LABORATORY MANNUAL

HEAT TRANSFER LAB

LC-ME-314

RPS College of Engineering & Technology
Balana

ME- 314 HEAT TRANSFER LAB.

L	T	P	
-	-	3	

Sessional : 25 Marks
Practical : 25 Marks
Total : 50 Marks
Duration of Exam: 3Hrs.

List of Experiments:

1. To determine the thermal conductivity of a metallic rod.
2. To determine the thermal conductivity of an insulating power.
3. Measurement of heat transfer rate in a channel flow using winglets.
4. To determine the thermal conductivity of a solid by the guarded hot plate method.
5. To find the effectiveness of a pin fin in a rectangular duct natural convective condition and plot temperature distribution along its length.
6. To find the effectiveness of a pin fin in a rectangular duct under forced convective and plot temperature distribution along its length.
7. To determine the surface heat transfer coefficient for a heated vertical tube under natural convection and plot the variation of local heat transfer coefficient along the length of the tube. Also compare the results with those of the correlation.
8. To determine average heat transfer coefficient for a externally heated horizontal pipe under forced convection & plot Reynolds and Nusselt numbers along the length of pipe. Also compare the results with those of the correlations.
9. To measure the emmisivity of the gray body (plate) at different temperature and plot the variation of emmisivity with surface temperature.
10. To find overall heat transfer coefficient and effectiveness of a heat exchange under parallel and counter flow conditions. Also plot the temperature distribution in both the cases along the length of heat of heat exchanger.
11. To verify the Stefen-Boltzmann constant for thermal radiation.
12. To demonstrate the super thermal conducting heat pipe and compare its working with that of the best conductor i.e. copper pipe. Also plot temperature variation along the length with time or three pipes.
13. To study the two phases heat transfer unit.
14. To determine the water side overall heat transfer coefficient on a cross-flow heat exchanger.
15. Design of Heat exchanger using CAD and verification using thermal analysis package eg. I-Deas etc.

Note:

1. At least ten experiments are to be performed in the semester.

2. At least seven experiments should be performed from the above list. Remaining three experiments may either be performed from the above list or designed & set by the concerned institute as per the scope of the syllabus.

EXPERIMENT NO. 1

Aim:- To determine thermal conductivity of metal rod.

INTRODUCTION:

Thermal conductivity is the 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 and pressure to which it is subjected, and whether or not it is a homogeneous material.

Table 1 – Lists the values of thermal conductivity of some common metal:

SOLID'S (Metal)	Thermal Conductivity W/m ◦C	State
Pure Copper	380	20 degree
Brass	110	- - do - -
Steel (0.5%C)	54	- - do - -
S. S.	17	- - do --

Mechanism of Thermal Energy Conduction in Metals:

Thermal energy may be conducted in solids by two modes:

1. Lattice Vibration.
2. Transport by free electrons.

Thermal energy can be conducted in solids by free electrons and by lattice vibrations. Large numbers of free electrons move about in the lattice structure of the material in good conductors. These electrons carry thermal energy from higher temperature region to lower temperature region in a similar way they transport electric charge. In fact, these electrons are frequently referred as electron gas .energy may also be transferred as vibrational energy in the lattice structure of the material .in general, however, this mode of energy transfer is not as large as electron transport and hence ,good electrical conductors are always good heat conductors, e.g. copper ,silver etc.

However, with increase in temperature, lattice vibrations come in the way of transport by free electrons and for most the metals thermal conductivity decreases with increase in temperature electrons transport and it is for this reason that good electrical conductors are almost always good heat conductor viz. Copper, Aluminium and silver. With increase in the temperature, however the increased lattice vibrations come in the way of the transport by free electrons for most of the pure metals the thermal conductivity y decreases with increase in the temperature.

APPARATUS:

The experimental set up consists of the metal bar, one end of which is heated by an electric heater while the other end of the bar projects inside the cooling water jacket. The middle portion of the bar is surrounded by a cylindrical shell filled with the asbestos insulating powder. The temperature of the bar is measured at eight different sections while the radial temperature distribution is measured by separate thermocouples at two different sections in the insulating shell.

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

SPECIFICATION:

- Metal bar – Copper, 25 mm O.D., approx. 430 mm long with insulation shell along the length and water cooled heat sink at the other end.
- Test length of the bar – 240 mm.
- Thermocouples – Chromel /alumel, 10 nos.
- Band Nichrome heater to heat the bar.
- Dimmerstat to control the heat input – 2A, 230 V.
- Voltmeter and Ammeter to measure the heater input.
- Multichannel Digital temperature indicator, 0.1°C least count, 0-200°C with channel selector switch.
- Measuring flask to measure water flow.

EXPERIMANTAL PROCEDURE:

- Start the electric supply.
- Start heating the bar by adjusting the heater input to, say, 80 volts or 100 volts.
- Start cooling water supply through the heat sink and adjust it around 350-400 cc per minute.
- Bar temperature will start rising. Go on checking the temperature at time intervals of 5 minutes.
- When all the temperatures remain steady, note down all the observations and complete the observation table.

OBSERVATION TABLE:

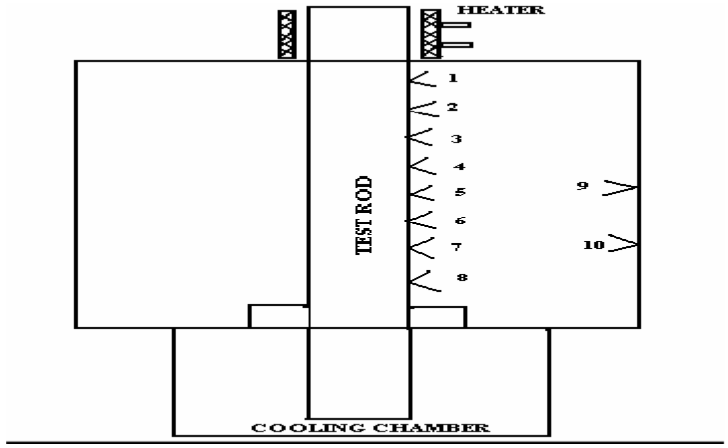
Sr. No.	Test Bar Tmperature °C								Shell Temperat ure °C		Water Temperat ure °C		Water Flow Rate Litr/Sec.
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	

Using the temperatures of the bar at various points, plot the temperature distribution along the length of the bar and determine the slopes of the graph (i.e. temperature drop per unit length) dT/dx at the sections AA, BB, CC as shown in figure.

(Note : As the value of temperature goes on decreasing along the length of the bar, the value of slope dT/dx is negative.)

Heat is flowing through the bar from heater end to water heat sink. When steady state is reached, heat passing through the section CC of the bar is heat taken by water.

Schematic Diagram:



1) Heat passing through section CC
   Q_{cc} = m. C_p . ΔT watts
   Where ,
   m = mass flow rate of cooling water, Kg/s
   C_p = specific heat of water
   = 4180 J/Kg °C
   ΔT = (Water outlet temperature) – (Water inlet

temperature) °CNow, Q_{cc} = - K_{cc} [dT/dx] . A_{cc}

A = Cross sectional area of the bar = 0.00049 m^2

K_{cc} =..................... W/ m °C

2) Heat passing through section BB
   Q_{bb} = Q_{cc} + Radial heat loss between CC & BB

$$= Q_{cc} + \frac{2\pi . K L_1 (T_6 - T_{10})}{Loge (r_o / r_i)}$$

Where,

k = Thermal conductivity of insulation
= 0.35 W/m°C
L_1 = Length of insulation cylinder
= 0.060 m
r_o = outer radius
= 0.105 m
r_i = inner radius

Q_{bb} = - K_{bb} $[dT/dx]_{bb}$ .A

K_{bb} = ... W/m°C

3) Similarly, heat passing through section AA
   $Q_{aa} = Q_{bb}$ + Radial heat loss between BB & AA

$$= Q_{bb} + \frac{2\pi . K L_2 . (T_3 - T_9)}{Log_e (r_o / r_i)}$$

Where

L_2 = 0.090 m

$Q_{aa} = - K_{aa} [dT/dx]_{aa} .A$

K_{aa} = ...W/m°C

Conclusion:-

1) Thermal conductivity of metal rod is found out to be ---------------

EXPERIMENT NO. 2

Aim: To determine the thermal conductivity of an insulating power.

