SHREE RAMCHANDRA EDUCATION SOCIETY'S

Shree Ramchandra College of Engineering, Lonikand, Pune

LAB MANUAL

HEAT TRANSFER LABORATORY

Shree Ramchandra College of Engineering, Lonikand, Pune

DEPARTMENT OF MECHANICAL ENGINEERING

<u>CERTIFICATE</u>

This is to certify that

Mr./Miss ________________________________
of class _____________Roll No.______________
Examination Seat No. ______________________
has completed all the practical work in the subject <u>HEAT TRANSFER</u> satisfactorily, as prescribed by University of Pune in the Academic Year 2013 -2014.

Staff In-charge Head of Department Principal

Shree Ramchandra College of Engineering, Lonikand, Pune
DEPARTMENT OF MECHANICAL ENGINEERING

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Signature of Subject Incharge   Head of Department   Principal

Shree Ramchandra College of Engineering, Lonikand, Pune

DEPARTMENT OF MECHANICAL ENGINEERING

HEAT TRANSFER LAB

Experiment No: 01

Heat Transfer Through Composite Wall

Aim: - Determination of temperature distribution along Composite Wall

Introduction:-

In practice, composite structures are present in many applications. By composite structures we mean that more than one layer of solid placed in the passage of heat flow by conduction.

Following list gives few examples where composite structures are present:

i) Insulated steam pipes
ii) Insulated pipes carrying refrigerator
iii) Walls of an A/C room
iv) Doors & sides of refrigerators
v) Doors and walls of cold storage

These composite walls are formed by placing layers of different materials such as:

i) Steel, copper or any other metallic walls
ii) Concrete or wood
iii) Insulating materials such as asbestos, thermocol, glass-wool, puff, cork etc.

Apparatus:-

The apparatus is useful to find out heat transfer through composite structures of different material with different thickness.

The setups consist of nichrome heater sandwiched between mica sheets & placed between two cast iron thick plates. These M.S. plates are placed between identical bakelite and press wood plates. The temperatures between these plates can be measured using the thermocouples used.

A control panel provides measurement of heat input using digital voltmeter & ammeter and it can be varied using dimmerstat. A digital temperature indicator is provided to measure the temperature at respective positions.

Procedure:-

i) Using a dimmerstat and wattmeter an electric input of 50W is to be given to the central heater & kept constant throughout the experiment. This will require 50v position on dimmerstat approximately.
ii) The temperature T_1 to T_8 will go on increasing slowly.
iii) When steady state is reached, record the observations in observation table.

Specifications:-

1) **Slabs :** Mild Steel : 0.15 mtr diameter & 0.02 mtr thickness.
Backlite : 0.15 mtr diameter & 0.02 thickness. Press
Wood : 0.15 mtr diameter & 0.02 thickness.

2. Heater : Nichrome heater wound on mice former and insulator with control unit capacity 500 watt maximum.
3. Heater control unit : 0 – 230 volt.
4. Voltmeter 0-1000V.
5. Ammeter : 0-2 A, Single phase Dimmer stat.

Observations:-

i) Voltmeter reading =
ii) Ammeter reading =
iii) Temperature =

Observation Table:-

SR. NO.	VOLTAGE (v) v	CURRENT (I) A	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)	T_7 (°C)	T_8 (°C)
1.										
2.										
3.										
4.										
5.										

Calculations:-

Considering the composite slab made of materials of thickness L_1, L_2, L_3 having thermal conductivity k_1, k_2, k_3.

Heat transfer can be calculated by using **Fourier's law**: Applying to other conditions,

Where,

Q = Heat input in watts
$= V \cdot I$
A = Area = $(\pi /4) \cdot d^2$

Sample Calculations:-

Remarks:-

i) Since the apparatus is similar, T_1 & T_2, T_3 & T_4, T_5 & T_6, T_7 & T_8 will be close to each other

ii) Plot the temperature distribution as shown in the schematic diagram on a separate graph paper

iii) The slop of temperature distribution will indicate the order of magnitude of thermal conductivity of material of composite wall.

- M.S. = less slope
- Bakelite = more slope
- Wood = maximum slope

iv) A very rough estimate of K values can be made by applying the Fourier' law of heat conduction. The apparatus forms the series of circuit on both sides of heater.

The values of thermal conductivities obtained below can be compared with the values given in the literature of their order of magnitude. However, the temperatures are measured only at central locations. The value obtained as above will be in their respected order of magnitude.

Result Table:-

SR. NO	VOLTAGE (V) v	CURRENT (I) A	THERMAL CONDUCTIVITY (W/m °K)		
			K_1	K_2	K_3
1.					
2.					
3.					
4.					

Conclusion:-

Expected Questions for Oral Examination :-

1. What is composite wall?

2. Write an equation for composite wall heat loss with inside & outside HTC h_A & h_B

3. Write the practical application of composite wall.

4. How composite systems are are analyzed for heat transfer?

5. Explain the analogy used in conduction.

6. Give two examples of composite cylindrical systems & spherical systems in actual practice & state how area is measured?

7. Describe and write an equation when a heater is insulated in the middle of symmetrical wall having two different materials. Sketch the system.

8. Write the sequence of insulating materials namely Aluminum Steel & Asbestos in wall furnace is to be logged.

9. What do you predict if composite walls are connected in series or parallel.

10. State application of composite wall in AC & Refrigeration.

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DEPARTMENT OF MECHANICAL ENGINEERING

HEAT TRANSFER LAB

Experiment No: 02

Emissivity of Metal Surface

Aim:- To determine the emissivity of metal surface.

Introduction:-

Emissivity of a surface is defined as "the ratio of emissive power of a surface (e) to emissivity power of a black surface (e_b).

$$E=e/ e_b$$

`Emissivity of perfect black surface is 1 & Emissivity of a perfect white surface is 0. All the practical surfaces are having emissivity between 0 to1.

