AMIRAJ
COLLEGE OF ENGINEERING & TECHNOLOGY

LABORATORY MANUAL

HEAT TRANSFER

SUBJECT CODE: 3151909

MECHANICAL ENGINEERING DEPARTMENT

B.E. 5th SEMESTER

NAME:____

ENROLLMENT NO: ____________________________________

BATCH NO: ____

YEAR: ____

Amiraj College of Engineering and Technology,

AMIRAJ
COLLEGE OF ENGINEERING & TECHNOLOGY

Amiraj College of Engineering and Technology,
Nr.Tata Nano Plant, Khoraj, Sanand, Ahmedabad.

CERTIFICATE

This is to certify that Mr. / Ms.
____

Of class______________________ Enrolment No ______________________________has

Satisfactorily completed the course in ____as by the Gujarat Technological University for ____ Year (B.E.) semester___ of Mechanical Engineering in the Academic year______________________.

Date of Submission:-

Faculty Name and Signature (Subject Teacher) **Head of Department (Mechanical)**

AMIRAJ COLLEGE OF ENGINEERING AND TECHNOLOGY
(MECHANICAL DEPARTMENT)
HEAT TRANSFER

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MECHANICAL ENGINEERING DEPARTMENT

B.E. 5th SEMESTER

INDEX

Aim

To determine the thermal conductivity of the metal rod

Introduction

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

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

Metals	Thermal Conductivity Watt/M ° K	State
Pure Copper	390	20°C
Brass	110	20°C
Steel	40-50	20°C
Stainless Steel	16-20	20°C

Mechanism of thermal energy condition in metals

Thermal energy may be conducted in solids by two modes:

1. Lattice vibrations
2. Transport by free electrons

In good electrical conductors a rather large no. of free electrons move about in the lattice structure of the material. Just as these electrons may transport electric charge, they may also carry thermal energy from a high temperature region to a low temperature region. In fact, these electrons are frequently referred as the electron gas. Energy may also be transmitted as vibrational energy in the lattice structure of the material. In general, however, this latter mode of energy transfer is not as large as the electron transport & it is for this reason that good electrical conductor are almost always good heat conductors i.e Copper, Aluminum & Silver.

With increase in the temperature, however the increased lattice vibrations come in the way of the transport by free electrons & for most of the pure metals the conductivity decreases with increase in the temperature.

Description

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 four different sections while the radial temperature distribution is measured by separate thermocouples in four different sections in the insulating shell. The heater is provided with a dimmerstat for controlling the heat input. Water under constant heat condition is circulated through the jacket and its flow rate and temperature rise are noted.

SPECIFICATIONS :

Length of the metal bar:	300 mm (Approx.)
Size of the metal bar(dia.):	25 mm
Test length of the bar:	175 mm
MOC of Metal Bar	Brass
No. of thermocouples on bar:	4
No. of thermocouples on Shell:	4
Heater coil:	Band type
Digital temperature indicator:	0-1000°(Multi Channel)
Dimmerstat:	2 Amp
Wattmeter	400 W
Shell Diameter:	175 mm

PROCEDURE

1. Adjust the flow rate to 150 ml / min using measuring Jar and Stop watch
2. Put the supply and adjust the varaic to obtain some heat input
3. Wait till steady state is reached
4. Take reading of thermocouples T_1 to T_0
5. Take two more reading at interval of 10 minutes and Tabulate

Sr. No.	**Temp On Metal Rod**			**Temp. on Insulating Shell**				**Water Temperature**			**Water Flow Rate**	
	T_1	T_2	T_3		T_5	T_6	T_7		T_9	T_0	ml	sec

THEORY

The heater will heat the bar at its end and heat will be conducted through the bar to other end. After attaining the steady state Heat flowing out of bar.

Heat flowing out of bar = Heat gained by water

$Q_w = m_w \times Cp_w \times (T_{out} - T_{in}) = m_w Cp_w (T_9 - T_0)$

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

Cp : Specific Heat of water 4186 J/kg K

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

Thermal Conductivity of Bar

1. Heat Conducted through the Bar (Q)

$$Q = Q_W + 2\pi KL(T_b-T_s) / (\ln r_o / r_i)$$

Where, Qw :Heat conducted through water

L= Length of Shell = 0.175 m

k:Thermal conductivity of Asbestos powder is 0.3 Kcal / hr – m degree

r_o& r_i: Radial distance of thermocouple in insulating shell.

2. Thermal conductivity of Bar (K)

$$Q = K \{ dt/dx \} \times A$$

Where, dt : Change in temperature. ($T_1 – T_3$)

dx : Length across temperature = 0.175 m

A: Area of the bar ($\pi/4 \times d^2$) = 1.96×10^{-3} m^2.

Conclusion:

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

SAMPLE CALCULATIONS:

Sr. No.	Temp On Metal Rod			Temp. on Insulating Shell			Water Temperature		Water Flow Rate	
	T_1	T_2	T_3	T_5	T_6	T_7	T_9	T_0	ml	sec
1	120	103	79.2	41.3	37.5	30.2	35.2	30	250	138

Now, 250 ml collected in 138 sec hence $m_w = 0.25/138 = 1.81 \text{ X } 10^{-3}$ kg/sec

$Q_w = m_w \text{ x } Cp_w \text{ x } (T_{out} – T_{in}) = m_w Cp_w (T_9 – T_0)$

$= 1.81 \text{ x} 10^{-3} \text{ x } 4186 \text{ x } (35.2 - 30) = 39.39$

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

Cp : Specific Heat of water = 4186 J/kg K

$T_9 – T_0 = (T_{out} – T_{in})$ for water

Thermal Conductivity of Bar

$$T_{avg\ b} = \frac{T_1 + T_2 + T_3 + T_4}{4} = (120+103+79.2+73.5)/4 = 93.925$$

$$T_{avg\ s} = \frac{T_5 + T_6 + T_7 + T_8}{4} = (41.3+37.5+30.2+55.6)/4 = 41.15$$

1. Heat Conducted through the Bar (Q)

$$Q = Q_W + 2\pi KL(T_b-T_s) / (\ln r_o / r_i)$$

Where, Qw :Heat conducted through water

L= Length of Shell = 0.175 m

k:Thermal conductivity of Asbestos powder is 0.349 W/ m K

r_o& r_i: Radial distance of thermocouple in insulating shell

$$Q = Q_W + \frac{2\ \pi \text{ x } 0.349 \text{ x } 0.175\ (93.925 – 41.15)}{\ln \{ 0.0875 / 0.0125 \}}$$

$$Q = 0.03936 + \frac{20.242}{1.946} = 10.4411$$

2. Thermal conductivity of Bar (K)

Q = K { dt/dx} x A

Where, dt : Change in temperature. ($T_1 – T_4$)
dx : Length across temperature = 0.175 m
A: Area of the bar ($\pi/4 \times d^2$) = 1.96×10^{-3} m^2

.

$49.801 = K \{46.5 / 0.175\} 1.96 \times 10^{-3}$

K = 95.62 W / m K

HMT.007.1 *NATURAL CONVECTION APPARATUS*

Aim

To determine the natural convection heat transfer coefficient for the vertical tube exposed to atmospheric air.

Introduction

Convection is the mode of heat transfer which generally takes place in liquid and gases. Consider a fluid flow over a heated surface, the molecules of fluid adjacent to the surface, absorb heat and become hot, on heating the molecules become lighter due to decrease in density, they rise up and the cold molecules of higher density come down in contact of heated surface, in this way, motion of molecules sets up in fluid due to developed density gradient.

Experimental Setup:

The experimental setup consist of a brass tube fitted in a rectangular duct, vertically. The duct is open at top and bottom, an electric heating element is kept in the center of the vertical tube, which in turn heats the tube surface longitudinally. The heat is lost from the tube to the surrounding air by natural convection. The temperature of the vertical tube is measured by seven thermocouples at different locations and thermocouple T_8 measures the duct temperature. The heat energy is measured by ammeter and voltmeter.