INTRODUCTION

Conduction of heat is flow of heat which occurs due to exchange of energy from one molecule to another without appreciable motion of molecules. In any heating process, heat is flowing outwards from heat generation point. In order to reduce losses heat, various types of insulation's are used in practice. Various powders e.g. asbestos powder, plaster of paris etc, are also used for heat insulation. In order to determine the appropriate thickness of insulation, knowledge of thermal conductivity material is essential. The unit enables to determine the thermal conductivity of insulating powders, using 'sphere in sphere' method.

APPARATUS

The apparatus consists of a smaller (inner) sphere, inside which is fitted a mica electric heater. Smaller sphere is fitted at the center of outer sphere. The insulating powder, whose thermal conductivity is to be determined, is fitted in the gap between the two spheres. The heat generated by the heater flows through the powder to the outer sphere. The outer sphere loses heat to atmosphere. The input to the heater is controlled by a dimmerstat and is measured on voltmeter and ammeter. Four thermocouples are provided on the outer surface of inner sphere and six thermocouples are on the inner surface of outer sphere, which are connected to multichannel digital temperature indicator. Average of outer & inner sphere temperatures give the temperature difference across the layer of powder.

SPECIFICATION:

- INNER SPHERE – 100 mm O.D., halved construction.
- OUTER SPHERE – 200 mm I.D., halved construction.
- HEATER – Mica flat heater, fitted inside inner sphere.
- CONTROLS – 1) Main Switch – 30 A , DPDT Switch
  2) Dimmerstat – 0-230 volts, 2A capacity
- MEASUREMENTS-
  1) Voltmeter – 0-200 volts

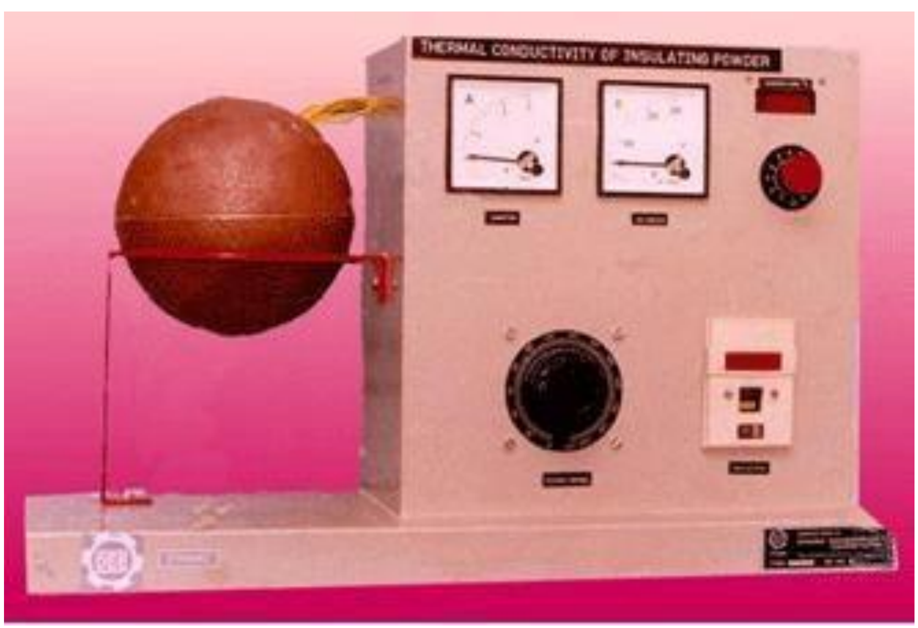
2) Ammeter- 0-1 Amp.
3) Multichannel digital temperature indicator, calibrated for cr/Al thermocouples.

PROCEDURE:

- Keep dimmerstat knob at ZERO position and switch ON the equipment.
- Slowly rotate the dimmerstat knob, so that voltage is applied across the heater. Let the temperature rise.
- Wait until steady state is reached.
- Note down the temperatures and input of heater in terms of volts and current.
- Repeat the procedure for different heat input.

OBSERVATIONS:

Sr. No.	TEMPERATURES ^{O}C										HEATER INPUT	
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	Volts	Amps



THEORY :

Consider the transfer of heat by conduction through the wall of a hollow sphere formed of insulating powder (Ref. fig.)

Let, r_i = radius of inner sphere, m

r_o = radius of outer sphere, m

T_i = avg. inner sphere temperature ◦c

T_o = avg. outer sphere temperature ◦c

Consider a thin spherical layer of thickness dr at radius r & temperature difference of dT across the layer. Applying Fourier Law of heat conduction, heat transfer rate,

$q = - k \cdot 4\pi \cdot r^2 \cdot [dT/dr]$

Where, k = thermal conductivity of insulating powder

$$\frac{q}{4.\pi.k} \times \frac{dr}{r} = - dT$$

Integrating between, ri to ro & Ti to To, we get

$$\frac{q}{4\pi k}\int_{r_i}^{r_o}\frac{dr}{r^2} = -\int_{T_i}^{T_o} dT$$

or $Q/4\pi k \times [1/r_i - 1/r_o] = (T_i - T_o)$

or $$q = \frac{4.\pi.k.r_i.r_o.(T_i - T_o)}{(r_o - r_i)}$$

From the measured value of q, T_i and T_o thermal conductivity of insulating powder can be determined as,

$$k = \frac{q(r_o - r_i)}{4.\pi.r_i.r_o.(T_i - T_o)}$$

CALCULATION:

- Heater input ; q = V × I watts
- Avg. inner sphere surface temperature

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

- Avg. outer sphere surface temperature

$$T_5 + T_6 + T_7 + \ldots + T_{10}$$

$$T_o = \frac{\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots}{6} \; °C$$

- Inner sphere radius = 50 mm = 0.05 m
- Outer sphere radius = 100 mm = 0.01 m

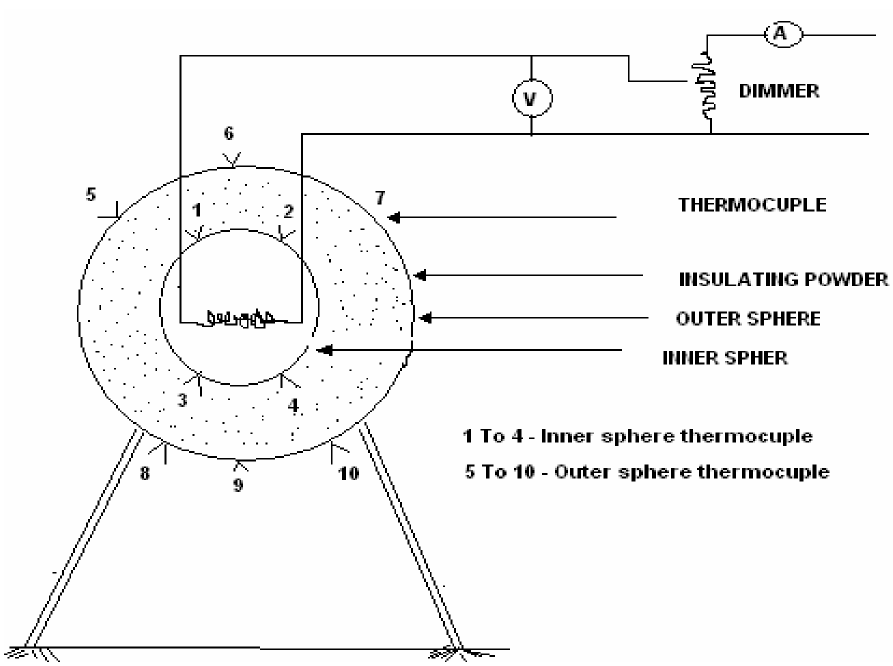
$$\text{Now,} \quad k = \frac{q.\,(r_o - r_i)}{4.\pi.r_i.r_o.\,(T_i - T_o)} \; W/m\,K$$

$$\text{at} \quad \frac{T_i + T_o}{2} \; °C$$

PRECAUTIONS:

- Operate all the switches and control gently.
- If thermal conductivity of the powder other than supplied is to be determined, then gently dismantle the outer sphere and remove the powder, taking care that heater connections and thermocouples are not disturbed.
- Earthing is essential for the unit.

