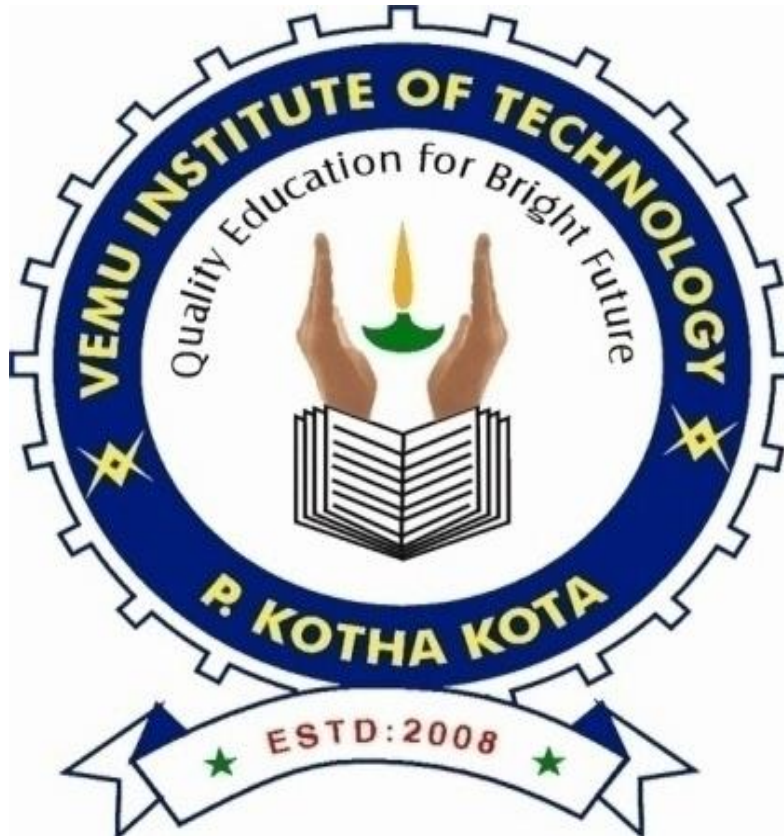


VEMU INSTITUTE OF TECHNOLOGY

(Affiliated To JNTUA University)

HEAT TRANSFER LAB (19A03503P)

LAB MANUAL



DEPARTMENT

Of

MECHANICAL ENGINEERING

VEMU INSTITUTE OF TECHNOLOGY
(Affiliated To JNTUA University)
DEPARTMENT OF MECHANICAL ENGINEERING

HEAT TRANSFER LAB (19A03503P)

LAB OBSERVATION

Certificate

**This is to certify that the bonafide record of work done by
Mr./Miss.....Bearing Roll No.....is a
student ofIn.....branch has
completedExperiments in.....laboratory
during the Academic year.....**

Signature of HOD

Signature of Lab- In charge

HEAT TRANSFER LABORATORY

Subject Code	: 19A03503P	No. of Credits	: 1.5
No. of Contact Hours /week	: 03	Max. Marks	: 70
Total No. of Contact Hours	:		

COURSE OBJECTIVES:

1. To provide students with the necessary skills to conduct experiments on conduction and convection of heat; collect data, perform analysis and interpret results to draw valid conclusions through standard test procedures
2. To determine thermal properties and performance of radiation heat transfer, heat exchanger, and condensation test.

COURSE OUTCOMES:

Upon completion of this course, students should be able to:

- CO1** Conduct experiments on conduction, convection and radiation of heat; collect data, perform analysis and interpret results to draw valid conclusions through standard test procedures
- CO2** Determine thermal properties and performance of heat exchanger, Emissivity and Condensation test.

Course Outcomes

S. No	Name of The Experiment	COs
1.	Composite wall Apparatus	CO1
2.	Thermal conductivity of Insulating Powder	CO1
3.	Thermal conductivity of metal rod	CO1
4.	Lagged pipe Apparatus	CO1
5.	Unsteady state heat transfer	CO1
6.	Pin fin apparatus	CO1
7.	Natural convection apparatus	CO1
8.	Forced convection apparatus	CO1
9.	Stefan Boltzmann Apparatus	CO2
10.	Emissivity measurement of radiating surfaces	CO2
11	Parallel and Counter flow Heat Exchanger	CO2
12	Condensation in Film wise and Drop wise forms	CO2
13	Study of pool boiling phenomenon and its regimes	CO2

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S. No	Name of The Experiment	Date	Page. No	Remarks
1.	Composite wall Apparatus			
2.	Thermal conductivity of Insulating Powder			
3.	Thermal conductivity of metal rod			
4.	Lagged pipe Apparatus			
5.	Unsteady state heat transfer			
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10.	Emissivity measurement of radiating surfaces			
11	Parallel and Counter flow Heat Exchanger			
12	Condensation in Film wise and Drop wise forms			
13	Study of pool boiling phenomenon and its regimes			

SCHEME OF EVALUATION

SN O	Experiment	Date	Marks Awarded				Total 30(M)
			Record 10(M)	Observation 10(M)	Attendance (5M)	Viva voce 5(M)	
1.	Composite wall Apparatus						
2.	Thermal conductivity of insulating powder						
3.	Thermal conductivity of metal rod						
4.	Lagged pipe Apparatus						
5.	Unsteady state heat transfer						
6.	Pin fin apparatus						
7.	Natural convection apparatus						
8.	Forced convection apparatus						
9.	Stefan Boltzmann Apparatus						
10.	Emissivity measurement of radiating surfaces						
11	Parallel and Counter flow Heat Exchanger						
12	Condensation in Film wise and Drop wise forms						
13	Study of pool boiling phenomenon and its regimes						

COMPOSITE WALL

Ex. No:

Date: -

AIM: - To determine the overall heat transfer coefficient and overall thermal resistance and overall thermal conductivity for the composite wall apparatus.

APPARATUS:-

1. Three slabs made of mild steel, asbestos and wooden plate.
2. Heater
3. Dimmer start
4. Thermocouples
5. Water jacket
6. Ammeter
7. Volt meter

THEORY:-

The apparatus consists of plates of different materials sandwiched between two aluminum plates. Three types of slabs are provided on both sides of heater which forms a composite structure. A small hand press frame is provided to ensure the perfect contact between the slabs. A dimmer stat is provided for varying the input to the heater and measurement of input is carried out by a voltmeter and ammeter. The experiment can be conducted at various values of input slabs, to read the temperature at the surface.

Formulas:-

$$1. \text{ overall heat transfer coefficient } (U) = \frac{1}{\frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3}} \text{ w/m}^2\text{k}$$

Where

L_1 =thickness of wooden plate=10 mm=0.01 m

L_2 = thickness of asbestos plate= 6mm=0.006 m

L_3 =thickness of mild steel=10 mm=0.01 m

K_1 = thermal conductivity of wood= $\frac{QL_1}{2A\Delta T_1}$ w/mk

K_2 = thermal conductivity of asbestos = $\frac{QL_2}{2A\Delta T_2}$ w/mk

K_3 = thermal conductivity of mild steel= $\frac{QL_3}{2A\Delta T_3}$ w/mk

$$\Delta T_1 = T_2 - T_1$$

$$\Delta T_2 = T_3 - T_2$$

$$\Delta T_3 = T_4 - T_3$$

$$\text{Area of the plate } A = \frac{\pi}{4} d^2 \text{ m}^2$$

Where

d= diameter of the plate=300 mm

$$2. \text{ Overall thermal resistance } R=R_1+R_2+R_3 \text{ in } \text{w}^{-1}\text{K}$$

Where

$$R_1=\text{Thermal resistance of wood} = \frac{L_1}{AK_1}$$

$$R_2= \text{Thermal resistance of asbestos} = \frac{L_2}{AK_2}$$

$$R_3= \text{Thermal resistance of mild steel} = \frac{L_3}{AK_3}$$

$$3. \text{ Temperature distribution } T_x = \left(\frac{T_x - T_y}{L}\right)x + T_x$$

PROCEDURE:-

1. Connect the equipment to power supply.
2. Adjust the power input to the required value.
3. Allow sufficient time to attain steady state.
4. Note down all the temperatures by operating the knob.
5. Repeat the experiment for different heat inputs.

PRECAUTIONS:-

1. Heat the dimmer start zero before start.
2. Increase voltage slowly.
3. Keep all the assembly undisturbed.
4. Remove the air gap between plates slowly by moving hand press gently.
5. When removing the plates do not disturb the thermocouples.
6. Do not increase above 200 V.
7. Operate selector switch off temperature indicator slowly.

GRAPH:-

1. Distance Vs Temperature distribution

TABLE:

S.No	Heat input			Temperature in (°C)							
	V (Volt)	I (amp)	V x I (Watts)	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											