The knowledge of emissivity is very necessary when want to find out heat exchange by radiation. The design of appliances is based radiation by the solar energy. The knowledge of emissivity of collector surface & reflecting surface is a must for the concerned engineering.

At a particular wavelength, over the spectrum wavelength, monochromatic emissivity is defined

as: $E=l/e_b$

Table given below gives the value of emissivity of some common material surfaces for ready references,

SURFACE	TEMPERATURE	EMMISIVITY
1.metal polished copper, steel, Stainless-steel, nickel	20-500°C	0-0.15
2.oxidizedcopper,steel, nickel Stainless-steel	UPTO 1000 °C	0.6-1.0
3.non-metals,brick,wood Marble, water	20-100 °C	0.8-1.0

Experimental Setup:-

The object of experiment is to determine the value of emissivity of given surface. The value of apparatus of two similar metallic disk .one of the disc is coated with black color to behave as black surface.(emissivity is assumed to be 1) & other disc is having plane machined surface. The discs are fitted with similar heater at bottom with asbestos covers. the two discs (all discs) are placed in an enclose in a symmetrical manner.

The heater terminals are taken out of enclosure are connected to main supply via a dimmerstat to vary the heater input voltmeter & ammeter are also connected in such way that major the heater I/P. The temperatures of two discs are measured by using separate thermocouples. One more thermocouples placed in enclosure to measure the surrounding temp. Digital temp. Indicator is used to measure the thermocouple o/p.

Procedure:-

1. Keep voltage about 50v for Black plate & about 40v for test plate.
2. After some time, gradually adjust voltage of test plate such as temp of both plates comes equal.

Specifications:-

01. diameter of test plate = 170 mm

02. diameter of black plate = 170 mm 03. Dimmerstat = 0 to 2 Amp, 260 v, AC

04. Temperature Indicator = 0 to 300° c, calibrated for Chromel Alumel thermocouple 3 in number. 05. Voltmeter = Digital 0 to 300 v, AC

06. Ammeter = Digital 0 to 5 Amp

07. Heater = Nichrome wire, band type, 400W

Observations:-:

1) Diameter of the disc = 148 mm
2) Radiating area of disc = $2\pi d^2/4$
3) Heater i/p to black disc =
4) Temp of black disc =
5) Heater i/p =
6) Temp of test disc =
7) T = (Tb+Tnb)/2
8) Temperature of enclosure =

Observation Table:-:

Observation no.	Black plate			Test plate			Ambient
	V(volt)	I(amp)	Tb(°c)	V(volt)	I(amp)	Tnb(°c)	
1							
2							
3							
4							

Calculation:-

Result Table:-

Observation Nos.	T1 (°k)	T2 (°k)	Emmisivity of test plate (w/m² k^4)
1			
2			
3			

Conclusion:-

Expected Questions for Oral Examination :-

1. Define radiation heat transfer mode.

2. Define Steffen Boltzmann.

3. State radiation out ways.

4. Define black body.

5. Define emissivity.

6. Define emissivity of few common engineering materials.

7. What do you mean by gray body?

8. Define Kirchhoff's law.

9. State emissivity of test plate.

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Experiment No: 02

Heat Transfer in Forced Convection

Aim: To calculate Heat Transfer in a Forced Convection

Description:-

The apparatus is 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 and two thermocouples are placed in the air stream at the entrance and exit of the test section to measure the air temperature. Test pipe is connected to the delivery side of the blower along with a orifice to measure flow of air through pipe. Input to the heater is given through a dimmerstat and 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 temperatures of pipe wall at various points in the test section. Air flow is measured with the help of orifice meter and the water manometer fitted on the board.

Specifications:-

01. Pipe diameter = (Dp) = 52 mm Diameter of test section = (D) = 40 mm
02. Length of Test Section = (L) = 500mm
03. Blower = 300CFM
04. Orifice Dia. =(do)= 20 mm
05. Dimmerstat = 0 to 500W
06. Temperature Indicator = 0 to 400° C
07. Voltmeter = Digital 0 to 100 V, AC
08. Ammeter = Digital 0 to 5 Amp
09. Heater = Nichrome wire, band type, 500W

Procedure:

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 and heat flow rates.
2. Reynold's number and Nusselt number for each experimental condition can be calculated. Plot these values on Log - Log graph. Plot on the same graph the Dittus Boelter correlation. Compare these two plots.
3. To plot and comment on the surface temperature distribution along the length of pipe.

Precautions:

01. Keep the dimmerstat at zero position before switching ON the power supply.
02. Start the blower unit first.
03. Increase the voltmeter gradually.
04. Do not stop the blower in between the testing period.
05. Do not disturb thermocouples while testing.
06. Operate selector switch of Temperature Indicator gently.
07. Do not exceed 200 Watts.

Operating Manual Procedure:-

01. Start the blower and adjust the flow by means of gate valve to some desired difference in manometer level.
2. Start the heating of test section with the help of dimmerstat and adjust desired heat input with the help of Voltmeter and Ammeter. 03. Take readings of all thermocouples at an interval of 10 minutes until steady state is reached. 04. Note the heater input.

Observations :-

01. Outer diameter of pipe (Do) 02. Diameter of test pipe (D) 03. Length to test section (L) 04. Diameter of the orifice (do), = 52 mm. = 40 mm.= 500 mm. = 20 mm.

