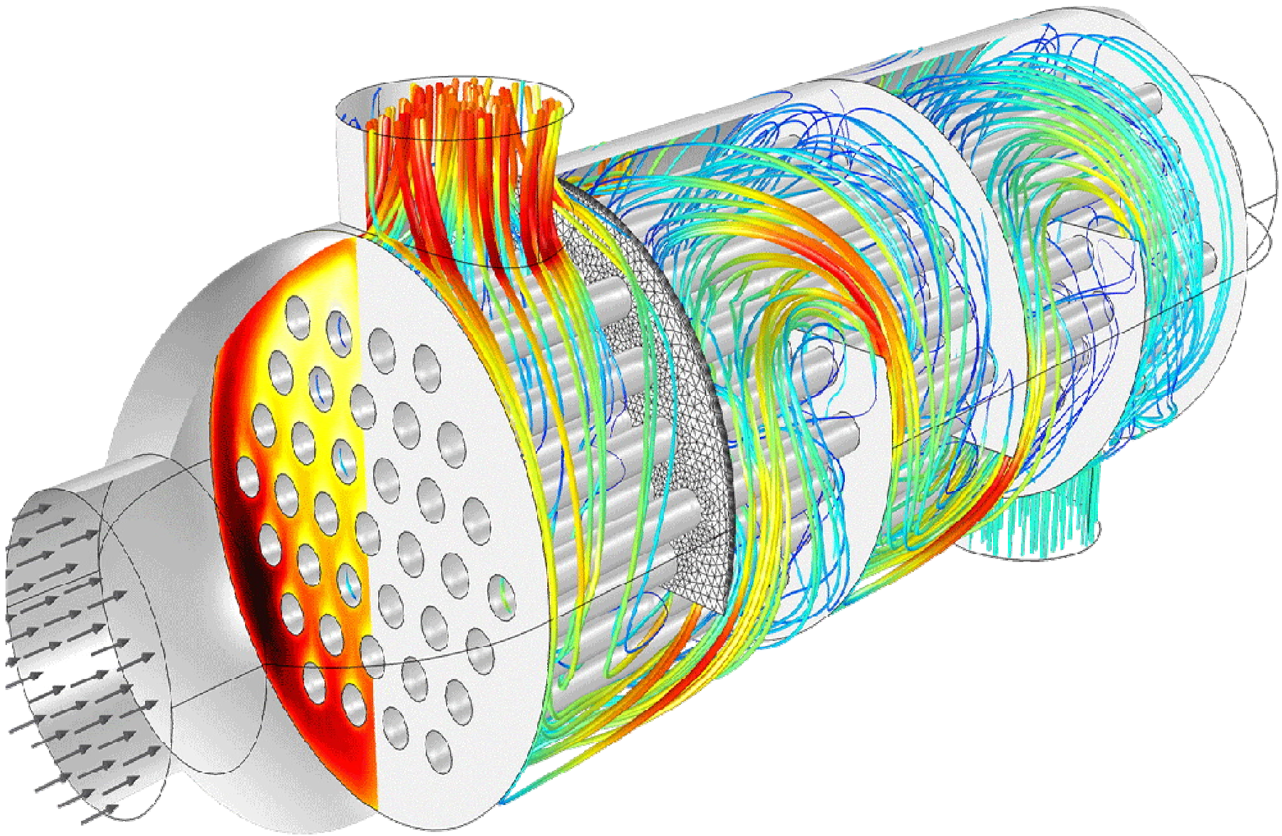
Lab Manual

Heat Transfer

3151909_A.Y.2022-23



Department of Mechanical Engineering
L.E.College, Morbi.

L.E.COLLEGE MORBI

Certificate

*This is to certify that Mr./Ms.*_____________________________________

*Enrollment No.*__________________*Branch*______________________________

Semester 5th *has satisfactory completed the course in the subject* ***Heat Transfer***

(3151909) in *this institute.*

Date of Submission: -___/____/ _______

Subject Faculty:

INDEX

Ex. No.	Experiment Title	CO	Date Of Experiment	Sign
1	To find thermal conductivity and total thermal resistance of composite wall	CO-1		
2	To measure thermal conductivity of insulating powder.	CO-1		
3	To calculate the thermal conductivity of the lagged pipe	CO-1		
4	To calculate the critical radius of insulation for a cylinder	CO-1		
5	To determine heat transfer of unsteady state heat conduction	CO-1		
6	To measure heat transfer coefficient in Natural Convection heat transfer. (VLAB)	CO-2		
7	To measure emissivity of a given test plate	CO-3		
8	To measure the value of Stefan Boltzmann constant on Stefan Boltzmann apparatus	CO-3		
9	To determine effectiveness of concentric tube heat exchanger	CO-4		
10	To perform experiment on Heat pipe demonstrator	CO-4		
11	To find out critical heat flux	CO-5		

Sr No.	Assignment Title	CO	Date Of Completion	Sign
1	Assignment On Conduction	CO-1		
2	Assignment On Convection	CO-2		
3	Assignment On Radiation	CO-3		
4	Assignment On Heat Exchanger	CO-4		
5	Assignment On Boiling and condensation	CO-5		

Rubrics for Assessment of Lab Experiments

Criteria	Marks			
Ability to conduct experiment	**(Exemplary) (3)**	**(Satisfactory) (2)**	**(Developing) (1)**	**(Unsatisfactory) (0)**
	Quite able to conduct the entire experiment with negligible help from the lab instructor.	Able to conduct experiment with some help from the lab instructor.	Able to conduct experiment with a lot of help from the lab instructor.	Unable to conduct experiment on his own; lab instructor provides help in almost every step of the experiment.
Data collection, analysis and interpretation	**(Exemplary) (4)**	**(Satisfactory) (3)**	**(Developing) (2)**	**(Unsatisfactory) (0-1)**
	Collects data very accurately; very systematically, always analyzes and interprets data correctly and precisely; always draws correct and useful conclusions; always compares theory against experiment and calculates related error.	Collects data accurately most of the time; systematically most of the time, Analyzes and interprets data correctly most of the time; most of the conclusion are correct and useful; compares theory against experimental data and calculates related error most of the time.	Some of the data collected is inaccurate; somewhat systematic in data collection, Analyzes and interprets data correctly occasionally; some conclusions are incorrect; occasionally compares theory against experimental data and calculates related error.	Much of the data collected is inaccurate; not at all systematic in data collection, Analyzes and interprets data incorrectly most of the time; many conclusions are incorrect; most of the time never attempts to compare theory against experiment data.
Subject Knowledge	**(Exemplary) (3)**	**(Satisfactory) (2)**	**(Developing) (1)**	**(Unsatisfactory) (0)**
	Fully understands the experiment, including its purpose and results; able to discuss experimental protocols in a clear and precise manner.	Has very good understanding of the experiment, its purpose and results; able to discuss experimental protocols in a reasonably clear manner.	Has some understanding of the experiment, its purpose and results; almost able to discuss experimental protocols in a clear manner.	Has poor understanding of the experiment, its purpose and results; unable to discuss experimental protocols.

Rubrics for Assessment of Assignments

Content Accuracy and Completion of assignment	**(Exemplary) (4)**	**(Satisfactory) (3)**	**(Developing) (2)**	**(Unsatisfactory) (0-1)**
	All examples/Questions are correct and Complete, All assignments nicely organized and neat	Partially examples/Questions are correct and Complete, All assignments partially organized and neat	Less examples/Questions are correct and Complete, All assignments less organized and neat	Examples/Questions are not correct and Complete, All assignments are not organized and neat

Experiment-1

AIM: To find Thermal conductivity and total thermal resistance of composite walls.

1. INTRODUCTION:-

There are a few system of considerable practical utility which are made up of two layers of different materials. For example, cold storage walls have a layer of bricks, a layer of thick insulation and plaster of both the sides. The treatment of conductive heat flow in such structures is the extension of single wall structures and known as composite walls or composite structures. In such composite structures each layer has a different value of resistance; the overall cumulative effect of this resistance's has to be studied. The heat flow is generally assumed to be one- dimensional.

2. DESCRIPTION OF APPARATUS :-

The apparatus consists of 3 layers of different materials (M.S., Bakelite and press wood) placed in series so as to make the composite walls. The rate of heat conducted through each layer is the same. The heater plate consists of a mica heater embedded in a single heater plate. In the experiment, it is assumed that the total heat flow's in the axial direction. But practically it is not possible as the heat flows in radial direction also. The control panel consists of a main switch, dimmerstat, voltmeter, ammeter and temperature indicator.