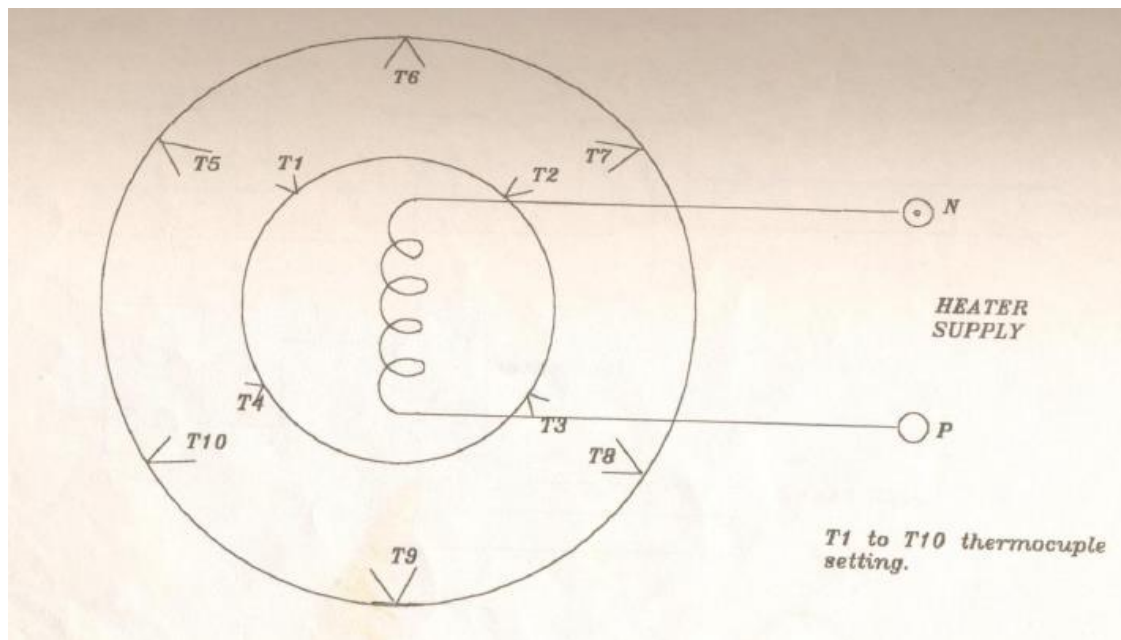
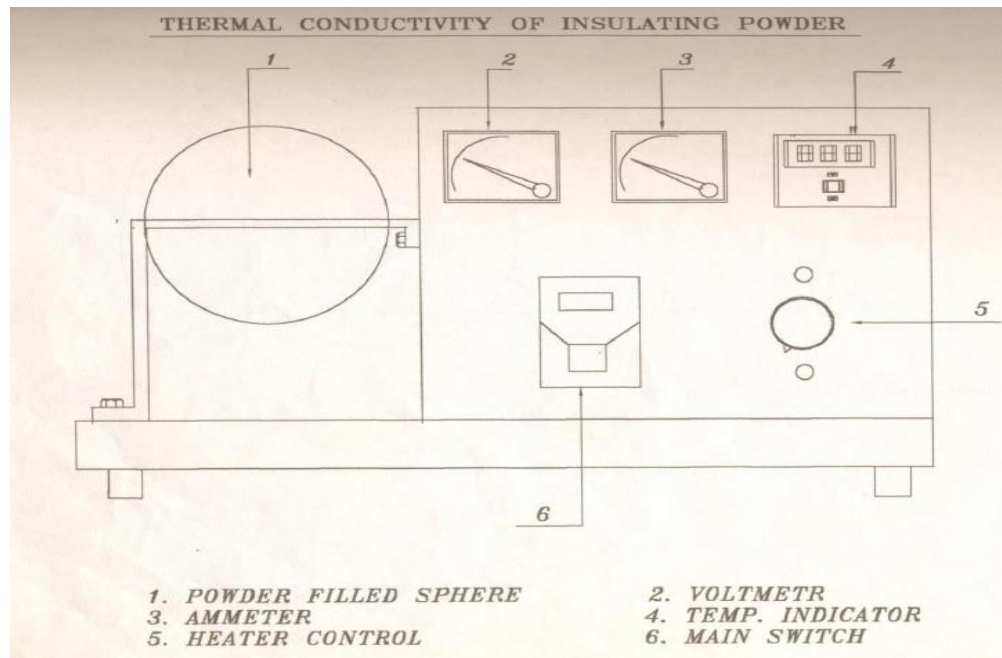
Model Calculations

RESULT:-

The overall heat transfer coefficient and overall thermal resistance for the composite wall has been determined.

1. Overall Thermal Conductivity of the Slab-----
2. Overall thermal resistance-----
3. Overall Heat transfer Co-efficient-----

THERMAL CONDUCTIVITY OF INSULATING POWDER



THERMAL CONDUCTIVITY OF INSULATING POWDER

Ex.No:-

Date:-

AIM:- To determine the thermal conductivity of insulating powders through concentric sphere apparatus.

APPARATUS:-

1. Inner sphere-100 mm O.D., halved construction.
2. Outer sphere-200 mm O.D., halved construction.
3. Heater-Mica flat heater, fitted inside inner sphere
4. Controls- a) Main Swith-30A , DPDT Switch
b) Dimmerstat-0-230 volts,2A capacity
5. Voltmeter-0-200 volts
6. Ammeter- 0-1 Amp
7. Multichannel digital temperature indicator, calibrated for Cr/Al thermo couples.

THEORY:-

Conduction of heat is flow of heat which occurs due to exchange of energy from one molecule to another without appreciable motion of molecules. In any heating process heat is flowing outwards from heat generation point. in order to reduce losses of heat, various types of insulations are used in practice. Various powders example asbestos powder, plaster of pairs etc. are used for heat insulation in order to determine the appropriate thickness of insulation, knowledge of thermal conductivity of heat insulation material is essential.

PROCEDURE:-

1. Keep dimmer stat knob at ZERO position and switch ON the equipment.
2. Slowly rotate the dimmer stat knob, so that voltage is applied across the heater .Let the temperature rise.
3. Wait until steady state is reached.
4. Note down all the temperatures and input of heater in terms of volts and current.
5. Repeat the procedure for different heat inputs.

PRECAUTIONS:-

1. Operate the all switches and controls gently.
2. Earthling is essential for the unit.

FORMULAS:-

1. *Thermal conductivity of insulating powder* $(k) = \frac{q \times (r_o - r_i)}{4\pi r_o r_i (T_i - T_o)} \text{ W/mk}$

Where

q= heat input in watts

r_i= inner radius of sphere=0.1 m

r_o= outer radius of sphere=0.2 m

average temperature of inner surface $T_i = \frac{T_1 + T_2 + T_3 + T_4 + T_5 + T_6}{6}$

average temperature of outer surface $T_o = \frac{T_7 + T_8 + T_9 + T_{10} + T_{11} + T_{12}}{6}$

2. *Thermal resistance of insulating powder (T.R)*

$$= \frac{(r_o - r_i)}{4\pi K(r_o - r_i)} \text{ k/w}$$

TABLE :-

S.No	Heat input			Inner surface Temperature(°C)						Outer surface Temperature(°C)					
	V (Volt)	I (amp)	V x I (Watts)	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀	T ₁₁	T ₁₂

RESULT:-

1. Thermal conductivity of the insulating powder is ----- W/m.K

THERMAL CONDUCTIVITY OF METAL ROD

Ex.No:-

Date:-

AIM:-

To find the thermal conductivity of given metal rod.

APPARATUS:-

1. Metal Bar-Copper, 20 mm O.D., approx, 430 mm long with insulation shell along the test length and water cooled heat sink at the other end.
2. Test length of the bar -240mm
3. Thermo couples-Chromel/aluminum, 10 nos.
4. Band Nichrome heater to heat the bar.
5. Dimmer stat to control the heater input-2A, 230V.
6. Voltmeter and Ammeter to measure heater input.
7. Multichannel Digital temperature indicator, 0 to 10 °C, least count, 0-200 °C with Channel selector switch.
8. Measuring flask to measure water flow.

THEORY:-

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

Thermal energy can be conducted in solids by free electrons and by lattice vibrations. Large number of free electron moves about in the lattice structure of the materials in good conductors. Energy may also be transfer as vibration energy in the lattice structure of the material.

Procedure:-

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

TABLE:

S.No	Heat input			Metal rod thermo couple reading in (°C)									Water temp (°C)		Volume flow rate of water V cc/min
													Inlet	Outlet	
	V (Volt)	I (amp)	VI (Watts)	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀	T ₁₁	

GRAPH:-

Distance Vs Temperature

FORMULAE:-

1. *thermal conductivity of metal rod* $(k) = \frac{m_f \times c_p \times (T_{11} - T_{10})}{A \times dT/dx} \text{ W/mk}$