Sr.No.	Voltage	Current	Temperature °C						Manometer Reading
	V Volts	I Amp.	T1	T2	T3	T4	T5	T6	h_W = mm of Water
1									
2									
3									
4									

Calculations:-

Conclusion :-

Expected Questions for Oral Examination :-

1. Define forced convection.

2. State application of forced convection.

3. Define Reynolds's number & right a equation for laminar & turbulent flow.

4. Define Nusselt number.

5. Define Prandt number.

6. Write down the equation for forced convection in tube.

7. What is bulk temperature?

8. How the heat absorbed by air is calculated?

9. How to calculate velocity of air flowing on tube.

10. What is heat transfer coefficient obtained by experiment?

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DEPARTMENT OF MECHANICAL ENGINEERING

HEAT TRANSFER LAB

Experiment No: 03

Thermal Conductivity of Insulating Powder

Aim: - To determine the thermal conductivity of insulating powder.

Introduction:-

Insulating material of different types such as asbestos, glass wool etc are used in engineering practice to prevent the leakages of heat. These materials offer resistance to heat flow and are useful in saving the energy. These materials possess a relatively small value of thermal conductivity. Table 1 gives the list of commonly used in insulating materials & their thermal conductivity values. Mechanical engineer should know these values & the method to determine these values.

Apparatus:-

The apparatus consists two thin walled copper spheres an electrical heater. The heater is prepared from Nichrome wire and embedded in mica sheet to insulate it electrically. The inner sphere is placed concentrically in the outer sphere. The space between two spheres is filled with commercially available asbestos powder. Thermocouples are filled on the outer surface of the inner sphere & inner surface of outer sphere. The assembled unit is placed on a tripod fixed on a wooden base.

Heat input to the heater is varied by a dimmerstat & is measured by voltmeter & ammeter on control panel. Temperature across the spherical layer of insulating powder is measured by thermocouples & temperature indicator.

Heat supplied to the heater is conducted across the spherical layer of insulation & is lost to the surroundings from the outer spherical surface by natural convection & radiation.

Theory:-

Fourier law for a spherical geometry with radical flow of heat can be written as,

$$dq = -K \cdot 4 \cdot \prod \cdot r^2 \cdot \frac{dT}{dr}$$

Integrating over inner radius (r_i) to outer radius (r_o)

$$\int_{r_i}^{r_o} \frac{dq \cdot dr}{r^2} = -\int_{T_i}^{T_o} 4 \cdot \prod \cdot K \cdot dT$$

$$Q = \frac{4 \cdot \prod \cdot K \cdot (T_i - T_o)}{\left(\frac{1}{r_i} - \frac{1}{r_o} \right)}$$

Where,

T_i : Average inner sphere temperature

T_o : Average outer sphere temperature

Table 1:-

Material	**Thermal Conductivity (K) = (W/m ^{0}K)**	**State**
Asbestos	0.23	20 ^{0}c
Plastic	0.58	20 ^{0}c
Wood	0.17	20 ^{0}c
Brick	0.23	20 ^{0}c
Concrete	1.279	20 ^{0}c
Fire brick	0.14	20 ^{0}c
Mineral wool	0.047	20 ^{0}c
Plaster	0.779	20 ^{0}c
Rubber	0.163	20 ^{0}c
Cork sheet	0.042	20 ^{0}c
Glass	0.744	20 ^{0}c

Observations:-

Heat input of about 20 watts is being given and kept constant throughout the experiment. The temperatures at inner and outer surfaces are checked. The time interval is 10 min. till the steady state is reached. Under the steady state conditions, the heat input & temperatures are noted in the final observation table and are recorded as under.

1) Average radius of inner sphere = 50 mm 2) Average radius of outer sphere = 100 mm

3) Thermocouples = 16

4) Dimmer strat = 0 to 500W

5) Heating Coil = 300 Watts

6) Insulating powder = Asbestos

Observation Table:-

No.	V (v)	I (A)	Inner sphere temp. (°C)				Outer sphere temp. (°C)								Avg. temp.	
			T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_i	T_o
1.																
2.																
3.																
4.																
5.																
6.																

Where, Average inner sphere temperature = $T_i = \dfrac{T_1 + T_2 + T_3 + T_4}{4}$

Average outer sphere temperature = $T_O = \dfrac{T_5 + T_6 + T_7 + T_8 + T_9 + T_{10} + T11 + T12}{8}$

Using equation (1) as above values of thermal conductivity K of given insulating powder can be calculate as

$$K = \frac{Q \cdot \left(\frac{1}{r_i} - \frac{1}{r_o} \right)}{4 \cdot \prod \cdot (T_i - T_O)} \quad \text{W/m ° k}$$

and is referred at mean temperature

$$T_{mean} = \frac{T_i + T_o}{2}$$

Remarks:-

1) This experiment can be conducted for 2/3 heater input values to find the 'K' at different mean temperatures.
2) This value obtained as above can be plotted against mean temperatures to study the variation of K with respect to temperature.
3) The value of thermal conductivity can be compared with the values given in literature & comment on variation observed if any.

Sample Calculations:-

Conclusion:-

Expected Questions for Oral Examination :-

1. Define thermal conductivity & its unit.

2. State Fourier's Law of conduction.

3. Arrange the following in ascending conducting value Air, Copper, Aluminum, Gold, Platinum, Brick, Rubber, Asbestos, Freon, Steel.

4. Why thermal conductivity of metals is high?

5. State the effect of pressure on thermal conductivity of gas.

6. State the highest & lowest conducting materials.

7. State thermal conductivity of Gold & Platinum.

8. Describe heat conductors & insulators along with their application in domestic, engineering & commercial sectors.

9. How temperature gradient is achieved in experiment?

10. State the example of one dimensional steady state heat conduction in day to day life.

11. Why the doors of refrigerators are made of fiber & electrical wires made of copper?

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DEPARTMENT OF MECHANICAL ENGINEERING

HEAT TRANSFER LAB

Experiment No: 04

Heat Transfer in Natural Convection

Aim:-To study heat transfer in natural convection

Introduction:-

In contrast to 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. Natural convection flow patterns for some common situations are shown in fig. I. The present experimental set-up is designed and fabricated to study natural convection from a vertical cylinder in terms of variation of local heat transfer coefficient along the length and also average heat transfer coefficient and its comparison with the value obtained by using a appropriate criterion or correction.