Schematic Diagram:



EXPERIMENT NO. 4

Aim: To determine the thermal conductivity of a solid by the guarded hot plate method.

GENERAL DESCRIPTION:

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

PRINCIPLES OF THE GUARDED HOT PLATE METHOD:

The essential parts- the hot plate, the cold plates, the heater assembly, thermocouples and the specimens in position are shown in the same figure.

For the measurement of thermal conductivity (k) what is required is to have a one dimensional heat flow through the flat specimen, an arrangement for maintaining its faces at constant temperature and 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 a guard which is separately heated. Temperatures are measured by calibrated thermocouples either attached to the specimens at the hot and cold faces. Two specimens are used to ensure that all the heat comes not through the specimen only. Knowing the heat input to the central plate heater, the temperature difference across the specimen, its thickness and the metering area, one can calculate K of the specimen by the following formula:

$$K = \frac{q}{2A} \times \frac{L}{T_h - T_c} \quad W/m\,°C \qquad \ldots\ldots\ldots\ldots\ (1)$$

Where, K = Thermal conductivity of sample, W/m °C
q = Heat flow rate in the specimen, Watts
A = Metering area of the specimen,
T_h = Hot plate temperature, °C

T_c = Cold plate temperature, °C

L = Thickness of specimen, m

If the specimen thickness are different and the respective hot and cold temperatures are different then

$$K = \frac{q}{A} \times (a + b) \quad W/ m\ °C$$

Where, $a = \dfrac{1}{(T_{h1} - T_{c1})/L_1}$

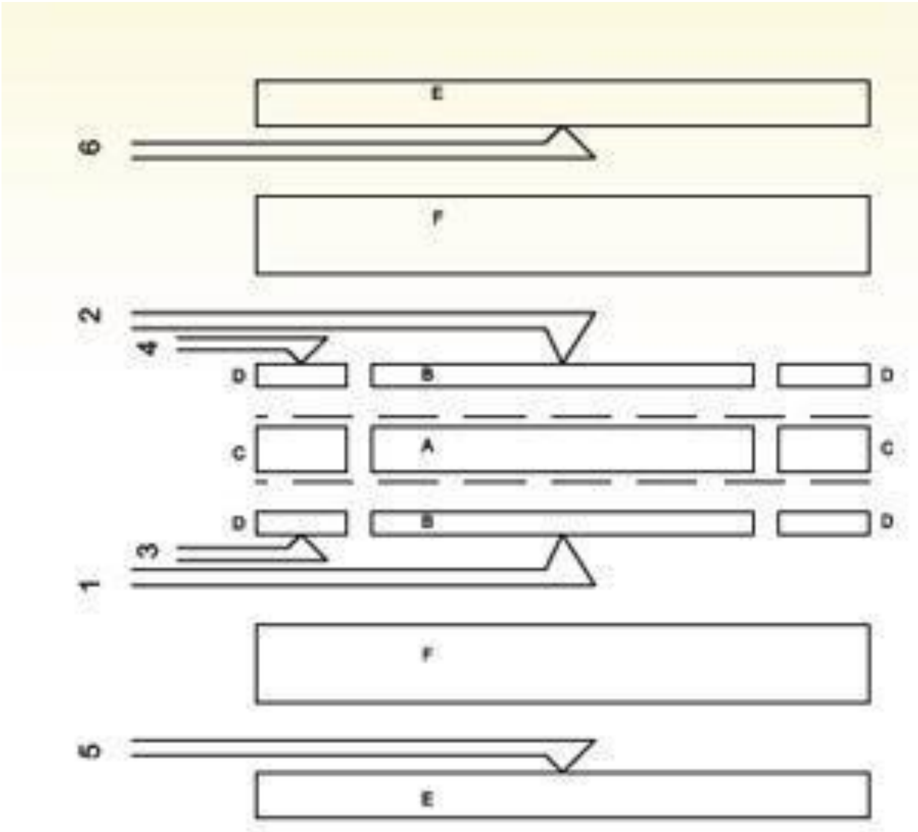
$b = \dfrac{1}{(T_{h2} - T_{c2})/L_2}$

Where suffix 1 is for upper specimen and 2 is for lower specimen.

APPARATUS:

The apparatus is designed and fabricated with IS 3336 as a guide line, having the following specifications :

- Diameter of the heating plate = 100 mm
- Width of the heating plate = 037 mm
- Inside diameter of the heating ring = 110 mm
- Outside diameter of the heating ring = 180 mm
- Max. thickness of the specimen = 025 mm
- Min. thickness of the specimen = 006 mm
- Diameter of the specimen = 180 mm
- Mean temperature range = 40 °c – 100 °C
- Max. temperature of hot plate = 170 °C
- Diameter of cooling plate = 180 mm
- Central Heater - Nichrome strip type wire sandwiched between mica sheets.
- Guarded Heater Rig - Nichrome strip type wire sandwiched between mica sheets.
- Dimmerstat - (0-2 Amp, 0-240 Volts.) - 2 Nos.
- Voltmeter - 0-200 V.
- Ammeter - 0-2 Amp.
- Thermocouple - (Chromel Alumel) - 6 Nos.
- Glass wool insulation around the assembly.
- Temperature Indicator - 0-200 °c
- Specimen supplied - Hylam (Backelite) 9.5 mm thick.



DISCRIPTION:

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

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

Specimens are held between the heater and cooling unit on each side of the apparatus. Thermocouple No. 5 and 6 measure the temperature of the upper cooling plate and lower cooling plate respectively.

The cooling chamber is a composite assembly of Aluminium casting and Aluminium cover with entry and exit adapter for water inlet and outlet.

TEST PROCEDURE:

The specimens are placed on either side of the plate assembly, uniformly touching the cooling plate. The outer container containing glass wool insulation is fixed over the test assembly carefully. The cooling circuit is started. Then input is given to central and guard heaters through separate single phase supply lines with a dimmerstat for each line and it is adjusted to maintain the desired temperatures. The guard heater input is adjusted in such a way that there is no radial heat flow which is checked from thermocouple readings and is adjusted accordingly. The input to the central heater (current and voltage) the thermocouple readings are recorded every 10 minutes till a reasonably steady state condition is reached. The readings are recorded in the observation table. The final steady state values are taken for calculation.

PRECAUTIONS:

- Keep dimerstat to ZERO voltage position before start.
- Increase the voltage gradually.
- Start the cooling circuit before switching ON the heaters and adjust the flow rate so that practically there is no temperature rise in the circulation.
- Keep the heater plate undisturbed and adjust the cooling plate after keeping the samples with the help of nuts gently.
- While fixing the insulation cover, be careful that heater and thermocouple connections as well as water connections are not disturbed.

OPERATIONAL INSTRUCTIONS:

For insuring that no radial heat transfer is there, generally outer heater input is about 2 to 3 times than central heating input.

OBSERVATION TABLE :

Sr No.	Main Heater				Ring Heater				Cooling Plate	
	V	I	T_1	T_2	V	I	T_3	T_4	T_5	T_6

CALCULATIONS :

- Main Heater Input (Inner Heater) = $V_1 \times I_1 = W_1$
- Ring Heater Input (Outer Heater) = $V_2 \times I_2 = W_2$
- Specimen Used =
- Specimen thickness 'L' =
- Diameter of specimen = 0.180 m
- Metering area

$$A = \frac{\pi}{4} (D + X)^2 = 0.00866 \text{ m}^2$$

Where, D = Dia. of the heating plate = 0.1 m

X = Width of gap between the plates = 0.005 m

- $$K = \frac{W_1 \times L}{2A \cdot (T_h - T_c)} \quad W/\,m°C$$

Referred at,

$$= \frac{T_h + T_c}{2}$$

Where,

$$T_h = \frac{T_1 + T_2}{2} \quad °C$$

$$T_c = \frac{T_5 + T_6}{2} \quad °C$$

EXPERIMENT NO. 5 & 6

Aim: To find the effectiveness of a pin fin in a rectangular duct natural & Forced convective condition and plot temperature distribution along its length.