Where

$A = \text{Area of the metal rod} = \frac{\pi}{4} d^2 \text{ in } m^2$

$D = \text{diameter of the metal rod} = 20 \text{ mm}$

$C_p = \text{Specific heat of water} = 4.180 \text{ KJ/Kg-K}$

$T_{10} = \text{Water inlet temperature}$

$T_{11} = \text{Water outlet temperature}$

$m_f = \text{mass flow rate of cooling water in kg/s}$

$m_f = v_w \times \rho_w \text{ in kg/sec}$

$V_w = \text{volume flow rate of water } m^3/\text{sec}$

$\rho_w = \text{density of water in } kg/m^3$

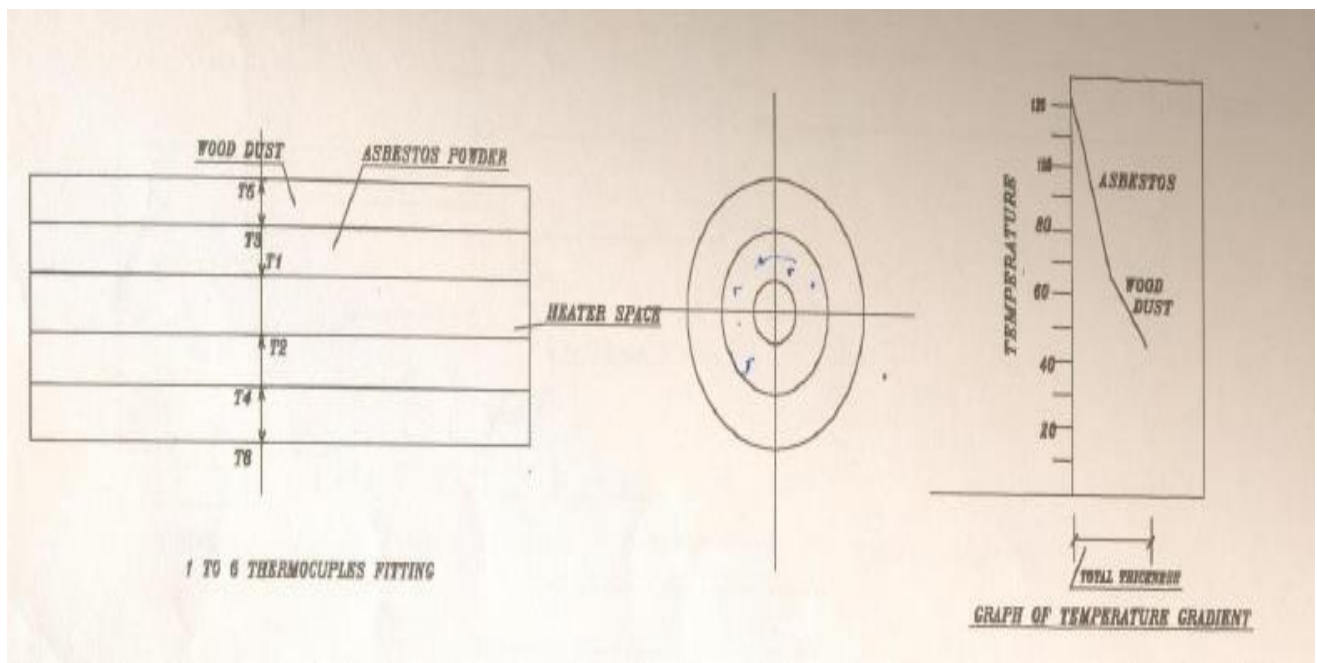
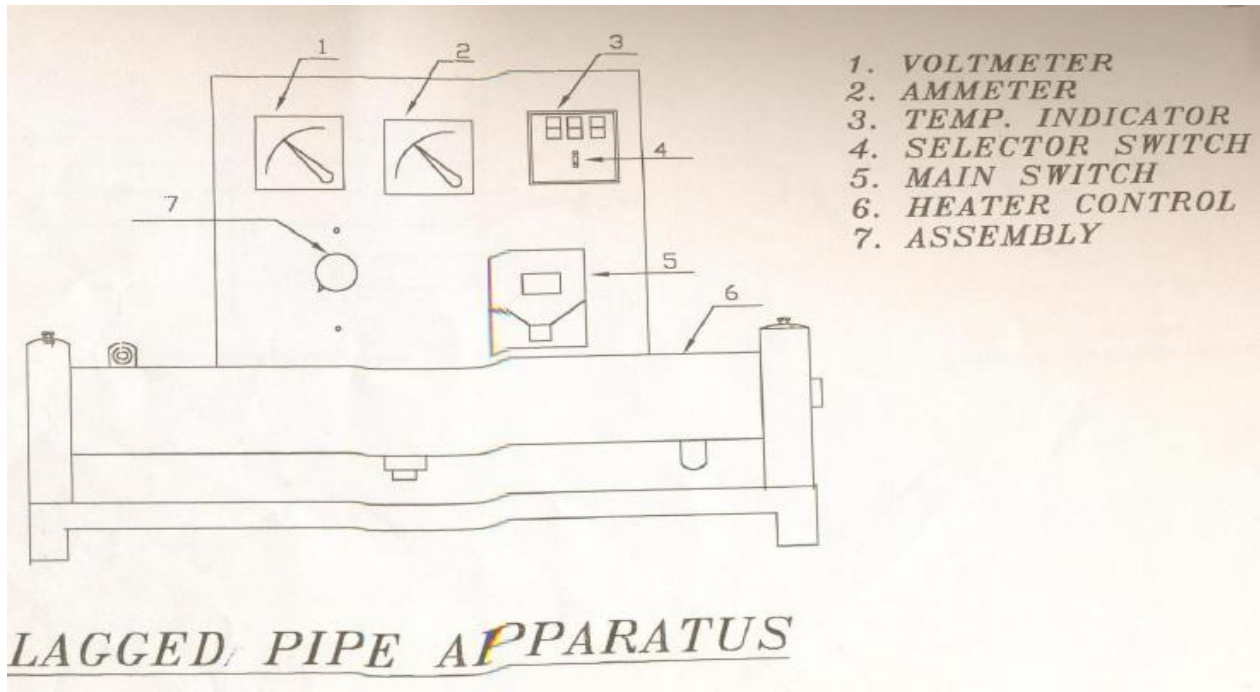
$1000 \text{ cc} = 0.001 \text{ m}^3$

$dT/dx = \text{temperature gradient (is calculated from graph)}$

RESULT:-

The thermal conductivity of given metal rod is (k) =-----

LAGGED PIPE APPARATUS



LAGGED PIPE APPARATUS

Ex.No:

Date:

AIM:- To determine the thermal conductivity, thermal resistance and overall heat transfer coefficient of different insulating materials.

APPARATUS:-

1. Volt meter
2. Ammeter
3. Lagged pipe apparatus
4. Temperature indicator
5. Dimmer stat

THEORY:-

The apparatus consist of a concentric pipes mounted on suitable stand. The hallow space of the inner most pipe consist of the heater. Between first two cylinders the insulating material is to be done filled compactly. Between second and third cylinders, another material is used for lagging is filled. The third cylinder is concentric to another outer cylinder. Water flows between these two cylinders. The thermocouples are attached to the surface of the cylinders appropriately to measure the temperature.

Consider one dimensional radial heat flow through a hallow cylinder under steady state conditions.

$$Q = 2\pi kL(T_1 - T_2) / \ln r_2/r_1$$

Where,

- T_1 and T_2 are the inner and outer wall temperatures.
- r_1 and r_2 be the inner and outer radius of the pipe.
- k = Thermal conductivity of the material.
- L = Length of the pipe.

FORMULAS:-

$$1. \text{Thermal conductivity of asbestos}(K_1) = \frac{Q \ln\left(\frac{r_2}{r_1}\right)}{2\pi L(\Delta T_1)} \text{ W/mk}$$

Where

Q=Heat input (V×I) Watts

r₁= radius of the heater rod=0.01 m

r₂=radius of the heater rod with asbestos lagging=0.02 m

$\Delta T_1 = \text{Heater temperature} - \text{asbestor temperature}$

L=length of cylinder=500 mm=0.5 m

$$2. \text{Thermal conductivity of saw dust}(K_2) = \frac{Q \ln\left(\frac{r_3}{r_2}\right)}{2\pi L(\Delta T_2)} \text{ W/mk}$$

Where,

Q=Heat input (V×I) Watts

r₃= radius of the heater rod with asbestos and saw dust lagging =0.04 m

r₂=radius of the heater rod with asbestos lagging=0.02 m

$\Delta T_2 = \text{Heater temperature} - \text{sawdust temperature}$

L=length of cylinder=500 mm=0.5 m

$$3. \text{Thermal resistance of asbestos}(R_A) = \frac{\Delta T_1}{Q} \text{ k/W}$$

$$4. \text{Thermal resistance of saw dust}(R_B) = \frac{\Delta T_2}{Q} \text{ k/W}$$

$$5. \text{Overall heat transfer coefficient}(U) = \frac{1}{r_1} \left[\frac{1}{\frac{\ln r_2/r_1}{k_1} + \frac{\ln r_3/r_2}{k_2}} \right] \text{ W/m}^2 \text{ k}$$

PROCEDURE:-

1. Switch on the unit and check if all channels of temperature indicator showing proper temperature.
2. Switch on the heater and using the regulator keep the power input at some particular value.
3. Allow the unit to stabilize for 20-30 minutes.
4. Now note down the ammeter and voltmeter readings which give the heat input.
5. Temperatures at node 1, 2 and 3 are the temperatures of heater rod, 4, 5 and 6 are the temperatures of asbestos layer, 7 and 8 are temperatures on the saw dust lagging.
6. The average temperature of each cylinder is taken for calculation.
7. The temperatures are measured by thermocouple with multi point digital temperature indicator.
8. The experiment may be repeated for different heat inputs.

PRECAUTIONS:

DO'S:

1. Before switching ON the unit make sure that the variac knob in zero position.
2. Operate thermocouple selector switch(TSS) gently.
3. Operate unit minimum twice in a week.
4. Increase the voltage slowly.

DONT'S:

1. Never switch ON main power supply before ensuring that all ON/OFF switches given on the panel are at OFF position.
2. Do not above 150 V.

TABLE:

S.No	Heater temperature(°C)				Asbestos temperature(°C)				Saw dust temperature(°C)				Heat Input	
	1	2	3	Avg	4	5	6	Avg	7	8	9	Avg	Volts(V)	Amps (I)

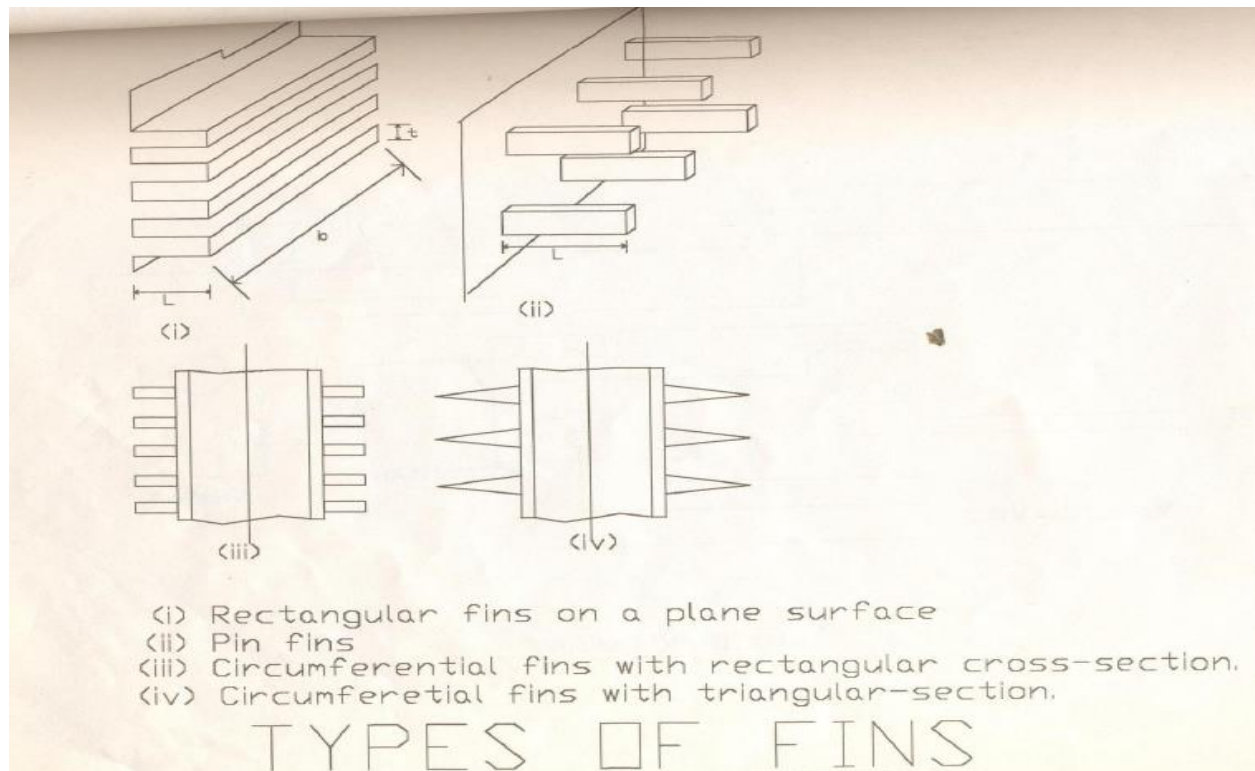
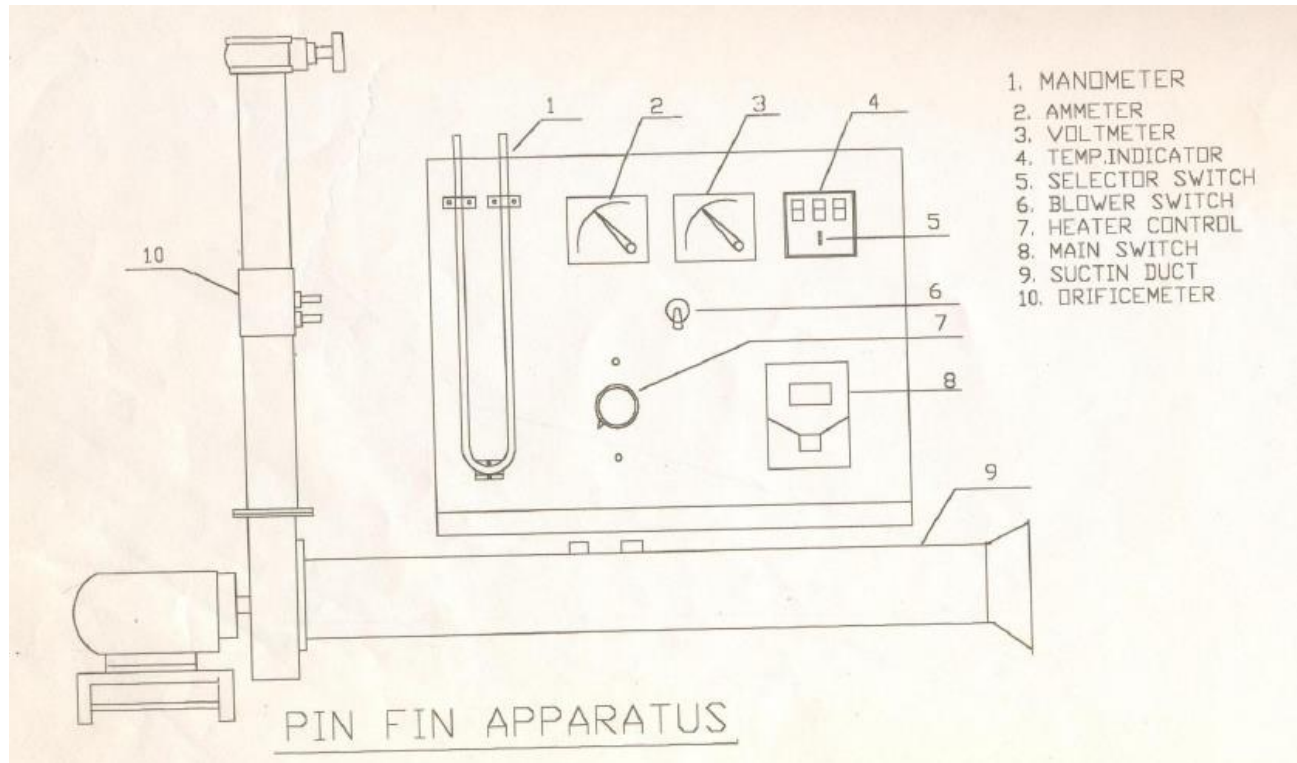
Model Calculation:

RESULT:-

Thermal conductivity, thermal resistance of asbestos, sawdust and overall heat transfer coefficient are as follows

1. Thermal conductivity of asbestos (K_1)=-----
2. Thermal conductivity of saw dust (K_2)=-----
3. Thermal resistance of asbestos (R_A)=-----
4. Thermal resistance of saw dust (R_B)=-----
5. Overall heat transfer coefficient (U)=-----

PIN FIN APPARATUS



PIN FIN APPARATUS

Ex. No:-

Date:-

AIM: - To determine the temperature distribution of a pin-fin for forced convection and natural convection and to find the fin efficiency.

APPARATUS:-

1. Pin fin
2. Rectangular duct
3. Electric heater
4. Thermocouples
5. Orifice

THEORY:-

Fins are used to increase the rate of heat transfer from a surface to the surrounding. Fluid where ever it is not possible to increase the value of the surface heat transfer coefficient rate the temperature difference between the surface and the fluid. Fins are fabricated in Varity forms. Fins around the air cooled engines are a common example. The aim of the experiment is to study the temperature distribution and the effectiveness of the fin, which place a important role in design.

SPECIFICATIONS:-

1. Duct width (b) =150 mm
2. Duct height (w) =100 mm
3. Orifice diameter (d_0) =20 mm
4. Orifice coefficient (C_d)=0.6
5. Fin length (l) = 14.5 mm
6. Fin diameter(d_f)=12 mm

PROCEDURE:-

1. Switch on the unit and check if all channels of temperature indicator showing proper temperature.
2. Switch on the heater and using the regulator keep the power input at some particular value.
3. Allow the unit to stabilize the 20-30 minutes.

a. Natural convention

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

b. Forced convention

Close the duct cover over the fin. Start the blower. Adjust the dimmer stat so that about 100-110 volts are supplied to the heater. When the temperature becomes steady, note down all the temperature and the manometer difference.

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

TABLE:

Q=V x I in Watts	Manometer reading In (mm)			Fin surface temperature (°C)						Ambient Temp (°C)
	h ₁	h ₂	h ₁ -h ₂	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇
										Natural convection
										Forced convection

GRAPH:-

1. Distance(x) in m vs. temperature distribution (Td) in °C (forced convection)
2. Distance(x) in m vs. temperature distribution (Td) in °C (natural convection)

FORMULAE:-

(A) FORCED CONVECTION

1. Efficiency of fin $\eta = \frac{\text{Tanh } mL}{mL}$

Where

$h =$ convective heat transfer coefficient W/m^2k

2. $h = \frac{N_u k}{d} W/m^2k$

$d =$ diameter of fin

$N_u =$ nusselt number

From data book

For $40 < Re < 4000$

$$N_u = 0.6853 (Re)^{0.466} (Pr)^{0.33}$$

$$T_{avg} = \frac{T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7}{7} \text{ } ^\circ\text{C}$$

$$T_f = \frac{T_{avg} + T_{amb}}{2} \text{ } ^\circ\text{C}$$

From data book

Take the reading at T_f

$K_{T_f} =$ -----w/mk

$\rho_{T_f} =$ -----kg/m³

$\gamma_{T_f} =$ -----m²/sec

$Pr_{T_f} =$ -----

$\mu_{T_f} =$ -----ns/m²

$$R_e = \frac{DV_a\rho_a}{\mu_a}$$

Where

$$D=L=0.145 \text{ m}$$

$$V_a = \text{velocity of air in the duct} = \frac{v_o}{W \times B} \text{ m/sec}$$

Where

$$W = \text{Duct height} = 100 \text{ mm}$$

$$B = \text{duct width} = 150 \text{ mm}$$

$$V_o = \text{volume of air flowing through the duct} = \frac{C_d \times a_1 \times a_2 \times \sqrt{2gh_a}}{\sqrt{a_1^2 - a_2^2}} \text{ m}^3$$

Where

$$C_d = \text{coefficient of orifice} = 0.6$$

$$a_1 = \text{area of pipe} = \frac{\pi}{4} d_1^2$$

$$d_1 = \text{diameter of pipe} = 40 \text{ mm}$$

$$a_2 = \text{area of orifice} = \frac{\pi}{4} d_2^2$$

$$d_2 = \text{diameter of orifice} = 20 \text{ mm}$$

$$h_a = \text{heat of air} = \frac{\rho_w}{\rho_a} \times h$$

Where

$$\rho_a = \text{density of air} = 1.128$$

$$h = h_1 - h_2$$

$$3. m = \sqrt{\frac{hp}{k_b A}}$$

Where

h= convective heat transfer coefficient

p= perimeter of the fin= $\pi \times \text{diameter of the fin}$

K_b= thermal conductivity of the brass rod=110.7w/mK

A= cross sectional area of the fin

$$3. \text{ temperature distribution } T_d = \left[\frac{\cosh m(L-x)}{\cosh ml} (T_{avg} - T_{amb}) \right] + T_{amb}$$

Where

X= distance between thermocouple and heater=0.029 m

(B) NATURAL CONVECTION

4. Efficiency of fin $\eta = \frac{\text{Tanh mL}}{\text{mL}}$

Where

$h =$ convective heat transfer coefficient W/m^2k

5. $h = \frac{N_u k}{d} W/m^2k$

$d =$ diameter of fin

$N_u =$ nusselt number

From data book

For $10^{-1} < Ra < 10^4$

$N_u = 1.1 \times [Gr Pr]^{1/6}$

$T_{avg} = \frac{T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7}{7} \text{ } ^\circ\text{C}$

$T_f = \frac{T_{avg} + T_{amb}}{2} \text{ } ^\circ\text{C}$

From data book

Take the reading at T_f

$K_{T_f} = \text{-----} w/mk$

$\rho_{T_f} = \text{-----} kg/m^3$

$\gamma_{T_f} = \text{-----} m^2/sec$

$Pr_{T_f} = \text{-----}$

$\mu_{T_f} = \text{-----} ns/m^2$

6. *rayliegh number* $R_a = (G_r P_r)$

Where

$$G_r = \textit{grasoph number} = \frac{g\beta\Delta TL^3}{\gamma^2}$$

$$\beta = \frac{1}{T_{avg} + 273}$$

$$L = D = 40 \text{ mm}$$

$$\Delta T = T_{avg} - T_{amb}$$

$$7.m = \sqrt{\frac{hp}{k_b A}}$$

Where

h= convective heat transfer coefficient

p= perimeter of the fin= $\pi \times \textit{daimeter of the fin}$

K_b= thermal conductivity of the brass rod=110.7

A= cross sectional area of the fin

$$\textit{temperature distribution } T_d = \left[\frac{\cosh m(L-x)}{\cosh ml} (T_{avg} - T_{amb}) \right] + T_{amb}$$

Where

X = distance between thermocouple and heater=0.029 m

PRECAUTIONS:-

1. Operate all the switches and controls gently.
2. Do not obstruct the suction of the duct are discharge pipe.
3. Open the duct cover over the fin for natural convention experiment.
4. Fill up water in the manometer and close duct cover for forced convention experiment.
5. Proper earthling to the unit is necessary.
6. While replace the fin, be carefully for fixing thermocouples. Incorrectly fixed thermocouples may show erratic readings.

RESULTS:-

The temperature distribution at pin fin for natural and forced convection and its efficiency has been determined

1. Forced convection-----
2. Natural convection-----

UNSTEADY STATE HEAT TRANSFER

Ex.No:-

Date:-

AIM:- To obtain the specimen temperature at any interval of time by practical and by theoretical methods and observe the heating and cooling curves of unsteady state.