Apparatus:-

The apparatus consists of a brass tube fitted in a rectangular duct in the vertical position .The duct is open at the top and bottom forms an enclosure and serves the purpose of undisturbed surroundings. One side of duct is fitted with window for the purpose of visualization. An electric heating element is kept in a vertical tube which in turn heats the tube surface. The heat is lost from the tube surface to the surrounding air by natural convection. The temperature of vertical tube is measured by seven thermocouples. The heat is measured by ammeter and voltmeter and is varied by thermocouples as shown in the fig. while the possible flow patterns and also the expected variation of local heat transfer coefficient is as shown in fig.3. the tube is polished to minimize the radiation losses.

Specifications: -

1. Diameter of tube'd' mm = 40 mm
2. Length of tube 'L' = 500 mm
3. Duct size = 250 mm x 250 mm x 600 mm
4. Number of thermocouples = 7
5. Temperature indicator = 0 to 400 ^{o}C
6. Ammeter (Digital) = 0 to 10 Amp
7. Voltmeter (Digital) = 0 to 1000 volts
8. Dimmer stat = 0 to 300 W
9. Heater = 300 Watts

Procedure: -

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 steel atmosphere, heat is transferred to the surrounding fluid by natural convection. The fluid layer in contact with the body gets heated and the hot fluid due to decrease in-the density rises up and the cold fluid rushes in from the bottom side. The process is continuous and the cold fluid rushes in from the bottom side. 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= Q / As (Ts-Ta)
Where,

h =average surface heat transfer coefficient, Q = heat transfer rate (watts),

As = area of transferring surface, Ts = average surface temperature

= (T 1 + T2+T3+T4+T5+T6) / 6

Ta = ambient temperature in the duct T7 °c.

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 the heat transferring surface of the fluid. The dependence of' h' on all members is generally expressed-in terms of non-dimensional groups as follows:

$h L\backslash k = C[gL^3 \beta \Delta T \, Cp \, \mu / 2\upsilon^2]^n$ where,

$hL\backslash k$ = Nusselt's number,

$gL^3 \beta \Delta T$ = grashoffs number, $Cp \, \mu$ = prandtl' s number.

C & n are constants depending on the shape;.and orientation of the heat transferring surface. $\beta = 1/(Tf+273)$ & $Tf = (Ts+Ta)/2$.

For the vertical cylinder, loss of heat by natural convection, the constants 'C' & 'n' have been determined. The following empirical correlations can be obtained.

$hL\backslash k = 0.48 \, (Gr.Pr)0.25$ for $10^4 < Gr.Pr < 10^7$ $hl/k = 0.125 \, (Gr.Pr)0.333$ for $10^7 < Gr.Pr < 10^{12}$

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

Procedure:-

1. Put ON the supply and adjust dimmer stat to obtain required heat input.
2. Wait till fairly steady state is reached which is confirmed from temperatures Tl & T7.
3. Note down surface temperature at various points.
4. Note ambient temperature 'T8'.
5. Repeat the experiment with different inputs.

OBSERV A TIONS:

1. cylinder outer diameter =
2. length of cylinder =

Observation Table:

Sr. No.	T1	T2	T3	T4	T5	T6	T7 (Ta)	V	I
1									
2									
3									
4									

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Result :-

Conclusion:

Expected Questions for Oral Examination :-

1. Write the general equation of heat conduction.

2. Define natural convection.

3. State difference between natural & forced convection.

4. State example of natural convection.

5. Quote engineering application of natural convection.

6. Define Grashof's number.

7. What is geometry of surface for experiment setup?

8. What is the value of heat transfer coefficient in average?

9. On what factor heat transfer coefficient depends?

10. State examples where natural convection can be replaced by forced convection.

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DEPARTMENT OF MECHANICAL ENGINEERING

HEAT TRANSFER LAB

Experiment No: 05

Critical Heat Flux at various bulk temperatures of water

Aim: To calculate Critical Heat Flux at various bulk temperatures of water.

Apparatus:

The apparatus consists of a cylindrical glass container housing the test heater and a heater coil for initial heating of the water. This heater coil is directly connected to the mains (heater R_1) and the heater (Nicrome wire) is connected also to mains via a dimmerstat. An ammeter is connected in series while a voltmeter across it to read the current and voltage. The glass container is kept on a stand.

The schematic arrangement of the apparatus is shown in figure.

Procedure :

1. Take sufficient amount of water in the container.
2. See that both the heaters are completely submerged.
3. Connect the test heater wire (Nichrome) across the studs.
4. Switch ON the main switch.
5. Switch ON the heater R_1.
6. Keep it on till you get the required bulk temperature of water in the container say 50 ^{0}C, 60^{0}C, 70^{0}C up to the saturation temperature
7. Switch OFF the heater R_1
8. Switch on test heater R_2.
9. Very gradually increase the voltage across it by slowly changing the various positions and stop a while at each position to observe the boiling phenomenon on wire.
10. Repeat this experiment by altering the bulk temperature of water.

Precautions:

1. Keep the dimmerstat to zero voltage position before starting the experiments.
2. Take sufficient amount of water in the container so that both the heaters are completely immersed.
3. Connect the test heater wire across the studs tightly.
4. Do not touch the water or terminal points after putting the switch in on position.
5. Very gently operate the voltage in steps and allow sufficient time in between.
6. After the attainment of critical heat flux condition decrease slowly the voltage and bring it to zero.