INTRODUCTION

Extended surface or fins are use to increase the heat transfer rates from a surface to the surrounding fluid wherever it is not possible to increase the value of the surface heat transfer coefficient or the temperature difference between the surface and the fluid. Fins are fabricated in variety of form. Fins around the air cooled engines are common examples.

As the fins extend from primary heat transfer surface, the temperature difference with the surrounding fluid diminishes towards the tip of the fin. The aim of the experiment is to study the temperature distribution and the effectiveness of the fin, which play an important role in design.

The apparatus consist of a simple pin fin which is fitted in a rectangular duct. The duct is attached to suction end of blower. One end of fin is heated by an electrical heater. Thermocouples are mounted along the length of fin and a thermocouple notes the duct fluid temperature. When top cover over the fin is opened and heating started, performance of fin with natural convection can be evaluated and with top cover closed & blower started, fin can be tested in forced convection.

Specification

1) Fins-12 mm O.D., effective length 102 mm with 5 Nos. of thermocouple position along with the length, made of brass, mild steel of aluminum-one each.

Fin is screwed in heater block which is heated by a band heater.

2) Duct-150*100 mm cross section,1000 mm long connected to suction side of blower.

3) F.H.P centrifugal blower with orifice and flow control value on discharge side.

4) Orifice-dia. 22 mm coefficient of discharge C_d =0.64.

5) Measurement and control

a) Dimmer stat to control heater input, 0-230 V, 2 amp.

b) Voltmeter 0-250 V, for heater supply voltage.

c) Ammeter 0-1 amp. for heater current.

d) Multichannel digital temperature indicator.

E) Water manometer connected to orifice meter.

<u>Theory-</u>

Let A = cross section area of the fin, m^2

P = circumference of the fin, m

L = length of fin=0.102 m.

T_1= Base temperature of the fin.

T_f = Duct fluid temperature (channel No. 6 of temperature indicator)

Ø= Temperature difference of fin and fluid temperature

= T- T_f

h = heat transfer coefficient, w/m^2 °C.

K_f = Thermal conductivity of the fin material.

= 110 W/ m K for brass

= 46 W/ m K for mild steel

= 232 W/ m K for aluminum

Heat is conducted along the length of fin and also lost to surrounding. Applying first law of thermodynamics to a control volume along the length of fin at a station which is at length 'x' from the base,

$$\frac{d^2T}{dx^2} - \frac{hP}{k_f A} \emptyset = 0 \quad \text{……………1}$$

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

$$\text{Where, } m = \sqrt{\frac{h.P}{k_f . A}} \quad \text{…………………3}$$

With the boundary conditions of $\emptyset = \emptyset_1$ at x = 0

$\emptyset_1 = T_1 - T_f$, assuming tip to be insulated.

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

$$\frac{\phi}{\phi_1} = \frac{T-T_f}{T_1-T_f} = \frac{\cos m\,(L-x)}{\cosh ml} \ldots\ldots\ldots\ldots\ldots 4$$

This is the equation for temperature distribution along the length of the fin. Temperatures T_1 and T_f will be known for the given situation and the value of 'h' depends upon mode of convection i.e. natural or forced.

EXPERIMENTAL PROCEDURE

A) NATURAL CONVECTION

Open the duct cover over the fin. Ensure proper earthing to the unit and switches on the main supply. Adjust dimmerstat so that about 80 volts are supplied to the heater. The fin will start heating. When the temperatures remain steady, note down the temperatures of the fin and duct fluid temperature. Repeat the experiment at different inputs to heater.

OBSERVATION-

Sr. NO	Input		Fin temperature °C					Duct fluid temp °C
	V	I	T_1	T_2	T_3	T_4	T_5	T_6

B) <u>FORCED CONVECTION-</u>

Close the duct cover over the fin. Start the blower. Adjust the dimmerstat so that about 100-110 volt are supplied to the heater. When the temperatures become steady, note down all the temperatures and the manometer difference.

Repeat the experiment at different inputs and at different air flow rates.

OBSERVATIONS TABLES-

Sr. No.	Manometer difference	Fin Temperature °C					Duct fluid temperature °C
	H (m of water)	T_1	T_2	T_3	T_4	T_5	$T_6 = T_f$

CALCULATION-

NOMENCLATURE-

T_m = Average fin temperature = (T_1 +T2+T_3+T_4+T_5)

$\Delta T = T_m - T_f$

T_{mf} = mean film temperature = $(T_m + T_f)/2$

ρ_a = Density of air, kg/m^3

ρ_w = Density of water, kg/m^3

D = Diameter of pin fin = 12×10^{-3} m.

d = Diameter of orifice = 22×10^{-3} m.

C_d = coefficient of discharge of orifice = 0.64

μ = Dynamic viscosity of air, N-s/ m^2

C_p = Specific heat of air, k J / kg °C

ν = Kinematic viscosity, m^2 / s.

K_{air} = Thermal conductivity of air, W/ m°C

β = volume expansion coefficient = 1/ (T_{mf} + 273)

H = manometer difference, m of water

V = velocity of air in duct, m/s

Q= volume flow rate of air, m^3/s

V_{tmf} = velocity of air at mean film temperature.

All properties are to be evaluated at mean film temperature.

NATURAL CONVECTION-

The fin under consideration is horizontal cylinder loosing heat by natural convection. For horizontal cylinder, Nusselt number,

$Nu = 1.10\ (Gr.\ Pr)^{1/6}$ ------- for $10^{-1} < Gr.\ Pr. < 10^4$.

$Nu = 0.53\ (Gr.\ Pr)^{1/4}$ ----------- for $10^4 < Gr.\ Pr. < 10^9$.

$Nu = 0.13\ (Gr.\ Pr)^{1/3}$ ---------- for $10^9 < Gr.\ Pr. < 10^{12}$

Where, Gr = Grashof number,

$= (\beta.g.D^3.\ \Delta T) / \nu^2$

Pr= Prandtl number

$= (Cp.\ \mu) / k_{air}$

Determine Nusselt number

Now, $Nu = (h.D) / k_{air}$

h =

From h, determine ‘m’ from equation (3)

Using h and m, determine temperature distribution in the fin from equation (4).

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

$q = (h.P.k_f.A)^{1/2} *(T_1 - T_f) \tanh mL$.................. 5

and efficiency of the fin can be calculated as,

$$\eta = \frac{(\tanh mL)}{mL} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ 6$$

Forced Convection –

As in natural convection, for horizontal cylinder loosing heat by forced convection,

$Nu = 0.065\ (Re)^{0.466}$ --------------- for $40 < Re < 4000$

$Nu = 0.174\ (Re)^{0.618}$ --------------- for $4000 < Re < 40000$

Where,

$$\text{Re} = \frac{Vtmf.D}{v}$$

$$V_{tmf} = \frac{V(T_{mf} + 273)}{(T_f + 273)}$$

Velocity of air is determined from air volume flow

$$Q = C_d \frac{\pi}{4} d^2 \sqrt{2.g.H\,(p_w - p_a)} \quad m^3/s$$

V = Q / Duct cross sectional area

= Q/(0.15 × 0.1) m / s

From Nusselt number, find out ‘ h’, and from ‘h’, find out ‘m’.

Now temperature distribution, heat transfer rate and effectiveness of the fin can be calculated using equation 4,5 and 6 respectively.

Conclusion –

1) Comment on the observed temperature distribution and calculation by theory, it is expected that observed temperatures should be slightly less than their calculated values because of radiation and non-insulated tip.

2) Plot the graphs of temperature distribution in both natural and forced convection.

Precautions

1) Operate all the switches and controls gently.

2) Do not obstruct the suction of the duct or discharge pipe.

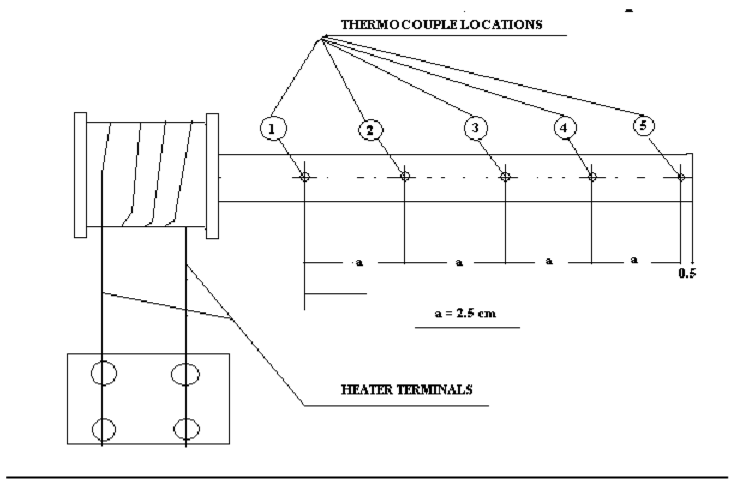
3) Open the duct cover the fin for normal convection experiment.