APPARATUS:-

1. Oil heater
2. Thermocouple
3. Digital temperature indicator
4. Dimmer stat
5. Voltmeter
6. Ammeter

THEORY:

Unsteady state designates a phenomenon which is time dependent. Conduction of heat in unsteady state refers to the transient conditions where in, heat flow and temperature distribution at any point of the system varies with time.

Transient conditions occur in heating or cooling of metal billets, cooling of I.C engine cylinder, brick burning and vulcanization of rubber.

PROCEDURE:-

1. Put on the mains switch.
2. Fill the oil jar up to $\frac{3}{4}$ th of its height.
3. Insert the thermocouple in jar having tag no 3
4. Keep the thermocouple no 2 near to the specimen inside the transparent chamber.
5. Start the oil heater by putting heaters toggle switch in downward direction.
6. Keep the selector switch at no 3 and observe the oil temperature.
7. When the oil temperature reaches up to 95°C insert the specimen in oil jar. At the same time note down the specimen temperature and start the stop watches.
8. Note down the specimen reading for every 10 sec check the oil temperature by selecting no 3 on selector switch.
9. Take the reading of specimen temperature till it comes nearly to hot oil temperature.
10. Now put the specimen inside the rectangular chamber. At the same time put off the heater.
11. Take the atmosphere temperature by selecting no 2 and specimen temperature. Note down the specimen temperature reading till it comes closer to atmospheric temperature.
12. Put off the main switch.

TABLE :

A. HEATING:-

S.No	Oil temp(t1) in (°C)	Specimen temp(t3) in (°C)at interval of 10 sec	Time in seconds

B. COOLOING:-

S.no	Atmosphere temp(t2) in (°C)	Specimen temp(t3) in (°C)at interval of 10 sec	Time in seconds

GRAPH:-

Time vs temperature

FORMULAE:-

HEATING:-

$$1. \frac{T - T_a}{T_s - T_a} = e^{-Bi \times Fo}$$

Where

T_a = atmospheric temperature

T_s = specimen temperature (hot oil temperature)

2. Biot No = hl/k

Where

K = thermal conductivity of copper = 386 w/mk

$$3. T_{mean} = \frac{T_{max} + T_{min}}{2}$$

From data book

Take the reading at T_m

K T_m = ----- w/mk

ρT_m = ----- kg/m³

γT_m = ----- m²/sec

Pr T_m = -----

μT_m = ----- ns/m²

4. Rayleigh number $R_a = (G_r P_r)$

Where

$$G_r = \text{Grashof number} = \frac{g\beta\Delta TL^3}{\gamma^2}$$

$$\beta = \frac{1}{T_{mean} + 273}$$

$$L = D = 30 \text{ mm}$$

$$\Delta T = T_s - T_a$$

$$5. \text{ nusullet number } N_u = 0.36 + \frac{0.518 \times (2.7 \times 10^6)^{0.25}}{[1 + (0.80)^{0.5625}]^{0.44}}$$

$$6. h = \frac{N_u \times k}{d} \text{ W/m}^2\text{K}$$

$$\text{characteristic length } L_c = \frac{rL}{2(r + L)} \text{ m}$$

$$\text{Fourier number } F_o = \frac{at}{(L_c)^2}$$

Where

a = coefficient of thermal expansion = $17.7 \times 10^{-6} / ^\circ\text{C}$

$$T = e^{-B_i \times F_o} \times (T_s - T_a) + T_a$$

COOLING:-

$$1. \frac{T - T_a}{T_s - T_a} = e^{-B_i \times F_o}$$

Where

T_a = atmospheric temperature

T_s = specimen temperature(initial)

$$2. \text{Biot No} = hl/k$$

Where

K = thermal conductivity of copper = 386 w/mk

$$T_{mean} = \frac{T_{max} + T_{min}}{2}$$

From data book

Take the reading at T_m

K T_m = -----w/mk

ρT_m = -----kg/m³

γT_m = -----m²/sec

Pr T_m = -----

μT_m = -----ns/m²

$$3. \text{rayleigh number } R_a = (G_r P_r)$$

Where

$$G_r = \text{grashof number} = \frac{g\beta\Delta TL^3}{\nu^2}$$

$$\beta = \frac{1}{T_{\text{mean}} + 273}$$

$$L = D = 30 \text{ mm}$$

$$\Delta T = T_s - T_a$$

$$\text{nusslet number } N_u = 0.36 + \frac{0.518 \times (2.7 \times 10^6)^{0.25}}{[1 + (0.80)^{0.5625}]^{0.44}}$$

$$h = \frac{N_u \times k_w}{a} / m^2k$$

$$\text{characteristic length } L_c = \frac{rL}{2(r+L)} \text{ m}$$

$$\text{fourier number } F_o = \frac{at}{(L_c)^2}$$

Where

a= coefficient of thermal expansion=17.7×10⁻⁶/°C

$$T = e^{-Bi \times Fo} \times (T_s - T_a) + T_a$$

RESULT:-

The specimen temperature at any interval of time by practical and theoretical methods is determined.

$$T = \text{-----}$$

NATURAL CONVECTION APPARATUS

Ex.No:-

Date:-

AIM:-To find out heat transfer coefficient and heat transfer rate from vertical cylinder in natural convection.

APPARATUS:-

1. Tube 38 mm Diameter, 500 mm Length.
2. Duct size (200 x 200 x 800)mm length.
3. Multi channel digital temperature indicator 0-300⁰C using Chromyl/Alumel thermocouple.
4. Ammeter 0-2 Amp. And Voltmeter 0-200 volts.
5. Dimmer stat 2 Amp, 240 volts.

THEORY:-

In contrast to the forced convection, natural convection phenomenon is due to the temperature difference between surface and the fluid and is not created by any external agency. Natural convection flow patterns for some commonly observed situations are shown in figure

The present experimental set up is designed and fabricated to study the natural convection phenomenon from a vertical cylinder in terms of variation of local heat transfer coefficient and its comparison its value obtained by using an appropriate co relation.

PROCEDURE:-

1. Put ON the supply and adjust the dimmer stat to obtain the required heat input (Say 40W, 60W, 70W etc)
2. Wait till the steady state is reached, which is confirmed from temperature readings
(T1 to T6).
3. Measure surface temperature at the various points i.e. T1 to T6.
4. Note the ambient temperature i.e. T_a
5. Repeat the experiment at different heat inputs (Do not exceed 80W).

PRECAUTIONS:-

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

TABLE:

S.No	Heat input			Thermo couple reading($^{\circ}$ C)							
	V (Volt)	I (Amp)	V x I (Watts)	T ₁	T ₂	T ₃	T ₄	T ₅	T ₅	T ₅	T ₅

FORMULAE:-

1. ambient temperature $T_a = \frac{T_1 + T_6}{2}$
2. *Surface temperature* $T_s = \frac{T_2 + T_3 + T_4 + T_5}{4}$
3. *Film temperature* $T_f = \frac{T_a + T_s}{2}$

From data book

Take the reading at T_f

K $T_f = \text{-----w/mk}$

$\rho T_f = \text{-----kg/m}^3$

$\gamma T_f = \text{-----m}^2/\text{sec}$

Pr $T_f = \text{-----}$

$\mu T_f = \text{----- ns/m}^2$

rayliegh number $R_a = (G_r P_r)$

Where

$$G_r = \textit{grashof number} = \frac{g\beta\Delta TL^3}{\gamma^2}$$

$$\beta = \frac{1}{T_f + 273}$$

$$L = D = 500 \text{ mm}$$

$$\Delta T = T_s - T_{amb}$$

From data book

For $10^8 < R_a < 10^{12}$

$$N_u = 0.13 \times [Gr Pr]^{1/3}$$

$$\text{free convection heat transfer coefficient } (h) = \frac{N_u k}{d} \text{ W/m}^2\text{K}$$

d= diameter

N_u = Nusselt number

4. *heat transfer rate by convection* $Q_c = h \times \pi d l (T_s - T_a)$ watts

Model Calculations

RESULT:-

The heat transfer coefficient and heat transfer rate from vertical cylinder in natural convection has been determined

1. h -----

2. Q -----

FORCED CONVECTION APPARATUS

Ex.No:-

Date:-

AIM:-

To calculate heat transfer rate and heat transfer coefficient in forced convection.

APPARATUS:-

1. Test pipe-33 mm I.D. 50 mm long.
2. Band heater for pipe-250W
3. Multichannel digital temperature indicator 0-300 °C using Chromel / Alumel thermocouples.
4. Dimerstat 2 Amps,240 Volts. for heater input control.
5. Voltmeter 0-200 volts
6. Ammeter 0-2Amps
7. Blower to force the air through test pipe
8. Orifice meter with water manometer

THEORY:-

Whenever a fluid is being forced over the heated surface forced convection heat transfer occurs. The dynamic apparatus consists of circular pipe through cold fluid, i.e. air is being forced. Pipe is heated by a band heater outside the pipe. Temperature of the pipe is measured with thermocouples attached to the pipe surface. Heater input is measured by a voltmeter and ammeter.

PROCEDURE:-

1. Put 'ON' mains supply.
2. Adjust the heater input with the help of dimmer stat.
3. Start the blower and adjust the air flow with valve.
4. Wait till steady state is reached and note down the reading in the observation table.