Specifications:

1. Glass Container – Diameter – 200 mm, Height – 120 mm
2. Heater for initial heating – Nichrome heater (R_1)
3. Test heater (R_2) Nichrome wire diameter – 0.093 mm
4. Length of test heater (R_2) – 100 mm
5. Dimmerstat – 10 Amp
6. Voltmeter – Digital
7. Ammeter - Digital
8. Thermometer – 0 – 110 ^{0}C

Observations:

1. Diameter of test heater wire, d =0.093mm
2. Length of the test heater, L = 100 mm = 0.1 m
3. Surface area (π.d.L), A =

Observation Table:

Sr. No.	Bulk Temperature of water ^{0}C	Ammeter Reading I (Amp)	Voltmeter Reading V (Volts)
1			
2			
3			
4			
5			

Calculations:

Heat Input (Q) = V x I

=

= Watts

Critical Heat Flux = $\frac{V \times I}{A}$ (where A is the surface area of wire)

=

= W/m^2

Result: -

Expected Questions for Oral Examination :-

1. Define excess temperature**.**

2. Define pool boiling.

3. Define flow boiling.

4. Give three examples of pool boiling & forced boiling.

5. Define sub cooled boiling.

6. What is superheated or bulk boiling.

7. State factor on which boiling process depends.

8. State various regines of pool boiling.

9. Define critical heat flux.

10. Why the heating coil is made spiral?

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DEPARTMENT OF MECHANICAL ENGINEERING

HEAT TRANSFER LAB

Experiment No: 06

Temperature distribution along the length of fin, fin effectiveness & its efficiency

Aim:-

To determine the temperature distribution along the length of fin & to determine fin effectiveness & its efficiency.

Introduction:-

Extended surface or fins are used to increase heat transfer rate from a surface to a fluid whereas it is not possible to increase the value of surface heat transfer coefficient & temp difference between surface & the fluid. The use of this is very common & they are fabricated in verity of shape circumferential fin along the cylinder of motor cycle engine & fin attached to condenser tube of refrigerator are few familiar examples.

It is obvious that a fin surface stick out from the primary heat transfer surface. A temp difference with surrounding fluid will steadily diminish a one moves along with fins. The main objectives of this experimental setup are to study a temp distribution is simple pin fin.

Apparatus:-

A brass fin of circular cross section is fitted across a long rectangular duct. The other end of duct is connected to the suction side of blower and air flows pass the fin perpendicular to its axis. One end of fin project out side the duct and is held by heater. Temp at five points along the length of fin are measured by thermocouples connected along the length of fin. The air flow rate is measured by an 'orifice' meter fitted on the delivered side of the blower.

Specification:-

1) Diameter of fin : 20mm
2) Length of fin : 210 mm
3) No. of thermocouples : 6, thermocouple :,
4) Material of fin Aluminium
5) Temp. indicator : digital, with compensation of ambient temp. up to 200 ^{0}c
6) Dimmer state : to vary heater i/p 2 amp 230 volts
7) Heater : 300 watts , band type suitable for mounting of fin ends
8) Voltmeter : digital, range 0 to 1000 V
9) Ammeter : digital, range 0 to 2 amp

Theory:-

Consider a fin connected at its base to a heated wall and transferring heat to the surrounding.

Let

A = cross-section area of fin. C
= circumference of fin.
L = length of fin = 210 mm
T1 = temp of fin at the beginning.
T_f = duct fluid temp.
$\Theta = T - T_f$ = rise in temp

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The heat conducted along the rod and also lost to surrounding fluid by convection.
Let

h = heat transfer coefficient
k = thermal conductivity of fin material.

along the length of fin at x. the resulting equation of heat balance appears as

$$(d^2\Theta / dx^2) - (h\,c/ kA)\,\Theta = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

And the general solution of equation (1) is

$$\Theta = C_1 e^{mx} + C_2 e^{-mx} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

Where

$$m = \sqrt{(h\,c/ kA)}$$

With boundary condition of $\Theta = \Theta o$ & $x = 0$
Where $\Theta o = T_o - T_f$ & assuming the fin tip to be insulated.

$(d\Theta / dx) = 0$ at $x = L$ result in obtaining equation (2)

In form

$$(T - T_f) / (T_o - T_f) = \cosh [m (L - x)] / \cosh (mL) \ \ldots..\ (3)$$

This is equation for temp distribution along length of fin. It is seen from the equation that for a fin of a given geometry with uniform cross-section, the temp at any point can be calculated by knowing the values of T1,Tf and x. Temp T1 and Tf will be known for a given situation and value of h depends on whether the force convection and can be obtain by using the co-relation as given below

1) <u>For free convection condition</u>
$Nu = 1.1 (Gr.Pr)^{1/5}$ ……..10 <Gr Pr< 10^4
$Nu = 0.53(Gr.Pr)^{1/4}$ …….. 10<Gr Pr< 10^9
$Nu = 0.13(Gr.Pr)^{1/4}$ …… 10 <Gr Pr< 10^2
2) <u>For forced convection</u>
$Nu = 0.615(Re)^{0.466}$

$$Nu = 0.174(Re)^{0.618}$$

Where

$Nu = h\ D / K_{air}$

$Re = \rho\ v\ D / \mu$ Reynolds number

$Gr = g\ \beta\ D^3\ \Delta T / v^2$ Grass Hoff number

$Pr = C_p\ \mu / k_{air}$ Prandtl number

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All properties are evaluated at mean film temp. The mean film temp is arithmetic average of fin temp and air temp.