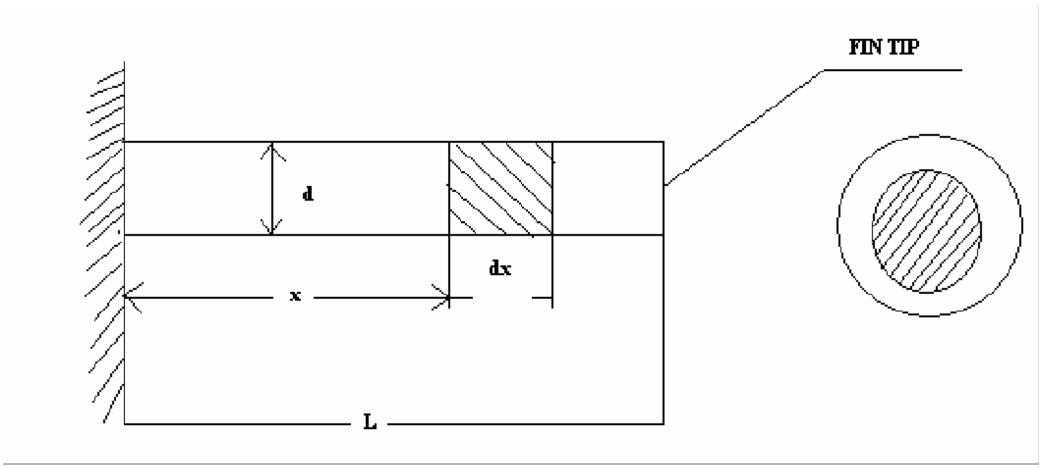
4) Fill up water in the manometer and closed duct cover for forced convection experiment.

5) Proper earthing to unit is necessary.

6) While replacing the fins, be carefully for the fixing the thermocouples. Incorrectly fixed thermocouples may show erratic readings.

Schematic Diagram





EXPERIMENT NO. 7

Aim: To determine the surface heat transfer coefficient for a heated vertical tube under natural convection and plot the variation of local heat transfer coefficient along the length of the tube. Also compare the results with those of the correlation.

INTRODUCTION:

In contrast to the forced convection, natural convection phenomenon is due to the temperature difference between the surface and the fluid and is not created by any external agency. The present experimental set up is designed and fabricated to study the natural convection phenomenon from a vertical cylinder in terms of the variation of local heat transfer coefficient along the length and also the average heat transfer coefficient and it's comparison with the value obtained by using an appropriate correlation.

APPARATUS:

The apparatus consists of a brass tube fitted in a rectangular vertical duct. The duct is open at the top and forms an enclosure and serves the purpose of undisturbed surrounding. One side of the duct is made up of perspex for visualization. An electric heating element is kept in the vertical tube which in turns heat the tube surface. The heat is lost from the tube to the surrounding air by natural convection. The temperature of vertical tube is measured by seven thermocouples. The heat input to the heater is measured by an ammeter and a voltmeter and is varied by a dimmerstat. The tube surface is polished to minimize the radiation losses.

SPECIFICATION:

- Diameter of the tube (d) = 38 mm
- Length of the tube (L) = 500 mm
- Duct size 200 mm × 200 mm × 800 mm Length
- Multichannel Digital Temperature Indicator 0 – 300 °C using Chriomel/Alumel thermocouple.
- Ammeter 0 – 2 Amp. and Voltmeter 0 – 200 Volts.
- Dimmerstat 2 Amp.240 Volts.

THEORY:

When a body is kept in still atmosphere, heat is transferred to the surrounding fluid by natural convection. The fluid layer in contact with the hot body gets heated, rises up due to the decrease in its density and the cold fluid rushes in to take place. The process is continuous and the heat transfer takes place due to the relative motion of hot and cold fluid particles.

The heat transfer coefficient is given by :

$$h = \frac{q - q_1}{A_s \times (T_s - T_a)} \quad \text{.......(1)}$$

Where, h = Average surface heat transfer coefficient ($W/m^2 °C$)

q = heat transfer rate (Watts)

A_s = Area of heat transferring surface = π.d.l (m^2)

T_s = Avg. surface temperature

$$= \frac{T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7}{7} \quad °C$$

T_a = Ambient temperature in the duct = T_8 °C

q_1 = heat loss by radiation = $\sigma . A . \varepsilon .(T_s^4 - T_a^4)$

Where, σ = Stefan Boltzmann constant = 5.667×10^{-8} $W/m^2 K^4$

A = Surface area of pipe = 0.59 m^2

ε = Emissivity of pipe material = 0.6

T_s & T_a = Surface and ambient temperatures in °K

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

$$\frac{h \times L}{k} = A \times [\mathrm{g}\frac{L^3 \beta \Delta T}{v^2} \times \frac{C_p \mu}{k}] \quad \text{.............2}$$

where , $\frac{h \times L}{k}$ .... Nusselt Number

$\frac{g . \beta ... ^3 . \Delta T}{^2}$ .... Grashof Number

$\frac{Cp . \mu}{K}$ .... Prandtl Number

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

Where, L = Characteristics dimension of the surface

K = Thermal conductivity of fluid

ν = Kinematic viscosity of fluid

C_p = Specific heat of fluid

β = coefficient of volumetric expansion for the fluid

g = Acceleration due to gravity

$\Delta T = [T_s - T_a]$

For gases, $$\beta = \frac{1}{(T_f + 273)} \quad /°K$$

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

For a vertical cylinder losing heat by natural convection, the constant 'A' & 'n' of equation (2) have been determined and the following empirical correlation's obtained.

$$\frac{h \times L}{k} = 0.59\,(Gr\,.\,Pr.)^{0.25} \quad \text{For } 10^4 < Gr.\,Pr. < 10^8 \quad \cdots\cdots (3)$$

$$\frac{h \times L}{K} = 0.13\,(Gr.Pr.)^{0.333} \quad \text{For } 10^8 < Gr.\,Pr. < 10^{12} \quad \cdots\cdots (4)$$

L = Length of cylinder

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

PROCEDURE:

- Put ON the supply and adjust the dimmerstat to obtain the required heat input - (Say 40 W, 60 W, 70 W etc.)
- Wait till the steady state is reached, which is conformed from temperature readings – (T_1- T_7).
- Measure surface temperature at the various points i.e. T_1 to T_7.
- Note the ambient temperature i.e. T_8
- Repeat the experiment at different heat input (**Do not exceed 80 w)**

OBSERVATIONS:

- O.D. cylinder = 38 mm.
- Length of cylinder = 500 mm.
- Input to heater = V × I Watts.

Sr. No.	Volt	Amp.	TEMPERATURE °C							
			T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8

CALCULATION:

- Calculate the value of average heat transfer coefficient, neglecting end losses using equation (1).
- Calculate and plot (Fig. 4) the variation of local heat transfer coefficient along the length of the tube.

$$T = T_1 \text{ to } T_7 \quad \text{and} \quad h = \frac{q}{A_s.(T - T_a)}$$

- Compare the experimentally obtained value with the predictions of the correlation equations (3) Or (4).

NOTE: The heat loss due to the radiation and conduction is not considered, but they are present, which give difference between actual and theoretical values.

PRECAUTIONS:

- Proper earthing is necessary for the equipment.
- Keep dimmerstat to ZERO volt position before putting ON main switch and increase it slowly.
- Keep at least 200 mm space behind the equipment.
- Operate the change-over switch of temperature indicator gently from one position to other i.e. from 1 to 8 position.
- **Never exceed input above 80 Watts.**

RESULT AND DISCUSSIONS –

The heat transfer coefficient is having a maximum value at the beginning as expected because of the just starting of the building of the layer and it decreases as expected in the upward direction due to thickening of layer and which is laminar one. This trend is maintained up to half of length (approx.) and beyond that there is little variation in the value of local heat transfer coefficient because of the transition and turbulent boundary layers. The last point shows somewhat increase in the value of heat transfer coefficient 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 radiation.