PRECAUTIONS:-

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

TABLE:

Room temperature $T_R=30+273.15=303.15$ K

S.No	Heater input			Differential manometer reading in mm			Air temp (°C)		Tube surface temp (°C)				
	Volt meter reading(V) Volts	Ammeter reading(I) amps	V x I Watts	h ₁	h ₂	h ₁ - h ₂	Inlet T ₁	Outlet T ₇	T ₂	T ₃	T ₄	T ₅	T ₆
				Avg									

FORMULAE:-

$$1. \quad h = \frac{N_u k}{d} \text{ W/m}^2\text{K}$$

d= diameter of pipe

N_u = nusselt number

From data book

For $40 < Re < 4000$

$$N_u = 0.023 (Re)^{0.8} (Pr)^{0.4}$$

$$T_s = \frac{T_2 + T_3 + T_4 + T_5}{4} \text{ } ^\circ\text{C}$$

$$T_{amb} = \frac{T_1 + T_6}{2} \text{ } ^\circ\text{C}$$

$$T_f = \frac{T_s + T_{amb}}{2} \text{ } ^\circ\text{C}$$

From data book

Take the reading at T_f

K_{T_f} = -----w/mk

ρ_{T_f} = -----kg/m³

ν_{T_f} = -----m²/sec

Pr_{T_f} = -----

μ_{T_f} = -----ns/m²

$$R_e = \frac{DV_a}{\rho_a}$$

Where

$$D=L=40 \text{ mm}$$

$$V_a = \text{velocity of air in the duct} = \frac{Q}{a_1} \text{ m/sec}$$

Where

$$\text{Discharge } Q = \frac{c_d \times a_1 \times a_2 \times \sqrt{2gh_a}}{\sqrt{a_1^2 - a_2^2}} \text{ m}^3$$

Where

$$C_d = \text{coefficient of orifice} = 0.6$$

$$a_1 = \text{area of pipe} = \frac{\pi}{4} d_1^2$$

$$d_1 = \text{diameter of pipe} = 40 \text{ mm}$$

$$a_2 = \text{area of orifice} = \frac{\pi}{4} d_2^2$$

$$d_2 = \text{diameter of orifice} = 20 \text{ mm}$$

$$h_a = \text{head of air} = \frac{\rho_w}{\rho_a} \times h$$

Where

$$\rho_a = \text{density of air} = 1.128$$

$$h = h_1 - h_2$$

2.LMTD METHOD:-

$$LMTD = \frac{(T_S - T_6) - (T_S - T_1)}{\ln\left(\frac{T_S - T_6}{T_S - T_1}\right)}$$

$$Q = hA(LMTD) \text{ watts}$$

$$h = \frac{Q}{A(LMTD)} \text{ W/m}^2\text{k}$$

$$A = \pi DL \text{ m}^2$$

Where

$$D = 0.04 \text{ m}$$

$$L = 0.4 \text{ m}$$

3. Newton's Law of cooling

$$Q = hA\Delta T \text{ watts}$$

$$\Delta T = (T_S - T_8)$$

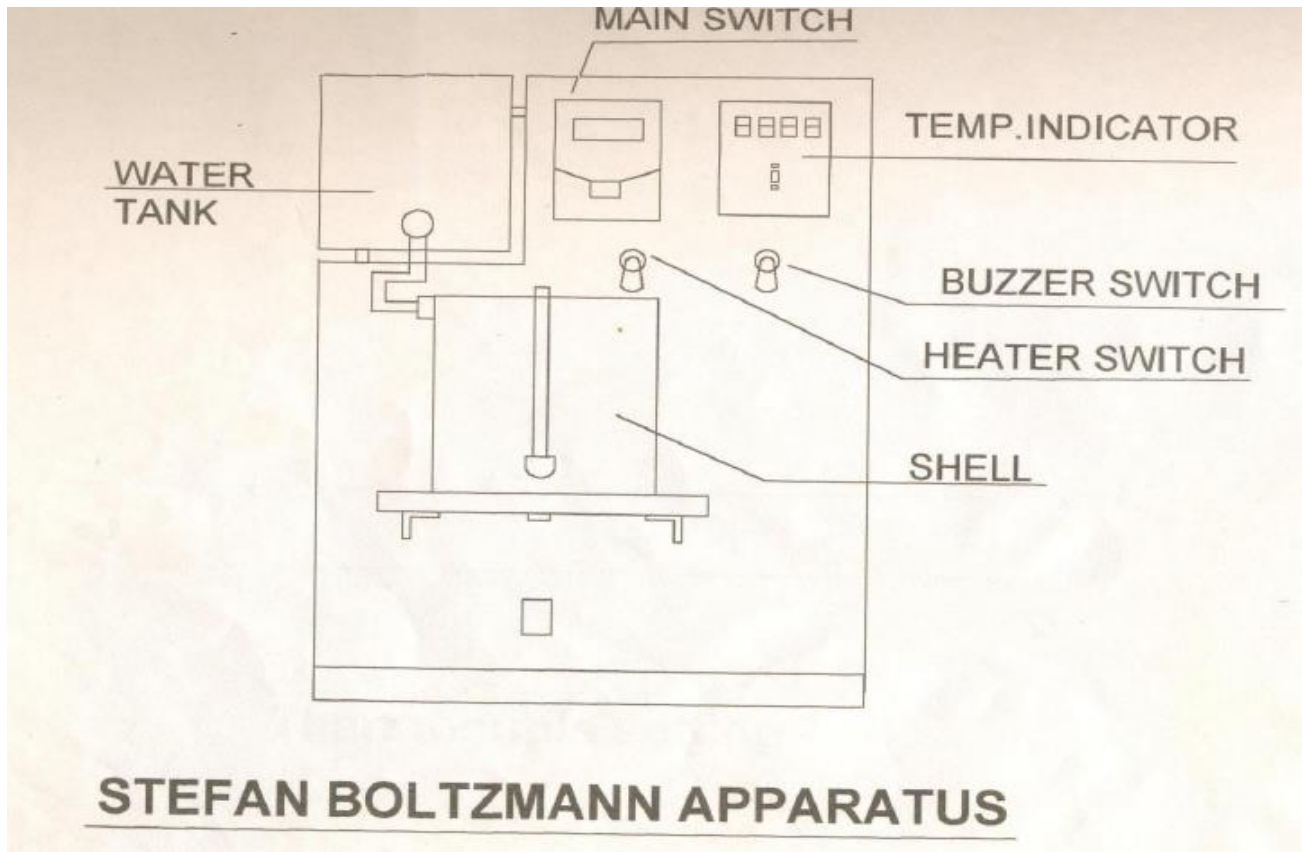
RESULT:-

The convective heat transfer rate and the Convective heat transfer rate by forced convection for flow of air inside a horizontal pipe has been determined.

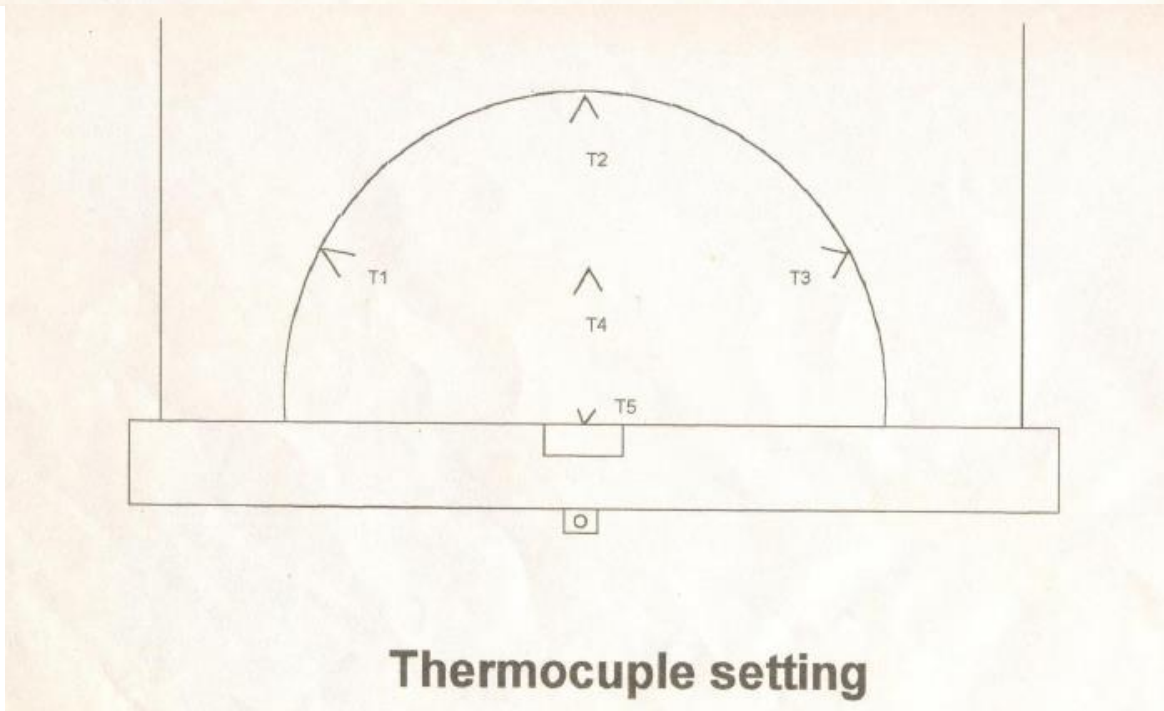
1.h =-----

2.Q =-----

STEFAN BOLTZMAN APPARATUS



STEFAN BOLTZMANN APPARATUS



Thermocouple setting

STEFAN BOLTZMAN APPARATUS

Ex.No:-

Date:-

AIM:- To determine the Stefan Boltzmann constant, by conducting an experiment on Stefan boltzman apparatus.

APPARATUS:-

1. Hemisphere
2. Heater
3. Temperature indicator
4. Stop watch.

THEORY:-

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

PROCEDURE:-

1. Allow water to flow through the hemisphere.
2. Remove the disc from the bottom of the hemisphere.
3. Switch on the heater and allow the hemisphere to reach a steady temperature.
4. Note down the temperature T_1, T_2, T_3 . The average of this temperature is the hemisphere temperatures
5. Refit the disc at the bottom of the hemisphere and start the stop clock. The rise in temperature T_4 with respect to time is noted. Also note down the disc temp at T_4 when steady state is reached (T_d).