Nomenclature

ρ = density of air , kg/m^3
D = diameter of fin, m
μ = dynamic viscosity, kgf. Sec / m^2 (in mks units) and N-s/ m (in SI unit)
v = kinematical viscosity, m^2/s
k = thermal conductivity of air k cal / hr m $^{\circ}$c (in mks unit) & w / m$^{\circ}$c (in SI unit)
g = acceleration due to gravity 9.81 m / s^2

Tm = average fin temp

$$= \frac{T1 + T2 + T3 + T4 + T5}{5}$$

$\Delta T = T_m - T_f$

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

ß = mean fin temp = $1 / (T_{mf} + 273)$

Pω = density of water = 1000 kg / m³
Pa = density of air at T1
Cd = 0. 64
d = diameter of orifice = 0. 025 m

& effectiveness of fin can also be calculated as

$\eta = \tanh \cdot mL / mL$

Experimental Procedure:-

To study the temp distribution along the length of fin. Fin in natural and forced convection, the procedure is as under

Natural convection

1) Start heating fin by switching on the heater element & adjust the voltage on dimmer stat to say 80 volts.
2) Note down the thermocouple reading 1 to 5
3) When steady state is reach record the final reading 1 to 5 & also the ambient temp reading 6
4) Repeat the same experiment with voltage 100 volts & 120 volts

Observation Table:-

1) Natural Convection:

Sr. No.	V volts	I Amp.	Manometer Height, (hw) mm	Fin temp ^0c					Ambient temp T_f
				T_1	T_2	T_3	T_4	T_5	

Conclusion:-

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Experiment No: 08

Performance of Parallel Flow & Counter Flow Heat Exchanger

Aim: - To study the performance of parallel flow and counter flow heat exchanger.

Introduction:-

Types of heat exchanger

Heat exchangers are device in which heat is transferred from one fluid from another. The necessity for doing this arises in a wide variety of applications including a space heating and cooling .thermal power production and chemical processes equipments. By considering the transfer process occurring in them, heat exchangers may generally be classified as belonging to one of three types .These are:

1. Direct transfer type
2. Storage (or regenerated) type
3. Direct contact type

A Direct Transfer Type Heat Exchanger is one in which the cold and hot fluid flows simultaneously through the device and heat is transformed through the walls separating the fluids. This type of heat exchanger is most widely used in practice. Most simpler type of heat exchanger is shown in the figure .This heat exchanger has concentric tube arrangement. One fluid flows through the inner tube while other flows through annular space between the two tubes. The heat transfer takes place across the walls of the inner tube, although simultaneous flows of both fluids occur in heat exchanger. There is no mixing of two fluids. There are also no moving parts.

A Storage Type Heat Exchanger (or regenerator) is one in which heat transfer from the hot fluid to the cold fluid occurs through a coupling medium in the form of porous solid materials. The hot and cold fluid flow alternately through the matrix. The hot fluid storing heat in it and the cold fluid attracting heat from it. In many applications a continuous flow has to be maintained on both hot and cold sides. In such cases it is common to use rotating type matrix.

Unlike the two previous types a Direct Contact Type Heat Exchanger is one in which the two fluids are not separated. If heat is to be transferred between gas and fluid, gas is either bubbled through the liquid or the liquid is separated in the form of droplets in the gas. For heat exchange between two liquids one liquid is sprayed through the other, the only restriction that the liquid have to be immiscible. Very often in Direct Contact Heat Exchanger the process of heat transfer is also accompanied by mass transfer. Cooling towers and scrubbers are two examples of such equipments.

The Direct Transfer Type Heat Exchanger is generally used in most applications. The most serious defect from which it suffers is the fact that with the passage of time, scale and direction tend to accumulates on heat exchanger.

If heat is to be transferred between gas and liquids gas is either bubbled through the liquid or the liquid is spread through in the form of droplets into the gas. For Heat exchanges between two liquids, one liquid is spread through the heat exchanger the process of heat transfer is also accompanied by mass transfer. Cooling and scrubbers are the two examples of such equipments.

The direct transfer type heat exchanger is generally used in most applications the most serious defect from which it suffers is the fact that with the passage of time, scale and direction tends to accumulate on Heat exchanger surface. This accumulation (called foaling) increases the thermal resistance to heat flow, so that the performance of the transfer type slowly deteriorates.

In contrast the storage type heat exchanger because of periodic flow reversal tends to the self cleaning. The storage type also resulting in a must compact arrangement than transfer type .the major disadvantage of he storage type is that sum mixing of hot and cold fluid is irreversible and that scaling the hot side from the cool side in the rotary design presents considerable difficulty.

Classification according to the flow arrangement:-

Proper classification of Heat exchanger also involves a specification of the flow arrangement. These are the basic arrangements, viz

1. Parallel Flow
2. Counter Flow
3. Cross flow

In the parallel flow Heat exchanger, the two fluid streams enter at one end, flow through in the same direction and leaves at the other end. In the counter flow, they flow in opposite direction. In cross flow Heat exchangers, one fluid moves through the Heat exchanger at right angles to the flow path of the other fluids .For e.g. the arrangement in the concentric tube Heat exchanger shown in the figure in parallel flow. Heat change in the direction of one of the fluid would result I counter flow the arrangement in direct contact Heat exchanger is shown in the figure is also counter flow .

Experimental setup:-

Experimental setup consists of tube. In this Heat exchanger which can operate as parallel flow Heat exchanger and as a counter flow Heat exchanger by closing and opening the walls .hot water obtained from electric geyser is flowing through the inner copper type. Cold water flows through the annular pipe fitted concentric with the inner tube. When cold water enters at the same end where hot water enters, it gives a parallel flow arrangement. When cold water enters at the exit side of hot water, we get counter flow arrangement. Figure shows schematic layout and valves position of respective arrangement.

Specifications:-

1. electric instant type geezer	3 kw cap 1 No.
2. glass thermometers 0 to110 c	4 Nos.
3. stop clock	1 No
4. measuring flask 1000cc	1 No
5. length of Heat exchanger	1 m
6. inner tube ID	0.0105 m
7. inner tube OD	0.0125 m
Copper material	
8. outer tube OD	0.0275 (27.5mm)
9. outer tube ID	0 .0338 (33.8mm)

Procedure:-

1. Parallel flow run.

   Place four thermometer in four thermo wells and allows water from supply line to flow through the inner tube and pouter tube as it required. Arrange valve position as shown in the figure to have parallel flow configuration.