Heat loss by radiation = $\sigma \cdot \varepsilon \cdot A \cdot (T_s^4 - T_a^4)$

Where, , σ = Stefan Boltzmann constant = 5.667×10^{-8} $W/m^2 K^4$

A = Surface area of pipe = 0.59 m^2

ε = Emissivity of pipe material = 0.6

T_s & T_a = Surface and ambient temperatures in °K

PROPERTIES OF AIR

T	ρ	C_p	$\mu \times 10^6$	K	Pr	$\nu \times 10^6$
°C	Kg/m^3	KJ/kg-k	N-sec/m^2	w/m-k		m^2/sec
0	1.293	1.005	17.2	0.0244	0.707	13.28
10	1.247	1.005	17.7	.0251	0.705	14.16
20	1.205	1.005	18.1	0.0259	0.703	15.06
30	1.165	1.005	18.6	0.0267	0.701	16.00
40	1.128	1.005	19.1	0.0276	0.699	16.96
50	1.093	1.005	19.6	0.0283	0.698	17.95
60	1.060	1.005	20.1	0.0290	0.696	18.97
70	1.029	1.009	20.6	0.0297	0.694	20.02
80	1.000	1.009	21.1	0.03035	0.692	21.09
90	0.972	1.009	21.5	0.0313	0.690	22.10
100	0.946	1.009	21.9	0.0321	0.688	23.13
120	0.898	1.009	22.9	0.0334	0.686	25.45
140	0.854	1.013	23.7	0.0349	0.684	27.80

EXPERIMENT NO. 8

Aim: To determine average heat transfer coefficient for a externally heated horizontal pipe under forced convection & plot Reynolds and Nusselt numbers along the length of pipe. Also compare the results with those of the correlations.

INTRODUCTION

Whenever a fluid is being forced over the heated surface, forced convection heat transfer occurs. The apparatus consists of a circular pipe, through which cold fluid, i.e. air is being forced. Pipe is heated by a band heater outside the pipe. Temperature of pipe is measured with thermocouples attached to pipe surface. Heater input is measured by a Voltmeter and Ammeter. Thus, heat transfer rate and heat transfer coefficient can be calculated.

SPECIFICATIONS:

- Test pipe – 33 mm I.D. 500 mm Long.
- Band heater for pipe.
- Multichannel Digital Temperature Indicator 0-300 °C using Chromel/ Alumel thermocouples.
- Dimmerstat 2Amps. 240 volts. for heater input control.
- Voltmeter 0-200 Volts.
- Ammeter 0-2 Amps.
- Blower to force the air through test pipe
- Orifice meter with water manometer.

PROCEDURE:

- Put ON mains supply.
- Adjust the heater input with the help of dimmerstat.
- Start the blower and adjust the air flow with valve.
- Wait still steady state is reached and note down the reading in the observation table.

OBSERVTIONS:

Sr. No.	Volt	Amp.	Temperature °C							Manometer Difference
	V	I	T_1	T_2	T_3	T_4	T_5	T_6	T_7	h_w

CALCULATIONS:

- Air inlet temperature T_1 = °C
- Air outlet temperature T_2 = °C
- Density of air

$$\rho_a = \frac{1.293 \times 273}{273 + T_1} \quad Kg/m^3$$

- Diameter of orifice = 22 mm

  Manometer difference = water head = h_w mtrs

  Air heads, $h_a = h_w (\rho_w - \rho_a)$

  Where, ρ_w = Density of water = 1000 Kg/m^3

  Air volume flow rate

  $Q = C_d \times a_o \times (2.g.h_a)^{1/2}$ m^3/sec

  Where, C_d = 0.64

  a_o = c.s. area of pipe

- Mass flow rate of air

  $m_a = Q \times \rho_a$ kg/s

  Velocity of air,

$$V = \frac{Q}{a_p} \quad m/sec$$

Where,

a_p = cross sectional area of pipe

= 8.33×10^{-4} m^2

- Heat gained by air, $q = m_a \times c_{pa} \times (T_7 - T_1)$

  Where, c_{pa} = specific heat of air = 1 kJ/Kg K OR 1000 J/Kg K

- Average inside surface temperature,

$$T_S = \frac{T_2 + T_3 + T_4 + T_5 + T_6}{5} \quad °C$$

- Bulk mean temperature of air,

$$Tm = \frac{T1 + T7}{\ldots} \quad °C$$

- Average surface heat transfer coefficient

- Actual heat loss due to forced convection = q - heat loss due to radiation

Heat loss due to radiation (q_1):-

$$q_1 = 0.4 \times A \times (T_s^4 - T_a^4) \times \sigma$$

σ = Stefan Boltzmann Constant

Actual heat loss = $q - q_1$

$$h_{expt} = \frac{q - q_1}{A \times (T_s - T_m)} \quad W/m^2\,K$$

Where, A = inside surface area of the pipe = $\pi \times di \times l$

$= \pi \times .033 \times 0.5$

$= 0.0518 \; m^2$

- Reynold's Number :

$$R_{eD} = \frac{V \times D}{\nu}$$

ν = kinematic viscosity at T_m

D = 0.033 m

If $R_{eD} < 2000$, flow is laminar.

For laminar flow $\frac{h.\,D}{k_{air}} = 4.36$

If $R_{eD} > 2000$, flow is turbulent.

For turbulent flow,

$$N_{uD} = \frac{h\,.\,D}{k_{air}}$$

$$= 0.023\,(R_{eD})^{0.8} \times (Pr.)^n$$

Where, n = 0.4 when fluid is being heated

N = 0.3 when fluid is being cooled

Determine h_{theo} from N_{uD}

NOTE: The calculated values and actual values may differ appreciably because of heat losses .the heat loss through natural convection, conduction and heat loss through insulation over the heater is not considered, but they are also present. The heat flux is not uniform practically, as assumed in theory, which gives difference between actual and theoretical value.

PRECAUTIONS

- While putting 'ON' the supply, keep dimmerstat at zero position and blower switch 'OFF'.
- Operate all the switches and controls gently.
- Do not obstruct the flow of air while experiment is going on

PROPERTIES OF AIR

T	ρ	Cp	$\mu \times 10^6$	K	Pr	$\nu \times 10^6$
°C	Kg/m^3	KJ/kg-K	N-sec/m^2	w/m-K		m^2/sec
0	1.293	1.005	17.2	0.0244	0.707	13.28
10	1.247	1.005	17.7	.0251	0.705	14.16
20	1.205	1.005	18.1	0.0259	0.703	15.06
30	1.165	1.005	18.6	0.0267	0.701	16.00
40	1.128	1.005	19.1	0.0276	0.699	16.96
50	1.093	1.005	19.6	0.0283	0.698	17.95
60	1.060	1.005	20.1	0.0290	0.696	18.97
70	1.029	1.009	20.6	0.0297	0.694	20.02
80	1.000	1.009	21.1	0.03035	0.692	21.09
90	0.972	1.009	21.5	0.0313	0.690	22.10
100	0.946	1.009	21.9	0.0321	0.688	23.13
120	0.898	1.009	22.9	0.0334	0.686	25.45
140	0.854	1.013	23.7	0.0349	0.684	27.80

EXPERIMENT NO. 9

Aim: To measure the emissivity of the gray body (plate) at different temperature and plot the variation of emissivity with surface temperature.

INTRODUCTION:

All the bodies emit and absorb the thermal radiation to and from surroundings. The rate of thermal depends upon the temperature of body. Thermal radiations are electromagnetic waves and they do not require any medium for propagation.

When thermal radiation strikes a body, part of it is reflected, part of it is absorbed and part of it is transmitted through body.

The fraction of incident energy reflected by the surface is called reflectivity (ρ). The fraction of incident energy absorbed by surface is called absorptivity (α) and the fraction of energy transmitted is called transmissivity (τ).The surface which absorb all the incident radiation is known as a black surface.

For a black surface,

$$\rho + \alpha + \tau = 1$$

The radiant flux, emitted from the surface is called emissive power (e).