When a hot body is kept in still air, the heat is transferred to surrounding fluid adjacent to the hot body. The adjacent fluid gets heated, it rises up due to decrease in its density and cold fluid rushes in to take place, and thus the fluid motion is setup and heat transfer takes place from the surface. The heat transfer rate from the surface by natural convection is expressed by Newton's law as:-

$$\mathbf{Q = A_s\, h\, (T_s - T_a)}$$

Where A_s = Surface area of Brass tube = π.d.L
h = heat transfer coefficient
T_s = Average Surface Temperature
T_a = Ambient Temperature.

Thus the convection coefficient can be evaluated as

$$\mathbf{h = Q / A_s\, .\, h\, .\, (T_s - T_a)}$$

Experimental Procedure:

1. Put on the heater switch and adjust the heater input through Dimmerstat.
2. Wait till the steady state condition is reached.
3. Note down the reading of all thermocouples through selector switch and wattmeter.
4. Repeat above procedure for next reading.

Specifications:

1. Diameter of tube, d= 25 mm
2. Total length of tube, L = 400mm
3. Capacity of heater = 200 W
4. No. of Thermocouples = 6 Nos.

Observation Table

Sr.No.							
	Watt	T_1	T_2	T_3	T_4	T_5	T_6 or T_a
1							
2							
3							

Calculations:

Heat Transfer Coefficient, $\mathbf{h = Q / A_s (T_s - T_a)}$

Where,

Q = V X I X 0.2 watts *

$\mathbf{A_s}$ = Surface area of Brass tube = π dL

h = Heat transfer coefficient

$\mathbf{T_s}$ = Average Surface Temperature

$\mathbf{T_a}$ = Ambient Temperature.

The average surface temperature of brass rod,

$T_S = (T_1 + T_2 + T_3 + T_4 + T_5) / 5$ = ______ °C

Ambient temperature Ta = ... ° C

Thus the convention coefficients can be evaluated as

= ________ $W/m^2.K$

* **Note:** Practically it is not possible to completely convert complete electrical energy supplied to heat energy. Commonly used heaters also have a band of insulation over the heating element which further reduces the amount of heat transfer to the test section. Also the heat generated in heating element is lost in radiation and convection losses due to surrounding air breeze. Due to this cumulative effect there is difference in heat transfer rate. Hence we introduce a loss factor of 0.2 in natural convection

Theoretical Method (Correct Method)

Film Temperature $T_f = \dfrac{T_s + T_a}{2}$ = ° C

Volumetric Coefficient, β = 1 / (T_f + 273) =_____° K^{-1}

Properties of air at the film temperature (T_f) from data book, Say at 350 K

ρ = 0.9980 kg/m^3
Cp = 1.0090 kJ/kg K
μ = 2.075 kg/ms x 10^{-5}
k_{air} = 0.03003 W / mK
v = 20.76 m^2/s X 10^{-6}

Gr = Grashof Number = $\dfrac{g\ \beta\ L3\ (\Delta T)}{v^2}$

Pr = Praudtl Number = $\mu Cp / k_{air}$

Where L = length of The Brass Tube, m

Nu = C $(Gr\ Pr)^n$

Where,
C = 0.56 and n = 0.25 for $10^4 < Gr\ Pr < 10^8$
C = 0.13 and n = 1/3 for $10^8 < GrPr < 10^{12}$

K_{air} =Thermal conductivity of air, W/m.K
v = Kinematics viscosity of air, m^2/s
μ = Dynamic viscosity of air, kg/m.s
Cp = Specific heat of air, J/kg.K
β = Coefficient of volumetric expansion of air, K^{-1}
ΔT = Ts – Ta in ^{0}C

Also

Nu = h. L / K_{air}

Or h = (N_u. K_{air}) /L

Results:

Value of h in Natural Convection is =_________W/ m^2. K

Conclusion:

The heat transfer coefficient in natural convection is much lower, because, the heat is transferred due to density gradient only, thus the value of heat transfer coefficient as also small. The phenomenon of natural convection also depends upon viscosity, thermal conductivity, volumetric expansion coefficient, β etc.

REVISIONS				
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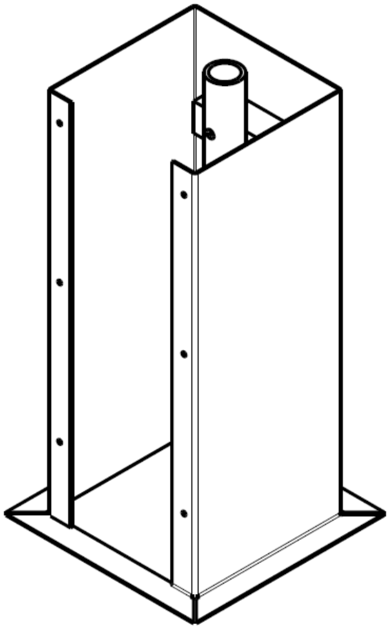

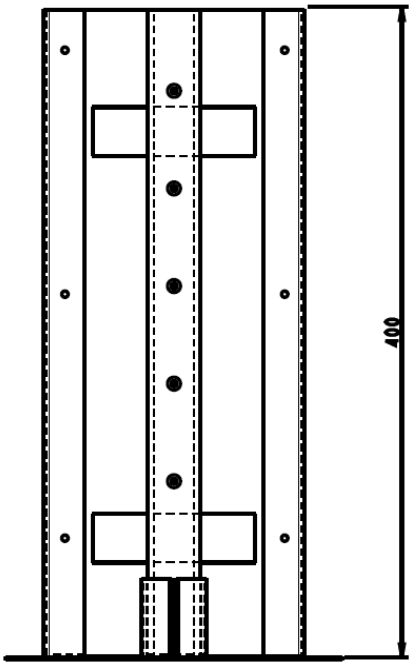

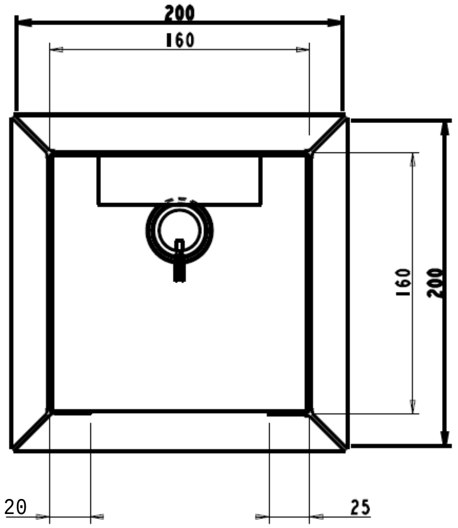

GENERAL TOLERANCE APPLY
AS PER 150-2768 m

MECHMATICS

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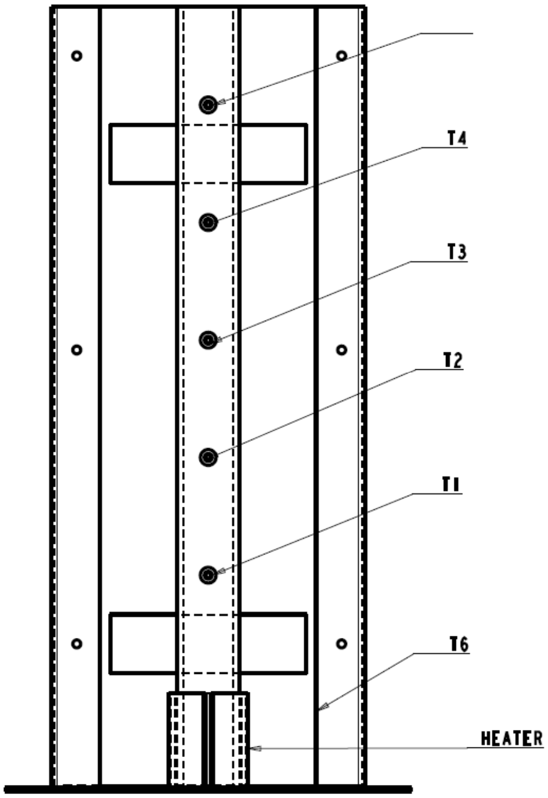