2. Adjust the flow rare of hot water side equal to about two liter per minute and cold water size equal to about four liter per minute. However note the flow rate carefully using measuring flask and stop watch.

3. Take the initial temp reading from four thermometer and note down the relative error if nay.

4. Put on the geyser and check for any leakage of electricity by test.

5. Note down the temp at an interval of 10 minutes up to steady state conditions. Check the flow rate and adjust to the initial fixed rate by minor adjustment if required.

6. After matching of the steady state note down the observation in the observation table.

Counter Flow Heat exchanger

1. to obtin cunter flow ,rearrange the valve position as shpown in the figure
2. adjust the flow rates on hot side nd cold side exactly equal at interval of ten minute.
3. check the tempersture at the intervals of ten minutes till the steady states obtained;.
4. check the flow rate and try to keep them constant as per initially obtainted for parallel flow arrangememt.
5. after reaching ,take a set of reading and calculate as per parallel flow arrangement.

Observation Table :

A. Parallel Flow Run

Hot Water Side			Cold Water Side		
Flow Rate	T_{hi}	T_{ho}	**Flow Rate**	T_{ci}	T_{co}

Calculations:

1. Rate of Heat Transfer (q) :

Rate of Heat Transfer for hot water (q_h) = ($m_h Cp_h$) (T_{hi} - T_{ho}) Take Cp_h & Cp_c = 4187 J/KgK

=

=

Rate of Heat Transfer for cold water (q_c) = ($m_c Cp_c$) ($T_{co} – T_{ci}$)

=

= =

2. Logarithmic Mean Temperature Difference (LMTD) = $\Delta T_m = (\Delta T_i - \Delta T_o) / \text{Log}_e (\Delta T_i / \Delta T_o)$

Where, for **Parallel Flow** : $\Delta T_i = T_{hi} – T_{ci}$

$\Delta T_o = T_{ho} – T_{co}$ =

=

=

Where, for **Parallel Flow** : $\Delta T_i = T_{hi} - T_{co}$

$\Delta T_o = T_{ho} - T_{ci}$

=

=

=

3. Overall Heat Transfer Coefficients (U) = $\frac{q}{A\Delta T_m}$ Where $A = \pi d_i l$ (d_i = 10.5 mm)

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

=

=

Result:

Expected Questions for Oral Examination :-

1. Define heat exchanger.

2. State practical application of heat exchanger.

3. Classify heat exchangers.

4. State significance of overall HTC.

5. Calculate Reynolds's number for experiment.

6. State LMTD approach parallel & counter flow heat exchanger.

7. Calculate heat exchange for given experiment.

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Experiment No: 07

Thermal Conductivity of Metal Rod

Aim: - Determination of thermal conductivity of metal rod

Introduction: -

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

Thermal conductivity of a material is found to depend upon the chemical composition of the substance or substance which it is composed of the phase (i.e. gas, liquid or solid) in which it exists. Its crystalline structure if a solid, the temperatures and the pressure to which it is subjected and whether or not it is a homogeneous material.

List of values of thermal conductivity:-

SR. NO.	MATERIAL			STATE
1.				
2.				
3.				
4.				
5.				
6.				
7.				

Mechanisms of thermal energy conduction in metals: -

Thermal energy in metals may be conducted in solids by two modes:

i) Lattice vibration

ii) Transport by free electrons.

In good electrical conductors a rather large number of free electrons move about in the lattice structure of material. Just as these electrons may transport electrical charge they may also carry thermal energy from 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 lattice mode of energy transfer is not as large as the electron transport it is for this reason that good electrical conductors are almost always good heat conductors viz. copper, aluminum and silver will increase in temperature. However, the increased lattice vibrations come in the way of transport by free electrons and for most of pure metals the thermal conductivity decreases with increase in temperature.

Apparatus: -

The experimental set up consist of metal bar, one end of which is heated by an electric heater while the other end project inside cooling water jacket. The middle portion of the bar is surrounded by a cylindrical shell filled with asbestos powder/glass wool bags. The temperature distribution is measured by separate thermocouple at two different sections in the cylindrical shell.

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

Specifications:-

1) Length of metal bar **:** 510 mm
2) Size of metal bar (diameter) **:** 25.4 mm
3) Test length of the bar **:** 315 mm

4) No. of thermocouples mounted on the bar : 6
5) No. of thermocouples in the insulation shell : 4
6) Heater coil : band type
7) Cooling jacket diameter : 90 mm
8) Temperature indicator 0-200° C, with multi-channel switch position. 1-5 thermocouple position on metal bar : Digital Display with switch.
9) Material of Metal Rod : Copper
10) Dimmerstat for heater coil : 2 Amp
11) Voltmeter : 0 to 300 Volts
12) Ammeter : 0 to 5 Amp
13) Measuring flask for water flow rate : 2 Ltrs.

Theory: -

The heater coil heat the bar at its end and heat will be conducted through other end after attaining the steady state referring the figure. Heat flowing out of the section A-A of bar,

$$P \cdot \omega = m \cdot Cp \cdot \Delta T$$

Where,

m = mass flow rate of cooling water.
C_p = specific heat of water.
$\Delta T = (T_{11} - T_{10})$

Thermal conductivity of bar at section A-A can now be calculated as,

$$P \cdot \omega = -K_{AA} \cdot A \cdot \left(\frac{dT}{dx} \right)_{AA}$$

The value of $(dT/dx)_{AA}$ is obtained experimentally. The negative sign is introduced because heat flows in the direction of decreasing temperature and serves to make the heat flux positive in the positive direction.