FORMULAS:-

$$1. \text{ stefan boltzman costant } (\sigma) = \frac{Q}{(T_h^4 - T_d^4) \times A}$$

Where,

Where Q=heat gained by disc/sec

$$Q = mc_p \Delta T$$

m= mass of the disc=0.005 kg

C_p=specific heat copper=381 J/kgK

$$\Delta T = \frac{dT}{dt} \text{ (calculated from graph)}$$

$$A = \text{Araea of the disc} = \frac{\pi}{4} d^2 m^2$$

D= diameter of the disc=0.02 m

$$T_h = \frac{T_1 + T_2 + T_3}{3}$$

T_d= steady temperature of disc

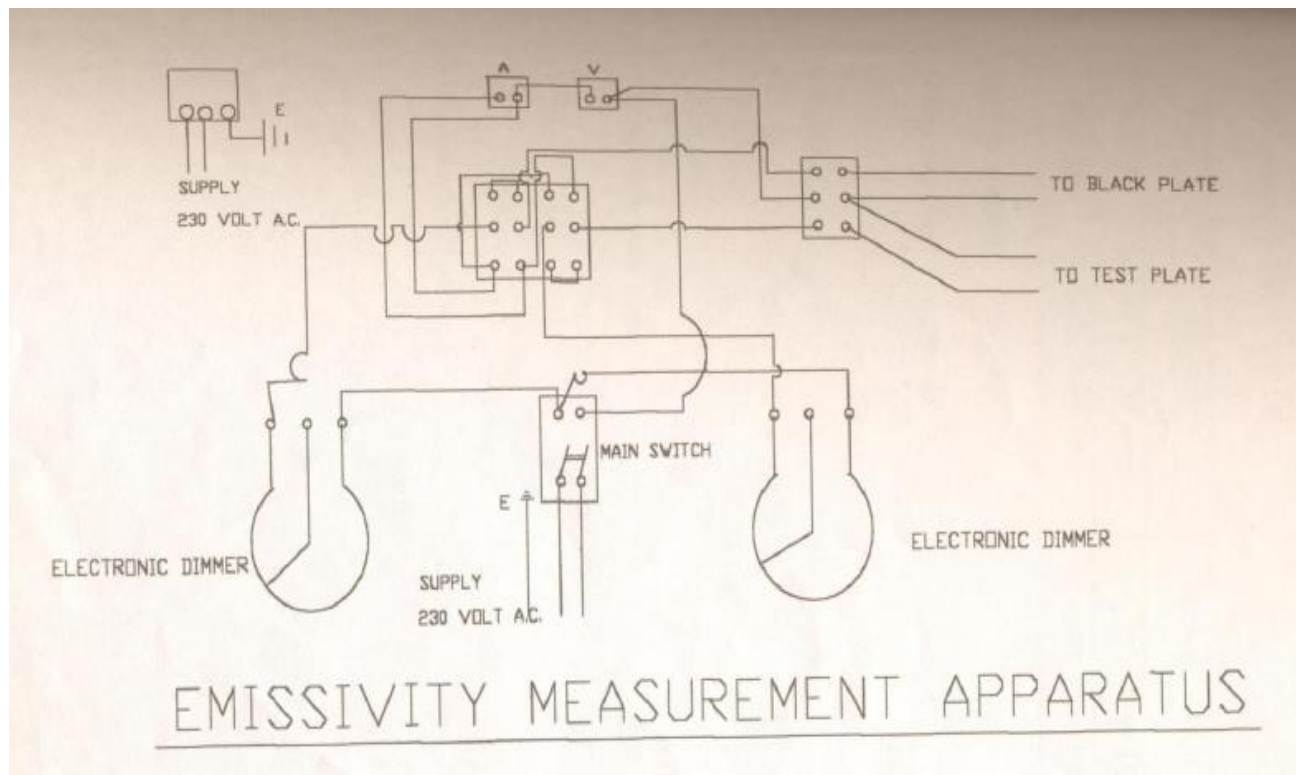
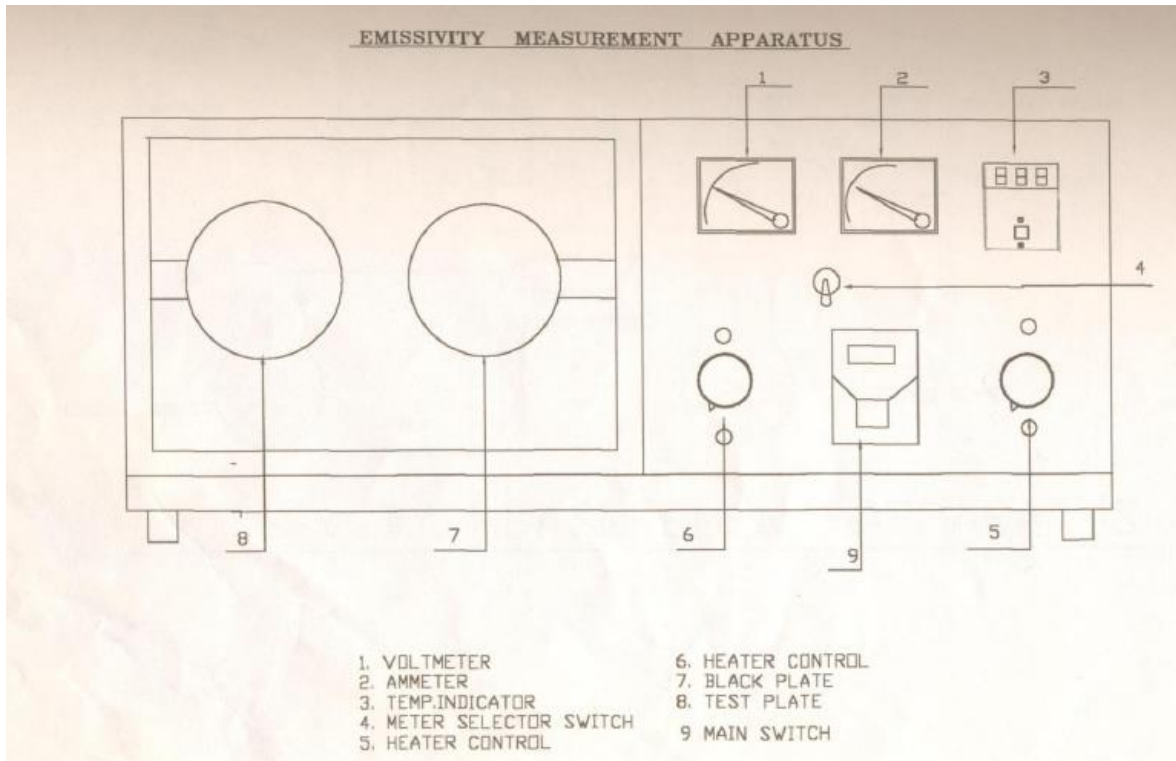
PRECAUTIONS:-

- 1) Never put on heater before putting water in the tank.
- 2) Put off the heater before draining the water from heater tank.
- 3) Drain the water after completion of experiment.
- 4) Operate all the switches and controls gently.

RESULT:-

The experiment on Stefan Boltzmann apparatus has been conducted and the value of Steffen Boltzmann constant is. -----

EMISSIVITY TEST ON RADIATING SURFACES



EMISSIVITY TEST ON RADIATING SURFACES

Ex. No:-

Date:-

AIM:- To measure the emissivity of the test plate surface.

APPARATUS:-

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

One of the plates is blackened outside for use a comparator (because black surface has $\epsilon=1$). Another plate having natural surface finish. Input to heaters can be controlled by separate dimmer stats. Heater input is measured on common ammeter and voltmeter. One thermocouple is fitted on surface on each plate is measure the surface temperature with digital temperature indicator. By adjusting the input to the heaters, both the plates are brought to same temperature, so that conduction and convection losses from both the plates are equal and difference in input is due to different emissivity.

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

THEORY:-

The radiation emitted per unit time per unit area from the surface of the body is called emissive power.

The emissive power of a body to the emissive power of a block body at the same temperature is known as emissivity of that body.

PROCEDURE:-

1. Connect the three pin plug to the 230V,50 HZ, 15 amps main supply and switch on the unit.
2. Allow the unit to stabilize. Certain power inputs to the block and test surfaces are at set values. i.e. equal.
3. Turn the thermocouple selector switch clockwise step by step and note down the temperatures indicated by the temperature indicator from channel 1 to 7.
4. Tabulate the readings and calculate.
5. After the experiment is over turn both the energy regulators 1&2.
6. For various power inputs repeat the experiment.

TABLE 6 :-

Heat Input $Q=V \times I$	Block body temp			Avg Temp T_b (°C)	Polished body temp			Avg temp T_p (°C)	Chamber temp T_7 (°C)	Emissivity (ϵ)
	T_1 (°C)	T_2 (°C)	T_3 (°C)		T_4 (°C)	T_5 (°C)	T_6 (°C)			

FORMULAS:-

$$1. \text{ emmissivity } (\epsilon_p) = \epsilon_b \times \left[\frac{(T_{ba}^4) - (T_{ca}^4)}{(T_{pa}^4) - (T_{ca}^4)} \right]$$

Where,

ϵ_b = emissivity of the block body = 1

$$T_{ba} = T_b + 273 \text{ k}$$

T_b = average block body temperature

$$T_{pa} = T_p + 273 \text{ k}$$

T_p = average polished body temperature

$$T_{ca} = T_4 + 273 \text{ k}$$

T_4 = chamber temperature

$$\epsilon_b > \epsilon_p$$

RESULT:-

Emissivity of the block body is greater than polished body.

Emissivity of the test plate surface is -----

PARALLEL AND COUNTER FLOW HEAT EXCHANGER

Ex.No:-

Date:-

AIM:- To find the overall heat transfer coefficient and effectiveness of a parallel flow and counter flow Heat exchanger.

APPARATUS:-

1. Stop watch
2. Measuring bar
3. Water supply
4. Temperature indicator
5. Concentric tube heat exchanger
6. Electric geyser
7. Valves
8. Measuring flask

THEORY:-

Heat exchanger is a device in which heat is transferred from one fluid to another fluid.

Eg:- radiator of car, condenser of the refrigerator.

Heat exchangers are classified into two types.

1. Parallel flow type:- in which fluid flow in the same direction.
2. Counter flow type:- in which fluid flow in the opposite direction.

PROCEDURE:-

1. Connect water supply at the back of the unit. The inlet water flows through geyser and inner pipe of the heat exchanger and flows out.
2. Also the inlet water flows through the annulus gap of the heat exchanger and flows out.
3. For parallel flow open valve V_2, V_4 , and V_5 .
4. For counter flow open valve V_3, V_1 , and V_5 .
5. Control the hot water flow approximately 2 lit/min. and cold water flow approximately 5 lit/min.
6. Switch on the geyser. Allow the temperature to reach steady state.
7. Note temperature T_1 And T_2 .(hot water inlet and outlet temp)
8. Under parallel flow condition T_3 is the cold water inlet temp. T_4 is the cold water outlet temp.
9. Under counter flow condition. T_4 is the cold water inlet temp. T_3 is the cold water outlet temp.
10. Note the time for 1 lit flow of hot and cold water. Calculate mass flow rate kg/sec.
11. Change the water flow rates and repeat the experiment.

PRECAUTIONS:-

1. Never switch on the geyser unless there is water supply through it.
2. If the red indicator on geyser goes of f during operation, increase the water supply, because it indicates that water temperature exceeds the set limit.
3. Ensure study water flow rate and temperatures in before noting down the readings, as fluctuating water supply can give erratic results.