GENERAL TOLERANCE APPLY AS PER 150-2768 m	MECHMATICS	CONVECTION ASS¿MBLY HTI2-0030 -

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SAMPLE READINGS

OBSERVATIONS

watt	T1	T2	T3	T4	T5	T6
44.29	**86**	**69**	**63**	**59**	**57**	**41**

ID in m	L in m	Surface Area	Ts	h
0.025	**0.4**	**0.0314**	**66.8**	**10.9341826**

Design Data Book at	**Tf**	**53.9**

Kinematic Viscosity	Pr No.	Thermal Conductivity	Cp	Beta	Gr	Gr.Pr
0.0000185	0.697	0.0283	1005	0.00305904	144780579.3	100912063.8

h	h
4.183735574	**4.026901582**
if 10^4 -- GrPr --10^8	if 10^8 -- GrPr --10^12

Value of h in Natural Convection is = 4.0269 W/ m^2. K

HMT.007 *FORCED CONVECTION APPARATUS*

AIM:

To determine the forced convection heat transfer coefficient for the flow through the given horizontal tube

INTRODUCTION

Convection is heat transfer by mass motion of a fluid such as air or water when the heated fluid is caused to move away from the source of heat, carrying energy with it. Convection above a hot surface occurs because hot air expands, becomes less dense, and rises. Convection can either be Natural or Forced

Natural convection results from the tendency of most fluids to expand when heated—i.e., to become less dense and to rise as a result of the increased buoyancy. Circulation caused by this effect accounts for the uniform heating of water in a kettle or air in a heated room: the heated molecules expand the space they move in through increased speed against one another, rise, and then cool and come closer together again, with increase in density and a resultant sinking.

Forced convection involves the transport of fluid by methods other than that resulting from variation of density with temperature. Movement of air by a fan or of water by a pump are examples of forced convection.

DESCRIPTION:

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

SPECFICATIONS:

1. Pipe Dia. (Do) : 32 mm.
   Pipe Dia. (Di) : 27.5 mm.
2. Length of Test Section (L) : 400 mm.
3. Blower
4. Orifice Dia. (d) : 16.5 mm.
5. Dimmersat : 0 to 2 Amp, 230 Volt AC
6. Wattmeter : 300 Watt
7. Heater : Band Type
8. Test Section Insulation : Glass Wool

PROCEDURE:

1. Start the blower & adjust the flow by means of gate valve to some desired difference in manometer level.
2. Start the heating of test section with help of dimmerstat & adjust desired input with the help of Wattmeter
3. Take readings of all thermocouples after an interval of 10 min until steady is reached.
4. Note the heater input.

OBSERVATION TABLE:

Sr. No.	Voltmeter V (Volt)	Ammeter I (Amp)	Temperatures							Manometer Reading Difference H in m of Water
			T_1 Air Inlet	T_2	T_3	T_4	T_5	T_6	T_7 Air Outlet	
1.										
2.										
3.										
4.										

CALCULATIONS:

Experimental Method:-

1. q = Actual Rate of Heat Transfer = V X I X 0.3

Note: Practically it is not possible to completely convert complete electrical energy supplied to heat energy. Commonly used heaters also have a band of insulation over the heating element which further reduces the amount of heat transfer to the test section. Also the heat generated in heating element is lost in radiation and convection losses due to surrounding air breeze. Due to this cumulative effect there is difference in heat transfer rate. Hence we introduce a loss factor of 0.3 in forced convection

2. Surface heat transfer co-efficient (h_a)

$$h_a = \frac{q}{A\,(T_s - T_a)}$$

Where,

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

= π Di L

Ta = Average of Temp. of air

$$\frac{T_1 + T_7}{2} \quad {}^0K$$

T_s = Average surface Temp.

$$= \frac{T_2 + T_3 + T_4 + T_5 + T_6}{5}$$

Theoretical Method :-

1. **Air flow rate (Q)**

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

Where,

d = dia. of orifice
C_d = Co-efficient of discharge = 0.64
H = Difference of water level in manometer
ρ w = Density of water = 1000 kg/m^3
g = Gravitational Acceleration = 9.81 m/s^2
ρ a = Density of air at
mean bulk Temp $\frac{T_1 + T_7}{2}$ kg/m^3

2. **Velocity of air (V)**

$$V = \frac{4\,Q}{\pi\,(\,Di\,)^2}$$

3. **Reynold's Number (Re)**

$$Re = \frac{V\,Di}{\nu}$$

Where,
ν = Kinematic viscosity to be evaluated
at average bulk Temp $\frac{T_1 + T_7}{2}$ m^2/s

4. Prandtl Number (Pr)

Pr = Prandtl number at average bulk Temp.

$\frac{T_1 + T_7}{2}$ -------------- w/m^0 k

5. The appropriate correlation for turbulent flow through closed Conduits is Dittus – Boelter correlation.

$$Nu = 0.023\, Re^{0.8}\ Pr^{0.4} \cdots\cdots\cdots \text{for } Re > 10000$$

OR

$$Nu = 0.036\, Re^{0.8}\ Pr^{0.4} \cdots\cdots\cdots \text{for } Re > 2300$$

6. Nusselt Number (Nu)

$$Nu = \frac{ha\ Di}{K}$$

Where,

K = Thermal conductivity of air
at average bulk Temp.
$\frac{T_1 + T_7}{2}$ -------------- w/m^0 k

CONCLUSION:

Heat Transfer Coefficient in forced Convection of air in a tube is found out to be _______

PRECAUTIONS:

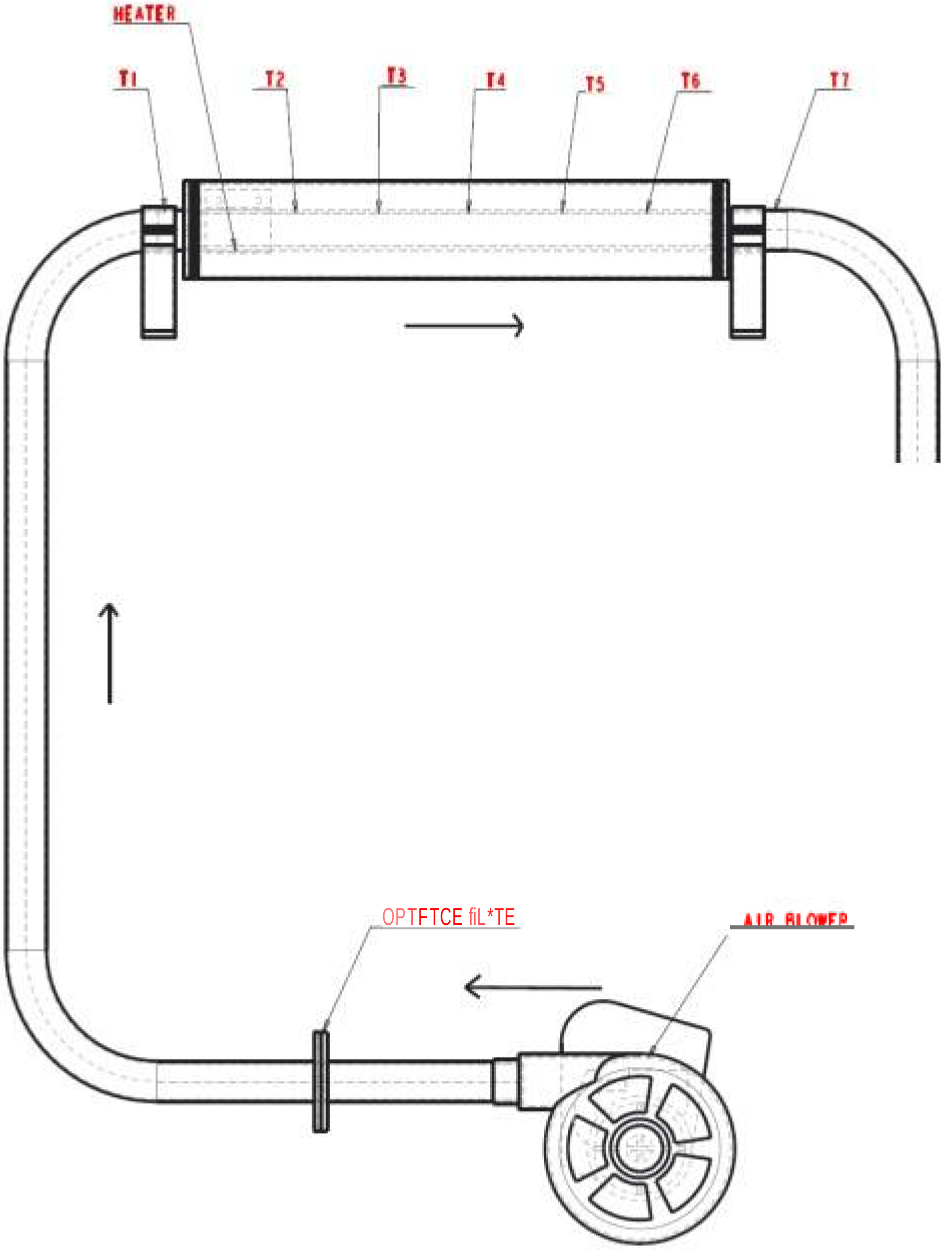
1. Keep the dimmerstat at zero position before switching ON the power supply.
2. Start the blower unit first.
3. Increase the voltmeter gradually.
4. Do Not stop the blower in between the testing period.
5. Do not disturb thermocouples while testing.
6. Operate selector switch of Temperature Indicator gently.
7. Do not exceed 150 W.

Properties Of Air

Temp ^{0}C	Density Kg/m^3	Kinematic Viscosity V x 10^{-6} m^2 /s	Prandil Number Pr	Thermal Diffusivity m^2/nr	Specific Heat C_p J/Kg K	Thermal Conductivity K x 10^{-3}	Coefficient of Viscosity x 10^6 Ns/m^2 or Kg/m
-50	1.584	9.23	0.728	45.7	1013	20.35	14.61
-40	1.515	10.04	0.728	49.6	1013	21.17	15.20
-30	1.453	10.80	0.723	53.7	1013	21.98	15.69
-20	1.395	11.61	0.716	68.3	1009	22.79	16.18
-10	1.342	12.43	0.712	52.8	1009	23.61	16.67
0	1.293	13.28	0.707	67.7	1005	24.42	17.16
10	1.247	14.16	0.705	72.2	1005	25.12	17.65
20	1.205	15.06	0.703	77.1	1005	25.93	18.14
30	1.165	16.00	0.701	82.3	1005	26.75	18.63
40	1.128	16.69	0.699	87.5	1005	27.56	19.12
50	1.093	17.95	0.698	92.6	1005	28.26	19.61
60	1.060	18.97	0.696	97.9	1005	28.96	20.10
70	1.029	20.02	0.694	102.8	1009	29.66	20.59
80	1.000	21.09	0.692	108.7	1009	30.47	21.08
90	0.972	22.10	0.690	114.8	1009	31.28	21.48
100	0.946	23.13	0.688	121.1	1009	32.10	21.87
120	0.898	25.45	0.686	132.6	1009	33.38	22.85
140	0.854	27.80	0.684	145.2	1013	34.89	23.73
160	0.815	30.09	0.682	158.0	1017	36.40	24.52
180	0.779	32.49	0.681	171.0	1022	37.80	25.30
200	0.746	34.85	0.680	184.9	1026	39.31	25.99
250	0.674	40.61	0.677	210.6	1038	42.68	27.36
300	0.615	48.20	0.674	257.6	1047	46.05	29.71
350	0.566	55.46	0.676	294.7	1059	49.08	31.38
400	0.524	63.09	0.678	335.2	1067	52.10	33.05
500	0.456	79.38	0.687	415.1	1093	57.45	36.19
600	0.404	96.99	0.699	499.0	1114	62.22	39.13
700	0.362	115.40	0.706	588.2	1135	66.87	41.78
800	0.329	1347.80	0.713	682.0	1156	71.76	44.33

REVISIONS

	REV		DATE	



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MECHMATICS

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ALL DIMENSIONS ARE IN MM

SAMPLE CALCULATIONS

Water manometer - orifice calculations						
Cd - Coefficient of Discharge	Orifce Dia in m	H Diff in Water Manometer in m	Pw in kg/m3	Pa in kg/m3	Q m3/sec	
0.65	0.015	0.009	1000	1.03	0.001503203	

Watt or VI	Temperature									
	On Test Section					Air Inlet	Air Outlet	dT	Ta	Ts
	T2	T3	T4	T5	T6	T1	T7	(T7 - T1)	(T1+T7)/2	
41	58	47	40	36	35	18	33	18	25.5	43.2

DESIGN DATA BOOK VALUES at Ta 25.5

Kinematic Viscosity	Prandltle Number	Thermal Conductivity
0.00001505	0.702	0.0264

Di in mm	L in mm	As (Surface Area) in m2	Ac (Cross Section Area) in m2	Heat Transfer Coefficient	V	Re	Nu Constant	Nu	Heat coefficient from Nu
27.5	400	0.03454	0.000593656	**20.11**	2.532	4626.78	0.023	17.69	**16.98725721**

CONCLUSION:

Heat Transfer Coefficient in forced Convection of air in a tube is found out to be 16.98 W /m^2 K

Aim :- To find out the thermal conductivity of power.

Description:-The apparatus consists of two thin walled concentric copper spheres. The inner Sphere houses the heating coil. The insulating powder (Asbestos powder – Lagging Material) is packed between the two shells. The powder supply to the heating coil is by Using a dimmerstat and is measured by Voltmeter and Ammeter. Choromel Alumel Thermocouples are use to measure the temperatures. Thermocouples (1) to (3) are Embedded on inner sphere and (4) to (7) are as shown in the fig. Temperature readings in turn enable to find out the Thermal Conductivity of the insulating powder as anisotropic material and the value of Thermal Conductivity can be determined. Consider the transfer of heat by conduction through the wall of a hollow sphere formed by the insulating powdered layer packed between two thin copper spheres

Let,

ri = Radius of inner sphere in meters=0.075m
ro = Radius of outer sphere in meters=0.250m
Ti = Average Temperature of the inner sphere in °C
To = Average Temperature of the outer sphere in °C