Heat conducted through section B-B of bar $= P \cdot \omega +$ Radial heat loss between section B-B and section A-A

$$= P \cdot \omega + 2 \cdot \prod \cdot K \cdot L \cdot \left(\frac{(T_8 - T_9)}{\ln \cdot \left(\frac{r_o}{r_i} \right)} \right)$$

$$= P_{BB}$$

Where,

K = 0.2 Kcal/hr-m°C

0.23 W/m-°k

L = 0.08 m

Thermal conductivity of section B-B is,

$$P \cdot \omega = -K_{AA} \cdot A \cdot \left(\frac{dT}{dx} \right)_{AA}$$

Heat conducted through the section C-C is,

$$P_{BB} + 2 \cdot \prod \cdot K \cdot L \cdot \left(\frac{T_6 - T_7}{\ln\left(r_o / r_i \right)} \right) = P_{CC}$$

and,

$$P_{CC} = -K_{CC} \cdot A \cdot \left(\frac{dT}{dx} \right)_{CC}$$

Thus, the thermal conductivity of bar can be calculated.

Procedure: -

1) Start the electric supply.
2) Give input to heater by slowly rotating the dimmerstat and adjust it to voltage equal to 80V, 120V, etc. for different sets.
3) Start the cooling water supply through the jacket and adjust it to about 300 to 350 cc per minute.
4) Go on checking the temperature at some specified time interval, say 5 minutes and continue this till a satisfactory steady state condition is reached.
5) Note down the temperature readings 1 to 11.
6) Note down the mass flow rate of water in Kg/hr and temperature rise in 0°C.

Observation Table: -

Thermocouple No.	Temperature (°C)

Sample Calculation: -

Result Table: -

Sr. No.	Section	Heat Flow Rate (Kcal/hr)	Thermal Conductivity (Kcal/hr-m°C)

Conclusion: -

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Experiment No: 8

Stefan Boltzman's constant

Aim:- To determine the value of safety Stefan Boltzman's constant.

Introduction:-

We know that all bodies at all temperature exert thermal radiation & like conduction convection this mode of heat transfer doesn't require any material medium. The propagation of energy takes place of electromagnetic waves emitted from the surface of body

Stefan Boltzman's Law:-

The most commonly used law of thermal radiation is Stefan Boltzman's law which states that the thermal radiation heat flux emitted from all the incident radiation following on it proportional to the fourth power of the absolute temp. of the surface & is given by following equation.

Thermal Radiation:

(q/A) = Heat Flux in w/m^2 = $\sigma \cdot T^2 \cdot \varepsilon \cdot \beta$

Where ,T= the surface temp. which emits the thermal radiation in k

σ = Stefan Boltzman's constant. = 5.67×10^{-8} W/m^{2} k

^{4} e_b = emissive power of black surface

The Stefan Boltzman's law can be divided by integrating plank's law where the Stefan Boltzman's law & value of σ is 5.67×10^{-8} w/m^{2}k^4

It is of historic interest to note down that Stefan Boltzman's law was independently developed before the plank's law & consequently was not originally derived in the manner as above.

Heat exchanger radiation between a small blank area element a large blank area enable to get following equation.

$$\sigma = \frac{m_c \left(dT/dt\right)_{t=0}}{A \cdot \left(T_S{}^4 - T_1{}^4\right)}$$

The slope of temp. against time is obtained at t = 0 & is substituted to obtain σ.

Apparatus:

1. A Water heater tank fitted with immersion type heater & liquid level alarm
2. An enclosure made of copper with in surface quoted with black point is mounted on bakelite plate
3. four thermocouples are mounted on a enclosure to since the surface temp. of enclosure.
4. The disc with black surface & the thermocouples mounted on it.
5. The control panel consists of
    a) Switch for heater
    b) Multi channel temp. indicated
    c) Liquid level alarm
    d) Timer for temp. measurement of disc

Procedure:-

1. fill the tank with water and switch on the heater switch. Check the temp. of water by means of provided
2. After achieving temp. at about 90^0C open the valves and allow the water to enter in enclosures.
3. Put off the meter supply.
4. Record the enclosure temperature.
5. Record the disc temperature before inserting heat in to enclosure.
6. Note down the temperature at every buzzer of 5 sec.

Observations:-

1. Mass of disc (m) = kg.
2. specific heat of disc (copper i.e. Cp) = j/kg^{0}c
3. Area of disc = m^2
4. Temp of enclosure surface =Ts= $\dfrac{T_1 + T_2 + T_3 + T_4}{4}$
5. .Record the temperature of test disc (Ts) in following table.

T1	T2	T3	T4

Time(sec)									
Temp(^{0}c)									

T1	T2	T3	T4

Time(sec)									
Temp(^{0}c)									

Remark:-

1. The value of 'σ' obtained by as above will be its order of magnitude.
2. due to certain limitation of experiment the value obtained as above may be accepted as reading
3. The main limitations are :
   a. Black surface of the enclosure & disc with emission only approve to equation 1.
   b. Heat transfer to rest plate disc from plate surface to bakelite plate by conduction.
   c. Limit size of disc
   d. Commercially available disc material & its assumed value of specific heat.
   e. Correct slope determinants due to instrument limitations.
4. The value obtained as above is facing close to its correct value of 5.67×10^{-8} w/m^2k^4.

Result Table:-

Obs. no	Avg temp T^0 k	Avg temp Ts^0 k	Stefan boltsman constant(σ) (w/m^2k^4)
1			
2			

Conclusion:-

Expected Questions for Oral Examination :-

1. Define unsteady state heat conduction.

2. State example of unsteady state heat conduction in actual practice.

3. State the significance radiation heat transfer applications.

4. State the governing equation of quantum theory.

5. What is a shape factor?

6. State the emissive powder of Sun if temperature on surface is 5785 K.

7. State the insulation used in the experiment.

8. Sketch a line diagram of the arrangement.

9. What is the cause of error in result of experiment?

10. How we can achieve vacuum?