The emissivity of a surface is ratio of emissive power of a surface to that of black surface at same temperature. Thus,

$$s = \frac{e}{e_b}$$

<u>THE APPARATUS</u>

The apparatus uses comparator method for determining the emissivity of test plate. It consists of two aluminum plates of equal physical dimensions. Mica heaters are provided inside the plates. The plates are mounted in an enclosure to provide undisturbed surroundings.

One of the plates is blackened outside for use as a comparator. Another plate is having neutral surface finish. Input to heaters can be controlled by separate dimmerstats. Heaters input are measured on common ammeter and voltmeter. One thermocouple is fitted on surface of each plate to measure the surface temperature with digital temperature indicator.

By adjusting input to the heaters, both the plates are brought to same temperature, so that conduction and convection losses from both the plates are equal and difference in input is due to different emissivities.

Holes are provided at black side bottom and at the top of enclosure for natural circulation of air over the plates. The plate is provided with perplex acrylic sheet at the front.

<u>EXPERMENTAL PROCEDURE</u>

1. Blacken one of the plates with the help of lamp black (Normally this is blackened at the works, but if blackening is wiped out, then blackening is necessary)
2. Keep both the dimmer knobs at ZERO position.
3. Insert the supply pin-top in the socket (which is properly earthed) and switch ‘ON’ the mains supply.
4. Switch ON the mains switch on the panel.
5. Keep the meter selector switch (toggle switch) at the black plate side position.
6. Adjust dimmer of black plate, so that around 110- 120 volts are supplied to black plate.
7. Now, switch the meter selector switch on other side.
8. Adjust test plate voltage slightly less than that of black plate (say100- 110 volts)
9. Check the temperatures (after, say 10 minutes) and adjust the dimmers so that temperatures of both the plates are equal and steady. Normally, very minor adjustments are required for this.
10. Note down the readings after the plates temperatures reach steady state.

<u>OBSERVATIONS</u>

Plate	Input		Surface Temp ^{O}C
	V	I	
Test Plate			T_1 =

Black Plate			T_2 =

Enclosure Temperature = T_3 °C

CALCULATIONS

1. Enclosure Temperature

$$T_E = T_3 \, °C$$

2. Plates surface temperature

$$T = T_1 = T_2 = \quad °C$$
$$T_S = (T + 273.15) \; °K$$

3. Heat input to black plate,
   $W_b = V \times I$ Watts
4. Heat input to test plates,
   $W_T = V \times I$ watts
5. Surface area of plates

$$A = 2 \times \frac{\pi}{4} D^2 + [\pi \times D \times t]$$
$$= 0.0447 \text{ m}^2$$

Where, D = dia. of plates = 0.16 m.

And, t = thickness of plates = 0.009 m.

6. For black plates,

$W_b = W_{CVb} + W_{Cdb} = W_{Rb}$ -----------------------(1)

Where,

W_{CVb} = Convection losses

W_{Cdb} = Conduction losses

W_{Rb} = Radiation losses

Similarly, for test plate,

$W_T = W_{CVT} + W_{CDT} + W_{RT}$ ------------------------- (2)

As both plates are of same physical dimensions, same material & at same temperatures,

$W_{CVb} = W_{CVT}$ & $W_{CDb} = W_{CDT}$

Subtracting equation 2 from 1 , we get,

$W_b - W_T = W_{Rb} - W_{RT}$

$= [\sigma \,.\, A.\varepsilon_b \; (T_S^4 - T_E^4)] - [\sigma \,.\, A \;.\, \varepsilon_T \,.\, (T_S^4 - T_E^4)]$

$= [\sigma \,.\, A \,.\, (T_S^4 - T_E^4)(\varepsilon_B - \varepsilon_T)]$

As emissivity of black plate is 1 ,

$W_b - W_T = \sigma \;.\; A \;.\; (T_S^4 - T_E^4) (1- \varepsilon_T)$

Where ,

ε =emissivity of test plate

σ =Stefan Boltzman constant =5.667 × 10^{-8} w/m^2 K^4

<u>Note-</u> Emissivity of oxidized aluminium plate i.e. test plate is normally within in the range of 0.3 to 0.7

CONCLUSION

The test plate was found to be……… at a temperature of ……… °K

PRECATIONS

(1) Black plate should be perfectly blackened.

(2) Never put your hands or papers over the holes provided at the top of enclosure.

(3) Keep at least 200 mm distance between the back side of unit and the wall

(4) Operate all the switches and knobs gently.

EXPERIMENT NO. 10

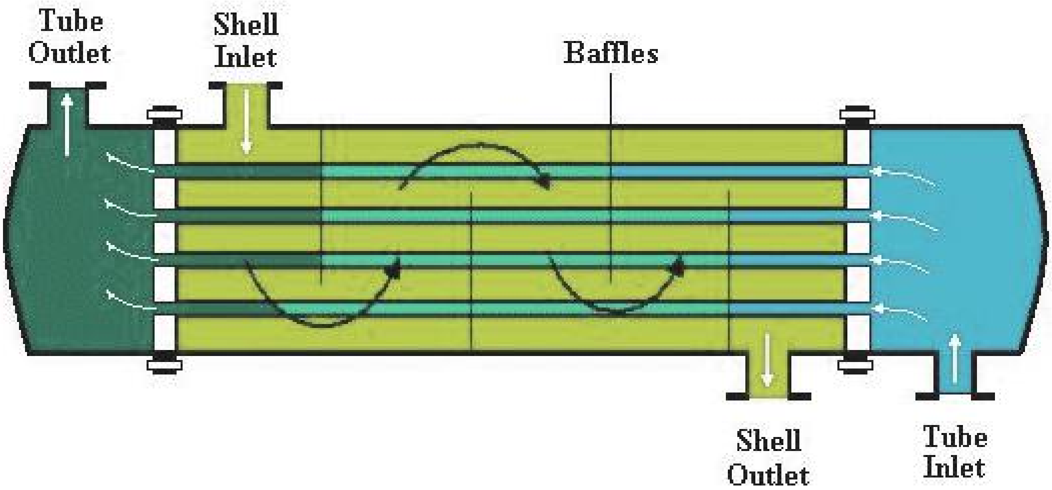
Aim: To find overall heat transfer coefficient and effectiveness of a heat exchange under parallel and counter flow conditions. Also plot the temperature distribution in both the cases along the length of heat of heat exchanger.

INTRODUCTION

SHELL AND TUBE HEAT EXCHANGER APPARATUS

Heat exchanger is the device used to transfer the heat from one fluid to another. Transfer of heat is needed for many applications. Commonly used types of heat exchanger are transfer type, storage type and direct contact type, both, hot and cold fluids are passing simultaneously through the heat exchanger and heat is being transferred through the separating wall between them. Transfer type heat exchangers are simple for connection are installations and hence are used in many applications.

In transfer type heat exchanger, different type of flow arrangements are used, viz, parallel, counter or cross flow. The shell and tube heat exchanger is two pass heat exchanger. The hot fluid is hot water obtained from water heater. The cold fluid is tap water. The schematic flow arrangement is shown in fig. Hot water enters the lower side of end box, flows through the tubes in lower half of shell and comes to the other end of the shell, where it reverses its direction, flows through tubes in upper half of the shell and leaves out. Cold water enters lower part of the shell passes over the tubes between the baffles and leaves out the shell through outlet at upper surface of shell.



SPECIFICATION

1) Shell -150 NB, 750 m. m long provided with end boxes.
2) One end box with divider plate.
3) 25% cut baffles – 4 Nos. in the shell.
4) Tubes – 4.5 I.D., 6.35 O.D., 750 m. m. copper with triangular pitch.- 32 Nos.
5) Instantaneous water heater, 3 kW capacity, to supply hot water.
6) Thermometer for measuring the water temperature.
7) Valves to control hot and cold water flow.

SERVICES REQUIRED FROM CUSTOMER-

1) Water supply about 10 lit/min at constant head.

2) 230V, 16A AC supply.

3) Floor space of about 1.5 mtr × 1mtr.

4) Suitable drain arrangement for water.