Where, $$T_i = \frac{T_1 + T_2 + T_3}{3}$$

$$T_o = \frac{T_4 + T_5 + T_6 + T_7}{4}$$

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

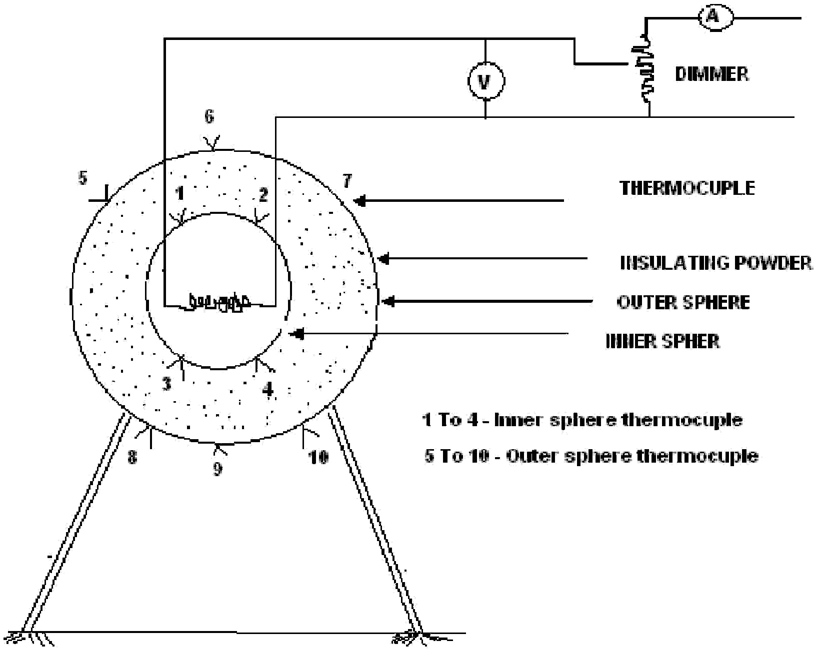
Form the experimental values of Q, Ti and To the unknown thermal conductivity K cal be Determined as …

$$K = \frac{Q\ (r_o - r_i)}{4\pi ri \times ro\ (T_i - T_o)}$$

Specifications:-

1. Radius of the inner copper sphere, ri = 75mm
2. Radius of the outer copper sphere, ro = 200mm
3. Voltmeter (0 – 100 – 200 V).
4. Ammeter (0 – 2 Amps.)
5. Temperature Indicator 0 – 300 ^{0}C calibrated for chromel alumel.
6. Dimmerstat 0 – 2A, 0 – 230 V.
7. Heater coil - Strip Heating Element sandwiched between mica sheets – 200 watts.
8. Chromel Alumel Thermocouples – No. (1) to (3) embedded on inner sphere to Measure Ti.

Schematic Diagram:



9. Chromel Alumel Thermocouples – No. (5) to (10) embedded on outer sphere to Measure To.

10. Insulating Powder – Asbestos magnesia commercially available powder and Packed between the two spheres.

Experimental Procedure:-

1. Start main switch of control panel.
2. Increase slowly the input to heater by the dimmerstat starting from zero volts Position.
3. Adjust input equal to 40 Watts Max. by Voltmeter and Ammeter. Wattage Q = VI
4. See that this input remains constant throughout the experiment.
5. Wait till fairly steady state condition is reached. This can be checked by reading Temperatures of thermocouples (1) to (7) and note changes in their readings with Time.
6. Note down the readings in the observations table as given below :

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

Inner Sphere:-

Thermocouple No.	1	2	3	Mean Temp. T_i = (T1+T2+T3)/3
	T1	T2	T3	
Temp.^{0}C				

Outer Sphere:-

Thermocouple No.	5	6	7	8	9	10	
							Mean Temp. T_0= (T4+T5+T6+T7)/4
Temp.^{0}C							

Calculation:-

W= V × I
Ti = Inner sphere mean temp. °C
To = Outer sphere mean temp. °C
ri = Radius of inner copper sphere = 0.075m.
ro = Radius of outer copper sphere = 0.200m.

Using Equation:-

q = 0.86 W   kcal /hr (In MKS units)

$$K = \frac{Q\ (r_o - r_i)}{4\pi ri \times ro\ (T_i - T_o)}$$

q =0.3 V × I w/m k (SI UNIT)

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

Conclusion:-
Thermal conductivity of powder is found out to be -------------

STEFAN BOLTZMAN APPARATUS

Aim

To determine the Stefan Boltzmann Constant for given Material

Introduction

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

$$Q / A = \sigma T^4 \text{ Watt/ } m^2 K^4 .$$

The constant of proportionality σ is called the Stefan Boltzman constant and has a value of 5.67×10^{-8} W/m^2 K^4 in S.I unit

Description

The apparatus consists of flanged copper hemisphere fixed on flat non-conducting plate. The outer surface is enclosed in a metal jacket used to heat at some suitable temperature. Four thermocouples are attached to various points on the surface and is measured by a temperature indicator.

The disc which is mounted in Bakelite plate is fitted in a hole drilled in the center of the base plate. Thermocouple is used to measure the temperature of disc

When the disc is inserted the temperature change with time is used to calculate the Stefan Boltzmann constant

SPECIFICATIONS :

Hemispherical enclosure dia.	:136 mm.
Water Jacket Diameter	:150 mm
Water Jaket Height	:145 mm
Base Plate Bakelite Dia	: 200 mm
Mass of test Disc	: 19.6×10^{-3} kg

PROCEDURE

1. Fill the water in upper tank.
2. Switch on the immersion heater and heat it up to around 70^0C
3. Switch off the heater and open the valve and allow the water into second tank
4. Allow in for steady state
5. Note down the reading of thermocouple T_2 to T_5
6. Insert the disc and immediately note down the temperature of T_6 at every five seconds
7. Draw the graph of temperature V/s time and calculate dT/dt

OBSERVATION TABLE

Sr. No.	**Temp. Readings**				**Time in sec for which T_5 is noted**										
	T_2	T_3	T_4	T_5	0	5	10	15	20	25	30	35	40	45	50

Calculations

T_s = surface temperature = $(T_1 + T_2 + T_3 + T_4) / 4 + 273$ K
T_5 = Disc Temperature = $T_5 + 273$ K
A_d = Surface area of the disc =
M = Mass of disc = 19.6×10^{-3} kg
S = specific heat of disc

= 0.1 Kcal/Kg. ^oC (Copper disc). (In MKS Units)

418.68 J/Kg ^oK (In S.I. Unit)

slope of dt/dx at t=0

= (31.6-29.7)/50

=0.038 k/sec

The value of can be obtained by using equation

$$\sigma = \frac{m.s\ (dT/dt)\ \text{at}\ t = 0}{A_D\ (T_5^4 - T_6^4)\ .\ 0.86} \quad w / m^2 . K^4 \ \text{(S.I Unit)}$$

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

$= (0.00269*418.68*0.038) / 3.46*10^{-4} *(324.6^4-302.7^4)*0.86$

$= 5.312 * 10^{-8}$ Watt / m^2K^4

Conclusion:

The Stefan Boltzmann constant was found out to be___________________

SAMPLE CALCULATIONS

OBSERVATION TABLE

SR. NO	Temp. Readings				Time in sec for which T_6 is noted										
	T_2	T_3	T_4	T_5	0	5	10	15	20	25	30	35	40	45	50
	54	50.2	51.2	51	29.7	30.1	30.4	30.6	30.7	30.8	30.9	31.2	31.3	31.5	31.6

Calculations

Ts = surface temperature = $(T_1 + T_2 + T_3 + T_4) / 4 + 273 = 51.6 + 273 = 324.6$ K

T_5 = Disc Temperature = $T_5 + 273 = 29.7 + 273 = 302.7$ K

A_d = Surface area of the disc = 21 mm dia = 3.46×10^{-4} m^2

M = Mass of disc = 2.69×10^{-3} kg

S = specific heat of disc

= 0.1 Kcal/Kg. ^oC (Copper disc). (In MKS Units)

418.68 J/Kg ^oK (In S.I. Unit)

Slope of (dT/dt) at t = 0.

$$= \frac{(31.6 - 29.7)}{50}$$

$$= 0.038 \text{ K/Sec}$$

The value of can be obtained by using equation

$$\sigma = \frac{m.s\,(dT/dt) \text{ at } t = 0}{A_D\,(T_5^4 - T_6^4) * 0.86} \quad w / m^2 . K^4 \text{ (S.I Unit)}$$

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

$$= \frac{0.00269 \times 418.68 \times 0.038}{3.46 \times 10^{-4} \times (324.6^4 - 302.7^4) \times 0.86}$$

= 5.312×10^{-8} Watt/ m^2 K^4 .

