Difference of levels in manometer, M

ρ_W = Density of water = 1000 Kg/m^3.

ρ_a = Density of air at T_f.

$C_d = 0.64$

d = Diameter of the orifice = 32 mm.

Velocity of air at (V) T_f =

$$\frac{Q}{\text{duct c/s Area}} = \text{m/sec.}$$

Velocity of air at T_{mf} =

$$V \times \frac{T_{mf} + 273}{T_f + 273} = \text{m/sec.}$$

Use this velocity in the calculation of R_e.

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

$q = \sqrt{h.c.K.A} \times (T_l - T_f) \text{ Tanh mL}$ ....(6)

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

Tanh mL

$$\eta = \frac{\quad}{mL} \qquad \text{..........(7).}$$

Experimental procedure:-

To study the temperature distribution along the length of a pin fin in natural & forced conviction, the procedure is as under.

(I) **Natural Convection.**

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

Precaution:-

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

(II) **Forced Convection :**

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

Precaution:-

1. See that the dimmerstat is at zero position before switching NO the heater.
2. Operate the changeover switch of temperature indicator, gently,
3. Be sure that the steady state is reached before taking the final readings.

Observation table:-

I **Natural Convection:-**

Sr. No.	V (volts)	I (Amps)	Fin Temperature(^{o} C) T_1	T_2	T_3	T_4	T_5	Amb.(^{o}C) Temp. $T_6 = T_F$
1								
2								
3								
4								

II **Forced Convection :**

Sr. No.	V (volts)	I (Amps)	Manometer readings (mm)	Fin Temperature(^{o} C) T_1	T_2	T_3	T_4	T_5	Amb.(^{o}C) Temp. $T_6 = T_F$
1									
2									
3									
4									

Result from experiment:-

(I) **Natural Convection :**

1. Plot the temperature distribution along the length of the fin from observed readings. (Fig 5)

2. Calculate G_r , P_r & obtain N_u from the equation (4) & finally get the value of **h** in natural convection.

3. Calculate the value of **m** & obtain the temperature at various locations along the length of the fin by using equation (3) & plot them (fig 5)

4. Calculate the values of heat transfer rate from the fin & the fin effectiveness by using equation (6) & (7).

5. Repeat the same procedure for all other sets of observations.

(II) **Forced Convection :**

1. Plot the temperature distribution along the length of the fin from observe readings (Fig. 6)

2. Calculate the value of **m** & obtain the temperatures at various locations along the length of fin by using equation (3) & plot them. (fig. 6).

3. Calculate R_e & P_r & obtain N_u from equation (5).

4. Calculate the value of heat transfer rate from the fin & the fin effectiveness by using equation (6) & (7).

5. Repeat the same procedure for all other sets of observations.

Calculation:-

I) Comment on the observed temperature distribution & 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 visualised on the plot of calculated temperatures.

	In MKS Units	In SI Units
K_{Brass} =	95 Kcal/hr.m.^{o} C.	110 w/m- ^{o} C
K_{Steel} =	40 Kcal/hr.m.^{o} C	46.5 w/m- ^{o} C
K_{Al} =	200 Kcal/hr.m.^{o} C	232 w/m- ^{o} C

(I) NATURAL CONVECTION :

1. Average fin temperature (Tm)

$$= \frac{T_1 + T_2 + T_3 + T_4 + T_5}{5}$$

Where, T_1 to T_5 = Temperature of Fin

2. Average Temperature of Fin and Fluid (T_{mF})

$$= \frac{T_m + T_f.}{2}$$

Where, T_m = Mean Temperature of Fin

T_F = T_6 = Temp. of Fluid (Air)

3. Properties of Air at (T_{mF})

i. Thermal Conductivity K_{air} = W /m ^{O}K

ii. Kinematic Viscosity ν = m^2/S

iii. Gravitational Acceleration g = 9.81 m^2/Sec

iv. Prandil Number Pr =

v. Density ρ = Kg/m^3

vi. β : Coefficient of Volumetric expansion $\beta = 1/(T_{mF}+273)$ K^{-1}

vii. Dynamic Viscosity μ = $N.S/m^2$ OR Kg/m^3

4. Grashoff Number (Gr)

$$= \frac{g \cdot \beta \cdot L^3 \cdot \Delta T}{\nu^2}$$

$$\Delta T = T_m - T_F$$

5. Nussel Number (Nu)

$Nu = 1.1\,(G_r.P_r)^{1/6}$ ....$10^{-1} < Gr.Pr. < 10^4$

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

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

6. Heat Transfer Co-Efficient (h) :

$$= \frac{Nu \times K_{Air}}{D}$$

Where,

D = Diameter of Fin

7. Slope (m) :

$$= \sqrt{\frac{hc}{KA}}$$

Where,

c = Circumference of Fin

A = Area of Fin

8. Effectiveness of Fin (μ)

= tanhmL

mL

(II) Forced Convection :

1. Average fin temperature (T_m)

$$= \frac{T_1 + T_2 + T_3 + T_4 + T_5}{5}$$

Where,

T_1 to T_5 = Temperature of Fin

2. Average Temperature of Fin and Fluid (T_{mF})

$$= \frac{T_m + T_F.}{2}$$

Where,

T_m = Mean Temperature of Fin

T_F = T_6 = Temp. of Fluid (Air)

3. Properties of Air at (T_{mF})

i.	Thermal Conductivity	K_{air}	=	W /m ^{O}K
ii.	Dynamic Viscosity	μ	=	N.S/m^2 OR Kg/m^3
iii.	Density	ρ	=	Kg/m^3

4. Discharge of Air in the Duct (Q) :

$$= Cd \quad \frac{\pi}{4} \quad x \quad d^2 \quad x\sqrt{2g(\frac{H.\varsigma w}{\varsigma a})}$$

5. Velocity of Air in the Duct at T_F (v) :

$$= \frac{Q}{\text{duct c/s Area}} \quad \text{m/sec.}$$

6. Velocity of Air in the Duct at T_{mF} (V):

$$= \quad V \times \frac{T_{mf} + 273}{T_f + 273} \quad \text{m/sec.}$$

7. Reynolds Number:

$$Re = \frac{\rho V D}{\mu}$$

8. Nussel Number (Nu):

$Nu = 0.165 (R_e)^{0.466}$ .... $40 < R_e < 4000$.

$Nu = 0.174 (R_e)^{0.618}$ .... $4000 < R_e < 40000$.

9. Heat Transfer Co-Efficient (h):

$$= \frac{Nu \times K_{Air}}{D}$$

Where,

D = Diameter of Fin

10. Slope (m) :

$$= \sqrt{\frac{hc}{KA}}$$

Where,

c = Circumference of Fin

A = Area of Fin

11. Effectiveness of Fin (μ)

$$= \frac{\tanh mL}{mL}$$

Conclusions:-

Marks: **Date:** **Faculty Sign:**