TABLE 10 :- for parallel flow

S.No	Time for 1 lit of hot water(sec)	Time for 1 lit of cold water(sec)	Hot water in (°C)		Cold water in (°C)	
			T _{hi}	T _{ho}	T _{ci}	T _{co}

Counter flow:-

S.No	Time for 1 lit of hot water(sec)	Time for 1 lit of cold water(sec)	Hot water in (°C)		Cold water in (°C)	
			T _{hi}	T _{ho}	T _{ci}	T _{co}

FORMULAE:-

1. PARALLEL FLOW:-

$$T_1 = T_{hi}$$

$$T_2 = T_{ho}$$

$$T_3 = T_{ci}$$

$$T_4 = T_{co}$$

$$\Delta T_i = T_1 - T_3$$

$$\Delta T_o = T_2 - T_4$$

$$a. \text{ LMTD} = \frac{\Delta T_i - \Delta T_o}{\ln \left[\frac{\Delta T_i}{\Delta T_o} \right]}$$

$$A = \pi dL \text{ m}^2$$

Where

D= outer diameter of copper tube=15 mm

L= length of the heat exchanger=2440 mm

$$b. U = \frac{q_h}{A \times \text{LMTD}} \text{ W/m}^2\text{k}$$

Where

$$q_h = m_h \times C_p \times (T_{hi} - T_{ho}) \text{ watts}$$

$$m_h = \delta_w \times Q_{hot}$$

$$C_p = 4.2 \times 10^3 \text{ J/kg c}$$

$$Q_{hot} = \text{discharge for } 1 \text{ m}^3/\text{sec}$$

$$c. \text{ for effectiveness } e = \frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}}$$

2. COUNTER FLOW:-

$$T_1 = T_{hi}$$

$$T_2 = T_{ho}$$

$$T_3 = T_{ci}$$

$$T_4 = T_{co}$$

$$\Delta T_i = T_1 - T_3$$

$$\Delta T_o = T_2 - T_4$$

$$a. \text{ LMTD} = \frac{\Delta T_i - \Delta T_o}{\ln \left[\frac{\Delta T_i}{\Delta T_o} \right]}$$

$$A = \pi dL \text{ m}^2$$

Where

D= outer diameter of copper tube=15 mm

L= length of the heat exchanger=2440 mm

$$b. \text{ } U = \frac{q_h}{A \times \text{LMTD}} \text{ W/m}^2 \text{ k}$$

Where

$$q_h = m_h \times C_p \times (T_{hi} - T_{ho}) \text{watts}$$

$$m_h = \delta_w \times Q_{hot}$$

$$C_p = 4.2 \times 10^3 \text{J/kg c}$$

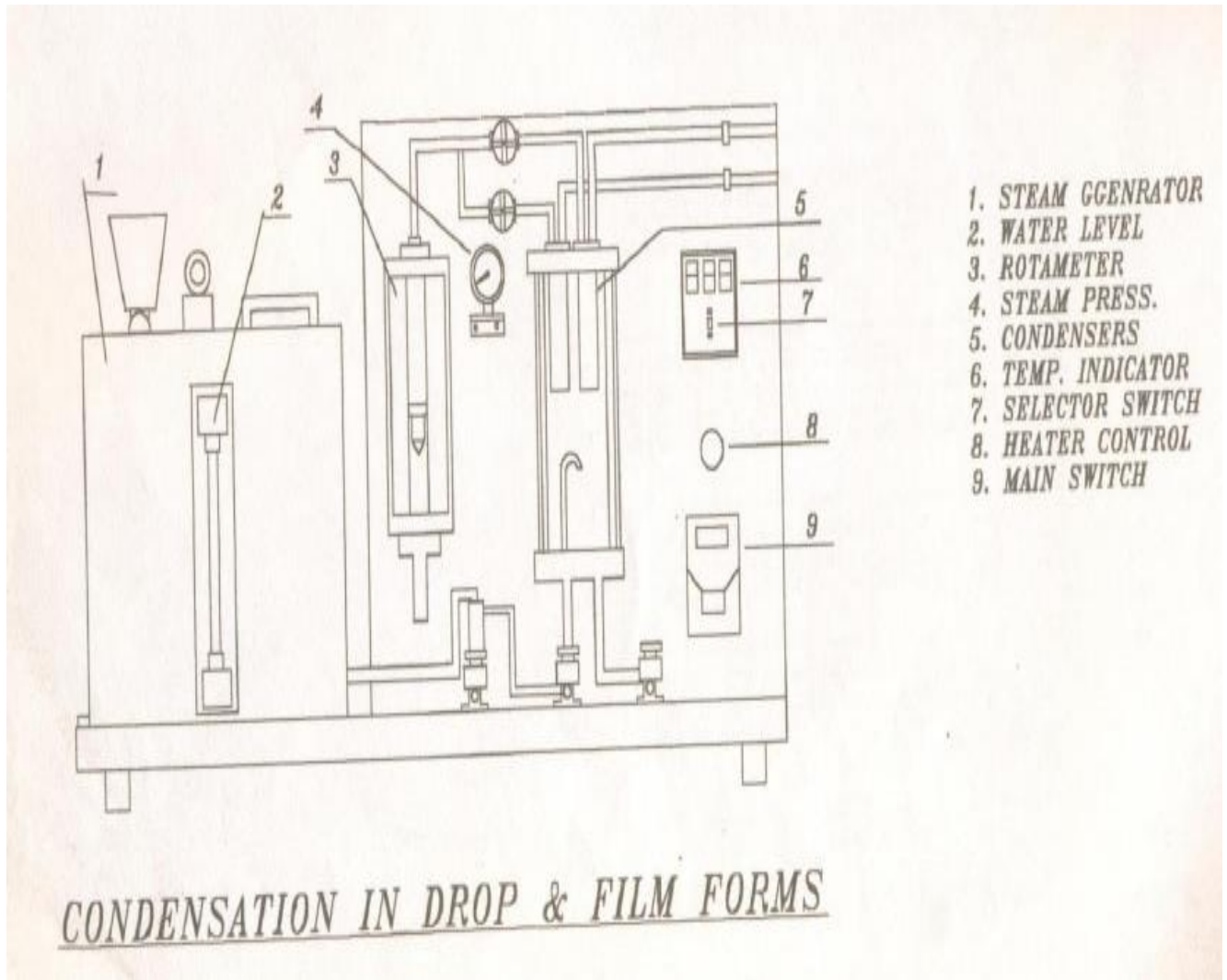
$$Q_{hot} = \text{discharge for } 1 \text{ m}^3 / \text{sec}$$

$$\text{for effectiveness } \epsilon = \frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}}$$

RESULT:- The overall heat transfer coefficient and effectiveness of parallel flow and counter flow has been determined.

1. Parallel flow (U)-----
2. Counter flow (U)-----
3. Parallel flow (ϵ)-----
4. Counter flow (ϵ)-----

CONDENSATION IN DROP WISE & FILM WISE FORMS



CONDENSATION IN DROP WISE & FILM WISE FORMS

Ex.No:-

Date:-

AIM:- To study and compare the drop wise and film wise condensation. Hence to determine LMTD and heat transfer coefficient.

APPARATUS:-

1. Steam generators
2. Rota meter
3. Condensers
4. Temperature indicator
5. Selector switch
6. Heater control
7. Main switch

THEORY:-

Condensation of vapor is needed in many of the processes, like steam condensers, refrigeration etc. when vapor comes in contact with the surface having temperature lower than saturation temperature, condensation occurs. When the condensate formed wets the surface, a film is formed over the surface and the condensation is film wise condensation. When condensate does not wet the surface, drops are formed over the surface and condensation is drop wise condensation.

The apparatus consists of two condensers, which are fitted inside a glass cylinder, which is clamped between two flanges. Steam from steam generator enters the cylinder through a separator. Water is circulated through the condensers. One of the condenser is with natural surface finish to promote film wise condensation and the other is chrome plated to create drop wise condensation. Water flow is measure by rotameter. Various temperatures are measured by digital temperature indicator. Steam pressure is measured by a pressure gauge. Thus heat transfer coefficients in drop wise and film wise condensation can be calculated.

PROCEDURE:-

1. First switch on the main switch.
2. Fill the water in boiler with the help of motor. Water level indicates in glass tube at the front of boiler.
3. Then switch on the heater button.
4. Wait for 15 to 20 min for getting required pressure.
5. Start the motor and adjust the flow rate by operating valves.
6. Allow the steam slowly to the chambers by opening valve.
7. The system is allowed to come to steady state.
8. Note down the temperature $T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8$.

PRECAUTIONS:-

1. Operate all the switches and controls gently.
2. Never allow the steam to enter the cylinder unless the water is flowing through condenses.
3. Always ensure that the equipment is earthed properly before switching on the supply.

Table:

S.No	Heat input			Temperature in °C								Water flow rate Q cc/sec	
												R _{t1}	R _{t2}
	V (Volt)	I (amp)	VI (Watts)	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈		

FORMULAE:-

FILM WISE CONDENSATION

1. Heat carried away by boiler $Q_{fw} = m_{fw} \times C_{pw} \times \Delta T$ watts

Where

$$m_{fw} = \text{mass flow rate of water in } kg/sec$$

$$C_{pw} = 4.187 \text{ } kj/kg \text{ } k$$

$$\Delta T = T_7 - T_1$$

$$2. LMTD = \frac{(T_3 - T_7) - (T_3 - T_2)}{\ln \left[\frac{T_3 - T_7}{T_3 - T_2} \right]}$$

$$3. \text{Heat transfer coefficient } h_o(f_w) = \frac{Q_{fw}}{a_o \times (LMTD)_{fw}} \text{ } W/m^2k$$

Where

$$a_o = \pi d_o L m^2$$

$$D_o = 16 \text{ mm}$$

$$L = 300 \text{ mm}$$

DROP WISE CONDENSATION

1. Heat carried away by boiler $Q_{dw} = m_{dw} \times C_{pw} \times \Delta T$ watts

Where

m_{dw} = mass flow rate of water in kg/sec

$C_{pw} = 4.187 \text{ kJ/kg K}$

$\Delta T = T_8 - T_1$

2. $LMTD = \frac{(T_4 - T_8) - (T_4 - T_5)}{\ln \left[\frac{T_4 - T_8}{T_4 - T_5} \right]}$

Heat transfer coefficient $h_o(d_w) = \frac{Q_{dw}}{a_o \times (LMTD)_{fw}} \text{ W/m}^2\text{K}$

Where

$a_o = \pi d_o L \text{ m}^2$

$D_o = 16 \text{ mm}$

$L = 300 \text{ mm}$

RESULT:- Thus we studied and compared the drop wise and film wise condensation.

For film wise condensation

1. LMTD=-----

2. h_o =-----

For drop wise condensation

1. LMTD=-----

2. h_o =-----