Conclusion:

The Stefan Boltzmann constant was found out to be **5.312×10^{-8} Watt/ m^{2}K^4**

Aim:- To determine Emissivity of non black test plate surface. Theory-

Under steady state conditions:

Let-Q1= Heater in put black plate.=V1I1 * 0.86

Q2 Watts = Heater input to test plate=V2I2*0.3

Note: Practically it is not possible to completely convert complete electrical energy supplied to heat energy. Commonly used heater sal so have aband of insulation over the heating element which further reduces the amount of heat transfer to the test section. Also the heat generated in heating element is lost in radiation and convection lossesdue to surrounding air breeze. Due to this cumulative effect the reisd if ference in heat transferrate. Hence we introduce a loss factor of 0.86 inforced convection

nd²/4 Area of plate, A=Area of plates = ----m^2

d=Diameter Of plate=160mm

Tb=Temperature of black plate °K Ta=Ambient temperature °K

E_b = Emissivity of black plate=1(To be assumed equal to unity.)

E=Emissivity of non-black test plates=Stefan Boltzmann constant.

(MKS=4.876x10-8Kcal/hr-m²**–°k□ I** MKS units)SI=5.67x10- **w/ ²k□ I** SI

units)) By using the Stefan Boltzmann Law:-0.86(W_1–W_2)= (E_b **– E σA** (Ts4–

Td4) (Q1–Q2)= 0.86VI-0.86VI=(E_b–E) **σA** ()

In SI Units

$(W_1 – W\ )=(\ E\ – E)\ \boldsymbol{\sigma A}\ (T_s^{\ 4} – T_d^{\ 4})$

Specifications:

1. Test Plate= Ø165mm

2.Black Plate=Ø165mmMaterialAluminum.

3.Heaterfor(1) Nichrome strip wound on mica sheet and sand wiched between two mica sheets.

4.Heater for(2) as above capacity of heater=200wattseachapprox.

5.Dimmer stat for(1)0–2A,0–260V

6.Dimmer stat for(2)0–2A,0–260V

7.Voltmeter0–100–200V,Ammeter0–2Amp.

8.Enclosure size 580mmx300mmx300mm approximately with one side of prepare x sheet.

9.Thermocouples– Choromel Alumel – (3Nos).

10.Temperatureindicator0–3000C.

11.ON/OFF switch

(1)Enclosure (2) Test Plate (3)Test Plate Heater (4)Black Plate

(5)Black Plate Heater(6) Thermocouple Socket(7) Acrylic Cover T1toT3 Thermocouple Position

1.Gradually in crease the input to the heater to black plateandadjustittosomevalueviz.30,50,75wattsandadjusttheheaterinputtotestplateslightlylessthantheBlackplate27,35,55wattsetc.

2.Checkthetemperatureofthetwoplates with small time intervals and adjust the Input of test plate only, by the dimmer stat so that the two plate swill be maintained At the same temperature.

3.This will required some trial and error and on eh as to wait sufficiently (more than One hour or so) to obtain the steady state condition.

4.After attaining the steady state condition record the temperatures. Volt meter and Ammeter readings for both the plates.

5. The same procedure is repeated for various surface temperature sin increasing Order.

SR.NO	**BLACKPLATETb**			**TESTPLATE Ts**			**Sr. ENCLOSURE TEMP Ta °c**
	V1	**I1**	**Tb**	**V2**	**I2**	**Ts**	**Ta**

For SI Unit:

(W_b–W_S)= (E_b–E_S) **σ**$_A$ **Ts□–T □ Cal ulatio s:**

Q_b = **σAE Ts□–TD□ Q =σEA Ts□–TD□**

Where,

Q_b = heat in put to disc coated with lamp black watt. In SI Unit

Q_b =V1I1Watts

Q_b =0.86V1I1watts

Q_S=heat in put to Specimen disc.(Kcal/hr)Qs=0.86V2I2Watts

Stefan Boltzmann Constant=4.876x10^- **K al/hr ²°k□I Sluits = . x -**
W/ ²k□

E= Emissivity of specimen to be determined (absorption) In SIun it,

$(W_b - W_s) = (E_b - E)$ **σ.A Ts□–Ta□ / .**

This fact could be verified by perfor mingt heex periment sat various values of Tsand EC anbe plotted inagraph.

Conclusion:-

Emissivity of nonblack test plate surface is found out to be________________

HEAT TRANSFER THROUGH A PIN FIN

OBJECTIVE:

To study the temp. distribution along the length of a pin fin under free and forced convection heat transfer.

THEORY:

Extended surfaces or fins are used to increase the heat transfer rate from a surface to a fluid wherever it is not possible to increase the value of the surface heat transfer coefficient of the temperature difference between the surface and the fluid. The use of this is very common and they are fabricated in a variety of shapes circumferential fins around the cylinder of the motor cycle engine and fins attached to condenser tubes of a refrigerator are few fins and tube heat exchanger examples.

- Fin effectiveness = $\varepsilon = \tan h\, mL/mL$

The temp. Profile within a pin fin is given by:

- $\theta/\theta 0 = *T-Tf]/[Tb-Tf] = [\cos h\, m(L-x) + H \sin h\, m\, (L-x)]/[\cos h\, m\, l + H \sin h\, mL]$

Where Tf is the free stream temp. of air, Tb is the temp. of fin at its base, T is the temp. within the fin at any x, L is the length of the fin and D is the fin diameter.

m is the fin parameter defined as :

Fin parameter $m = \surd *h\ C\ /\ (Kb\ A)+$

Kb = Thermal conductivity of Brass fin = 95 kcal/h-m°C

Where C = Perimeter = πD

A = Cross sectional area of Fin = $(\pi/4)$ D2

h is the convective heat transfer coefficient that can be estimated from :

- For free convection:

Nu = 1.1 (GrPr)1/6 for 0.1<GrPr<10,000
Nu = 0.53 (Gr Pr)1/4 for 10,000<GrPr<109
Nu = 0.13 (GrPr)1/3 for 109<GrPr<1012

- For Forced Convection:

Nu = 0.615 (Re)0.466 for 40<Re<4000
Nu = 0.174 (Re)0.618 for 4000<Re<40,000

DESCRIPTION:

Three fins made of aluminium, brass & M.S, of circular cross section is fitted along a rectangular duct. The other end of the duct is connected to the suction side of a blower and the air flows past the fins perpendicular to its axis. One end of the fins projects outside the duct and is heated by a heater. Temperatures at five points along the length of the fins are measured by RTD PT-100 type temperature sensors. The flow rate is measured by an orifice meter fitted on the delivery side of the blower.

EXPERIMENTAL PROCEDURE:-

NATURAL CONVECTION

1. Connect the sensor socket & heater to the fin which to be tested(aluminum/ brass / M.S)
2. Start heating the fin by switching ON the heater element and adjust the voltage up to a certain level by adjusting the dimmerstat.
3. Note down the temp. sensor readings (1) to (5) at a time interval of 5 minutes.

When steady state is reached, record the final readings of Temp. Sensor No. 1 to 5 and also the ambient temp. Reading. i.e. Temp. Sensor No.6

FORCED CONVECTION

1. Connect the sensor socket & heater to the fin which to be tested (aluminum/ brass / M.S)
2. Start heating the fins by switching ON the heater and adjust the dimmerstat voltage
3. Start the blower and adjust the difference of level in the manometer H
4. Note down the temp. sensor readings (1) to (5) at a time interval of 5 minutes.
5. When the steady state is reached, record the final readings (1) to (5) and also record the ambient temp. readings by (6)
6. Repeat the same experiment with another H.