EXPERIMENTAL PROCEDURE-

1) Connect the water supply and start water flow, for heat water (tube side) keep flow rate above 2.5 Lit/min (maximum flow rate is 7 Lit/min), keep cold water (shell side) flow rate between 3 to 8 Lit/min.
2) Connect the main electric supply (250V, 15 A) and switch 'ON' the water heater.

NEVER SWITCH ON THE HEATER BEFORE STARTING WATER SUPPLY-

3) Observe water inlet and outlet temperatures.
4) Wait till steady state is reached and note down the observation
5) Repeat the procedure by changing the water flow rate.

OBSERVATION-

Sr. No	HOT WATER			COLD WATER		
	Inlet temp' T_{hi} °C	Outlet tempe rature T_{ho}°C	Discharge Time for 10 ltrs of water.	Inlet temperatur eT_{ci}°C	Outlet temperature T_{co}°C	Discharge time for 10 ltrs of water.

DATA-

1) Sp. Heat of water =C_{pw} = 4.2 KJ/Kg K

2) Inside area of tube = $A_i = 4.5 \times 10^{-3} \times \pi \times 0.75 \times 32 = 0.34 m^2$

3) Outside area of tubes = $A_o = 6.35 \times 10^{-3} \times \pi \times 0.75 \times 32 = 0.48 m^2$

4) Density of water, ρ_w = 1000 Kg/m^3

CACULATIONS

1. Hot water inlet temperature T_{hi} = °C Hot water outlet temperature T_{ho} = °C Cold water inlet temperature T_{ci} = °C Cold water outlet temperature T_{co} = °C

2. Mass flow rate –

Let time required for 10 ltrs. Flow of water in measuring tank for cold water be t_c and hot water be t_h ,

Volume flow rate, $v_c = 0.01 / t_c$ m^3 / s

Mass flow rate, $m_c = v_c \times \rho_w$ Kg / s

Similarly, for hot water , $m_h = v_h \times \rho_w$ Kg / s.

3. Heat collected by cold water

$$Q_c = m_c \times c_{pw} (t_{co} - t_{ci}) \quad KJ / s$$

Heat lost by hot water

$$Q_h = m_h \times c_{pw} (T_{hi} - T_{ho}) \quad KJ / s$$

4. Logarithmic mean temperature difference (LMTD)

For shell and tube heat exchanger,

$$\Delta T = F \times LMTD_{cf}$$

Where, $LMTD_{cf}$ = LMTD if the arrangement was counterflow,

(for1 – shell pass and 2 – tube pass, $LMTD_{cf}$ should be taken)

$$LMTD_{cf} = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{In \frac{(T_{hi} - T_{co})}{(T_{hi} - T_{ci})}}$$

and,

F = correction factor

For finding out correction factor, values of R and S are required

$R = T_{co} - T_{ci} / T_{hi} - T_{ho}$

$S = T_{hi} - T_{ho} / T_{hi} - T_{ci}$

Find out value of F from graph using values of R and S.

5. Heat transfer coefficient,

I. Inside heat transfer coefficient

$$U_i = Q_h / A_i . \Delta T$$

II. Outside heat transfer coefficient

$U_o = Q_c / A_o . \Delta T$

6. Effectiveness of heat exchanger –

$$\varepsilon = \frac{Rate\ of\ heat\ transfer\ in\ heat\ exchanger}{Maximum\ possible\ heat\ transfer\ rate}$$

$$s = \frac{m_h.c_p.(\ t_{hi} - t_{ho})}{(\ m.c_p\ )(\ t_{hi} - t_{ci}\ )}$$

Where, $(m.\ c_p)$ is smaller of two capacity rates of m_h or m_c.

RESULTS:-

Obs. No	ΔT	U_i	U_o	ε

PRECAUTIONS:-

1. Start water supply before switching on the water heater put water heater OFF before closing the water supply.
2. Use all the controls and switches gently. Do not disturb thermocouples or wires.
3. Keep the flow rates in the prescribed range, mentioned in experimental procedure. Too low flow rate for hot water may give very high temperature, which may cause thermostat to put off the heater. Too high flow rate will give appreciable temperature rise of water.
5. Use clean water for the experiment. Water containing impurities or floating particles may clog the tubes.

EXPERIMENT NO. 11

Aim: To verify the Stefen-Boltzmann constant for thermal radiation.

INTRODUCTION:

All the substances emit thermal radiation. When heat radiation is incident over a body, part of radiation is absorbed, transmitted through and reflected by the body. A surface which absorbs all thermal radiation incident over it, is called black surface. For black surface, transmissivity and reflectivity are zero and absorptivity is unity. Stefan Boltzmann Law states that emissivity of a surface is proportional to fourth power of absolute surface temperature i.e.

$$e \propto T^4$$

or $$e = \varepsilon . \sigma . T^4$$

where , e = emissive power of surface

T = Absolute temperature

σ = Stefan Boltzmann Constant

ε = Emissivity of the surface

Value of Stefan Boltzmann constant is taken as

$$\sigma = 5.667 \times 10^{-8} \quad W/ m^2 K^4$$

For black surface, ε = 1, hence above equation reduces to

$$e = \sigma . T^4$$

APPARATUS:

The apparatus of a water heated jacket of hemispherical shape. A copper test disc is fitted at the center of jacket. The hot water is obtained from a hot water tank, fitted to the panel, in which water is heated by an electric immersion heater. The hot water is taken around the hemisphere, so that hemisphere temperature rises. The test disc is then inserted at the center. Thermocouples are fitted inside hemisphere to average out hemisphere temperature. Another thermocouple fitted at the center of test disc measures the temperature of test disc.

A timer with a small buzzer is provided to note down the disc temperature at the time intervals of 5 seconds.

PROCEDURE:

- See that water inlet cock of water jacket is closed and fill up sufficient water in the heater tank.
- Put ON the heater.
- Blacken the test disc with the help of lamp black and let it to cool.
- Put the thermometer and check water temperature.
- Boil the water and switch OFF the heater.
- See that drain cock of water jacket is closed and open water inlet cock.
- See that there is sufficient water above the top of hemisphere (A piezometer tube is fitted to indicate water level).
- Note down the hemisphere temperature (i.e. upto channel 1 to 4)
- Note down the test disc temperature (i.e. channel No. 5)
- Start the timer. Buzzer will start ringing. At the start of timer cycle, insert test disk into the hole at the bottom of the hemisphere.
- Note down the temperature of disc, every time the buzzer rings. Take at least 4-5 readings.

OBSERVATIONS:

HEMISPHERE TEMPERATURE (°C)	TIME INTERVAL (Sec.)	TEST DISC TEMPERATURE (°C)
T_1 =	05	T_5 =
T_2 =	10	T_5 =
T_3 =	15	T_5 =
T_4 =	20	T_5 =

CALCULATIONS:

- Area of test disc, A = $\pi/4 \times d^2 = 3.14 \times 10^{-4}$ m^2 (d =20 mm)
- Weight of test disc, m = 5.2 gms. = 5.2×10^{-3} kg.
- Plot a graph of temperature rise of disc with time as base and find out it's slope at origin i.e.

  [dT/dt] at t = 0 k/sec.

- Hemisphere temperature

$$T_H = \frac{T_1 + T_2 + T_3 + T_4}{4} + 273.15 \text{ K}$$

- Initial test disc temperature

$$T_D = T_5 + 273.15 \quad \text{K}$$

- As area of hemisphere is very large as compared to that of test disc, we can put

$$q = \sigma . \varepsilon A. (T^4 - T_D^4)$$

Where, q = heat gained by disc/sec

= m.ρ.(dT/dt)

σ = Stefan Boltzmann constant

m = mass of test disc = 5.2×10^{-3} kg

ε = emissivity of test disc = 1

A = Area of disc

ρ = Specific heat of copper = 381 J/Kg °C

$$\varepsilon = \frac{m.\ \rho.\ (dT/dt)}{A\ .\ (T_H^4 - T_D^4)} \quad W/m^2\ K^4$$

Theoretical value of σ is 5.667×10^{-8} W/m^2K^4

In the experiment, this value may deviate due to reasons like convection, temperature drop of hemisphere, heat losses etc.

PRECAUTIONS:

- Never put ON the heater before putting water in the tank.
- Put OFF the heater before draining the water from heater tank.
- Drain the water after completion of experiment.
- Operate all the switches and controls gently.