SPECIFICATIONS :

Duct Size	:	150 x 100 x 1000 mm
Diameter of the fin	:	12.7 mm: Length of the fin : 125 mm (Aluminium, Brass, Mild steel)
Diameter of the Orifice	:	35 mm
Dia. of the delivery Pipe	:	70 mm
Coefficient of Discharge, Co	:	0.64
Control Panel	:	Digital Voltmeter (0-300 V) Digital Ammeter (0-2 A) Dimmer stat (0-230 V), 2 A Digital Temp. Indicator (0-200ºC) ON/OFF switch, mains indicator, etc.
Temperature Sensors	:	RTD PT-100 type (18 Nos.)

OBSERVATION & CALCULATIONS:

FOR NATURAL CONVECTION

EXPT.	POWER INPUT W= V x I		FIN TEMP. °C					AMBIENT TEMP. T6
			T1 X	T2 X	T3 X	T4 X	T5 X	
	V	I	2.5 CM	5 CM	7.5 CM	10 CM	12.5 CM	
BRASS								
ALUMINIUM								
MILD STEEL								

Mean Temp. of the Fin, Tm = (T1+ T2+ T3+ T4+ T5)/5

Ambient Air Temp. T6 = Tf = °C

Mean Fluid Temp. Tmf = (Tm+ Tf)/2

Properties of air at mean fluid temp. (From material properties handbook)

Density, ρ = ___________kg/m3

Viscosity μ = ___________kg/ms

Kinematic Viscosity, v = __________m2/sec

Thermal Conductivity, K = ___________kcal/hrm°C

Specific Heat Cp = ___________kcal/kg°C

Prandlts's No. Pr = Cp μ/K

β = 1/(Tmf + 273.15)

Grashof No. Gf = (g β DT)/v

ΔT = (Tm -Tf)

Using the Correlation for Free Convection :

Nusselt No. Nu = 0.53 (Gr Pr)1/4

= h D / kair

Free convective heat transfer co eff. h= Nu kair / D

Fin Parameter, m = (h C / kb A)^0.5

Thermal Conductivity of brass kb = 95 kcal/hrmºC

Perimeter C = π D
Cross sectional area of fin A = π/4* D^2

Fin Dia, D = 12.7 x 10-3 m
Fin Length L = 125 x 10-3 m

Fin effectiveness ε = tan h m L/ mL

Parameter H = h / kb m

Theoretical Temp. Profile within the Fin =

θ/θ0 = [T-Tf]/[Tb-Tf] = [cos h m(L-x)+ H sin h m (L-x)]/[cos h m L + H sin h mL]

Taking Base Temp. Tb = T1

FOR FORCED CONVECTION

EXPT.	POWER INPUT W= Vx I		FIN TEMP. ºC					AMBIENT TEMP. T6	MANOMETER READING (H) cm
			T1 X	T2 X	T3 X	T4 X	T5 X		
	V	I	2.5 CM	5 CM	7.5 CM	10 CM	12.5 CM		
BRASS									
ALUMINIUM									
MILD STEEL									

For forced convection

Orifice Coefficient Cd = 0.64

Volumetric Flow of Air, Q = C(π/4)d √ * 2g ΔH+

H = * h(ρw/ρa -1)] m of air
100

Velocity of Air, V = Q/a at ambient fluid temp.

ρw = 1000 kg/m3
ρa = 1.21 kg/m3

Velocity of air at mean fluid temp. (Tmf) = V1 = V x (Tmf + 273.15)/(Tf + 273.15)

Mean Temp. of the Fin, Tm = (T1+ T2+ T3+ T4+ T5)/5

Ambient Air Temp. T6 = Tf = ºC

Mean Fluid Temp. Tmf = (Tm+ Tf)/2

Properties of air at mean fluid temp. (From material properties handbook)

Density, ρ = ___________kg/m3

Viscosity μ = ___________kg/ms

Kinematic Viscosity, v = μ/ ρ__________m2/sec

Thermal Conductivity, K = __________kcal/hrmºC

Specific Heat Cp = __________kcal/kgºC

Prandlts's No. Pr = Cp μ/K

Using co-relation for Forced convection:

Nusselt No. Nu = 0.615 (Re)0.466

Nu = h D / Kair

Heat Transfer Coefficient, h = Nu Kair / D

Fin Parameter m = √h C / Kb A

Fin effectiveness ε = tan h m L/ mL

Parameter H = h / kb m

Theoretical Temp. Profile within the Fin

θ/θ0 = *T-Tf]/[Tb-Tf] = [cos h m(L-x)+ H sin h m (L-x)]/[cos h m L + H sin h mL]

Taking Base Temp. Tb = T1

Where,

Kb = thermal conductivity of Brass fin
C = Perimeter
Tm = Fin mean temp.
Tf = Fin temp. at any point
X = Distance of sensor at the base of the fin
g = Acc. Due to gavity
D = Fin Diameter
Gr = Grashof Number
Pr = Prandlt Number
Nu = Nusselt Number
Kair = Air conductivity at mean temp.
h = heat transfer coefficient
m = Fin perimeter
A = Cross sectional are of Fin
L = Fin Length
ε = Fin effectiveness

PRECAUTIONS & MAINTENANCE INSTRUCTIONS :

1. Never run the apparatus if the power supply is less than 180 volts and above 230 volts.
2. Use stabilized A.C. single phase supply only.
3. Never switch ON mains power supply before ensuring that all the ON/OFF switches given on the panel are at OFF position.
4. Keep all the assembly undisturbed.
5. Operate selector switch of temperature indicator gently.
6. Always keep the apparatus free from dust.

TROUBLE SHOOTING :

1. If the electric panel is not showing the input on mains light, check the main supply.
2. If the temperature of any sensor is not displayed in DTI, check the connection.

OBJECTIVE:

To study the heat transfer through shell & tube heat exchanger.

AIM:

- **To determine the rate of heat transfer.**
- **To determine the LMTD.**
- **To determine the heat transfer coefficient**.

INTRODUCTION:

Temperature can be defined as the amount of energy that a substance has. Heat exchangers are used to transfer that energy from one substance to another. In process units it is necessary to control the temperature of incoming and outgoing streams. These streams can either be gases or liquids. Heat exchangers raise or lower the temperature of these streams by transferring heat to or from the stream.

Heat exchangers are a device that exchanges the heat between two fluids of different temperatures that are separated by a solid wall. The temperature gradient or the differences in temperature facilitate this transfer of heat. Transfer of heat happens by three principle means: radiation, conduction and convection. In the use of heat exchangers radiation does take place. However, in comparison to conduction and convection, radiation does not play a major role. Conduction occurs as the heat from the higher temperature fluid passes through the solid wall. To maximize the heat transfer, the wall should be thin and made of a very conductive material. The biggest contribution to heat transfer in a heat exchanger is made through convection.

In a heat exchanger forced convection allows for the transfer of heat of one moving stream to another moving stream. With convection as heat is transferred through the pipe wall it is mixed into the stream and the flow of the stream removes the transferred heat. This maintains a temperature gradient between the two fluids.

The shell & tube heat exchanger is one of the simplest types of heat exchangers. In case of shell & tube heat exchanger one fluid flows inside a tube and the other fluid flows through the shell side. This is a concentric tube construction. Flow in a double-pass heat exchanger can be co-current or counter-current. In this double pass heat exchanger a hot process fluid flowing through the inner tube transfers its heat to cooling water flowing in the shell side. The system is in steady state until conditions change, such as flow rate or inlet temperature. These changes in conditions cause the temperature distribution to change with time until a new steady state is reached. The new steady state will be observed once the inlet and outlet temperatures for the process and coolant fluid become stable. In reality, the temperatures will never be completely stable, but with large enough changes in inlet temperatures or flow rates a relative steady state can be experimentally observed.

THEORY:

As with any process the analysis of a heat exchanger begins with an energy and material balance. Before doing a complete energy balance a few assumptions can be made. The first assumption is that the energy lost to the surroundings from the cooling water or from the U-bends in the inner pipe to the surroundings is negligible. We also assume negligible potential or kinetic energy changes and constant physical properties such as specific heats and density. These assumptions also simplify the basic heat-exchanger equations.

The determination of the overall heat-transfer coefficient is necessary in order to determine the heat transferred from the inner pipe to the outer pipe. This coefficient takes into account all of the conductive and convective resistances (k and h, respectively) between fluids separated by the inner pipe, and also takes into account thermal resistances caused by fouling (rust, scaling, i.e.) on both sides of the inner pipe. For a shell & tube heat exchanger the overall heat transfer coefficient, U, can be expressed as

$$\frac{1}{UA} = \frac{1}{A_0 h_0} + \frac{R_{f0}}{A_0} + \frac{1}{2k\pi l}\ln\left(\frac{d_o}{d_i}\right) + \frac{R_{fi}}{A_i} + \frac{1}{A_i h_i}$$

In a heat exchanger the log-mean temperature difference is the appropriate average temperature difference to use in heat transfer calculations. The equation for the log-mean temperature difference is

$$\Delta T_{LM} = \frac{(T_{io} - T_{oi}) - (T_{ii} - T_{oo})}{\ln\left(\frac{T_{io} - T_{oi}}{T_{ii} - T_{oo}}\right)}$$

$$T_{ia} = \frac{T_{io} + T_{ii}}{2}$$

$$T_{oa} = \frac{T_{oo} + T_{oi}}{2}$$

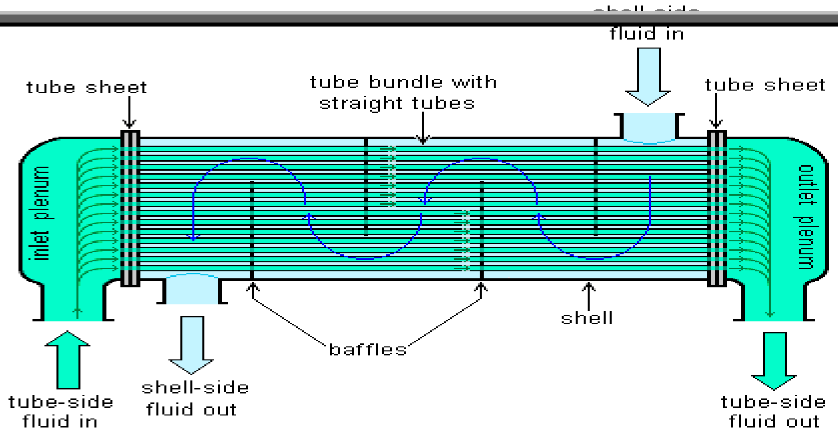
Thermal conductivity, *k,* can be evaluated at the average of the average temperatures. In a double-pipe heat exchanger the inner pipe is made of a conductive metal and is thin.

The problem can be further simplified if the equipment is assumed to be clean, which means that no scaling exists. This is a poor simplification with the double-pipe heat exchanger in the laboratory, because it is many years old. The fouling factors R_{fo} and R_{fi} can be looked up from various sources, including *Standards of the*

Now everything that was necessary for an energy balance is available.

$$m_i C_{P_i} \frac{dT_{ia}}{dt} = q_i \rho_i C_{pi} (T_{ii} - T_{io}) - UA\,\Delta T_{LM}$$

$$m_o C_{p_o} \frac{dT_{oa}}{dt} = q_o \rho_o C_{po} (T_{oi} - T_{oo}) - UA\,\Delta T_{LM}$$



DESCRIPTION:

The Experimental setup consists of a shell & tube Heat Exchanger. Hot water flows through inner tube in one direction only and cold water flows through the Shell Side. Flow rates of hot and cold fluid are measured using rotameters.A magnetic drive pump is used to circulate the hot water from sump tank to inner tube. Sump tank is fitted with heaters and digital temperature indicator to control the temperature. The whole assembly is painted with good Structure.

EXPERIMENTAL PROCEDURE:

1. Clean the apparatus and add clean water to the water bath.
2. Switch on the power supply and adjust the temperature of hot water with the help of DTC
3. Connect the cold water supply to the inlet of cold water
4. After reaching your ambition temperature now supply the hot water and cold water at a particular flow rate.
5. Wait for sometime to reach steady state
6. Now note down the reading of all sensors provided with this equipment.
7. Same procedure can be repeated at different flow rate and different ho water temperature

SPECIFICATIONS:

System : water to water

Shell : material S.S,dia 220 mm,length 500mm,25% cut sectional baffle(4 nos)

Tube : ID 9.5 mm,OD 13 mm,Length 500mm(25 Nos)

Water flow measurement : Rotameters (2 No.s) each for hot and cold water

Water circulation : magnetic pump made of polypropylene to circulate hot water (Max working Temperature 85 ^{0}C)

Hot water tank	:	Made of SS insulated with ceramic wool
Heaters	:	Nichrome wire heater (2 No.s)
Temperature Sensors	:	RTD PT -100 type 5 No.s
Control panel	:	Digital temperature controller (0- 200^0C) Digital Temp. Indicator (0-200º C) with multi channel switch ON/OFF switch, mains indicator, etc.

UTILITES REQUIRED:

Water Supply	:	10 lit/min (approx) and drain
Electricity Supply	:	1 Phase. 220 V AC, 3 kW.
Floor Area	:	2 m x 0.6 m

FORMULAE:

DATA: **OD of InnerTube $d_o = 0.013$ m**

Length of the Tube L=1.5 m

T_{hi} = Hot water inlet temperature = T_1

T_{ho} = Hot water outlet temperature = T_2

T_{ci} = Cold water inlet temperature = T_3

T_{co} = Cold water outlet temperature = T_4

Specific heat of water = 4.2 Kj/kg^{o}C

TABULATION AND CALCULATION:-

S.No	Hot water			Cold water		
	Flow rate(LPH)	Inlet Temperature $T_{hi} = T_1$	Outlet Temperature $T_{ho} = T_2$	Flow rate (LPH)	Inlet Temperature $T_{Ci} = T_3$	Outlet Temperature $T_{ho} = T_4$
1						
2						
3						
4						

Formula:

Heat gained by cold water

$$Q_C = m_C \times C_{Pc} \times \left(T_{co} - T_{Ci}\right)$$

Where, m_c = mass flow rate of cold water

C_{pc} = Specific heat of cold water

Heat loss by hot water

$$Q_h = m_h \times C_{Ph} \times \left(T_{hi} - T_{ho}\right)$$

Where, m_h = mass flow rate of hot water

C_{ph} = Specific heat of hot water

Average heat transfer

$$Q_{avg} = \frac{Q_C + Q_h}{2}$$

For heat exchanger

$$\Delta T_1 = \left(T_{hi} - T_{co}\right)$$

$$\Delta T_2 = \left(T_{ho} - T_{ci}\right)$$

Log mean temperature difference

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)}$$

Heat transfer Area

$$A = N \times \pi \times d_o \times L \quad m^2$$

Where N = No of Tubes= 20 Nos

d_o = OD of Inner tube= 0.016 m

L = Length of heat exchanger=1.2 m

Overall heat transfer co-efficient

$$U = \frac{Q_{avg}}{A \times LMTD}$$

PRECAUTIONS & MAINTENANCE INSTRUCTIONS:

1. Never run the apparatus if the power supply is less than 180 volts and above 230 volts.
2. Use stabilized A.C. single phase supply only.
3. Never switch ON mains power supply before ensuring that all the ON/OFF switches given on the panel are at OFF position.
4. Keep all the assembly undisturbed.
5. Operate selector switch of temperature indicator gently.
6. Always keep the apparatus free from dust.

TROUBLE SHOOTING:

1. If the electric panel is not showing the input on mains light, check the main supply.
2. If the temperature of any sensor is not displayed in DTI, check the connection.