The temperature indicator can measure temperatures of 8 different points. Thus the thermocouple tapings in the test section are as follows,

T_1 & T_2 – Temperatures within the heater plates and M.S. plates at the center of the heater. Above and below the heater plates respectively.

T_3 & T_4 – Temperatures within the M.S. plates and Bakelite plates at the center. Above and below the upper and lower M.S. plates respectively.

T_5 & T_6 Temperatures within the Bakelite plates and press wood plates at the center. Above and below the upper and lower Bakelite plates respectively.

T_7 & T_8 Temperatures after the press wood plates at the center. Above and below upper and lower press wood plates respectively.

3. SPECIFICATIONS: -

1. Slab size-
    a) M.S. - Dia. 250mm. and 25 mm thick.
    b) Bakelite Plate - Dia. 250 mm. and 10 mm thick.
    c) Press Wood - Dia. 250 mm. and 10 mm thick.
2. Heater plate: Mica heater embedded in a single heater plate.
3. Heater control unit: 230 Volts & 2 A. Single phase dimmerstat – 1No.
4. Input to the heaters can be read by voltmeter and ammeter.
5. Multichannel digital temperature indicator.
6. Water cooled heat sinks at the end of composite slabs.

4. EXPERIMENTS TO BE CARRIED OUT : -

1. To find Thermal conductivity and total thermal resistance of composite walls
2. To plot temperature gradient along composite wall structure.

5.PRECAUTIONS : -

1. Ensure the dimmerstat is at minimum position before start.
2. Increase the voltage slowly.

3. Do not disturb the thermocouple settings.
4. Always keep the voltage below 150 Volts.
5. Operate the selector switch of the temperature indicator gently.

6.EXPERIMENTAL PROCEDURE: -

1. Ensure the dimmerstat is at minimum position before start.
2. ‘ ON ‘ the main switch.
3. Apply the voltage approximately up to 80 volts.
4. After the steady state is reached i.e. the temperatures of the thermocouples T_1 & T_2 of the main heater surface remains constant for more than 2 minutes. Fill up the following observation table.

7. OBSERVATIONS TABLE :-

Sr. No.	Volt ‘V’	Current ‘I’	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8

8.CALCULATIONS:-

1. Heater input

$$Q = V \times I$$

2. Mean readings

i) $$T_a = \frac{T_1 + T_2}{2}$$

ii) $$T_b = \frac{T_3 + T_4}{2}$$

iii) $$T_c = \frac{T_5 + T_6}{2}$$

iv) $$T_d = \frac{T_7 + T_8}{2}$$

3. i) Thermal conductivity of the slab.

$$K = \frac{Q \times L}{A \times (T_a - T_d)} \quad W / m . ^\circ C$$

Where, L = Length of the slab = 0.056 m

& A = Area of the heater = $\prod/4 \times (0.15)^2$
= 0.017 m²)

Note – For calculating the thermal conductivity of the composite walls, it is assumed that due to large diameter of the plates, heat flowing through the center portion is unidirectional i.e. axial flow . Thus for calculations, central diameter area where unidirectional flow is assumed is considered. Accordingly thermocouples are placed to the center of the plates.

ii) Thermal resistance of the slab –

$$R = \frac{T_a - T_d}{Q} \quad °C/W$$

4. i) Thermal conductivity of the M.S.

$$K = \frac{Q \times L}{A \times (T_a - T_b)} \quad W/m.°C$$

Where, L = Length of the M.S. = 0.025 m

& A = Area of the heater = $\prod/4 \times (0.30)^2$
= 0.0706 m^2

ii)Thermal resistance of the M.S. –

$$R = \frac{T_a - T_b}{Q} \quad °C/W$$

5. i) Thermal conductivity of the Bakelite.

$$K = \frac{Q \times L}{A \times (T_b - T_c)} \quad W/m.°C$$

Where, L = Length of the Bakelite= 0.019 m

& A = Area of the heater = 0.0706 m^2)

ii)Thermal resistance of the Brass. –

$$R = \frac{T_a - T_b}{Q} \quad ° k/W$$

6. i) Thermal conductivity of the Bakelite.

$$K = \frac{Q \times L}{A \times (T_c - T_d)} \quad W/m.k$$

Where, L = Length of the M.S. = 0.010 m

& A = Area of the heater = 0.0490 m^2)

ii) Thermal resistance of the Bakelite –

$$R = \frac{T_a - T_b}{Q} \quad ^\circ k/W$$

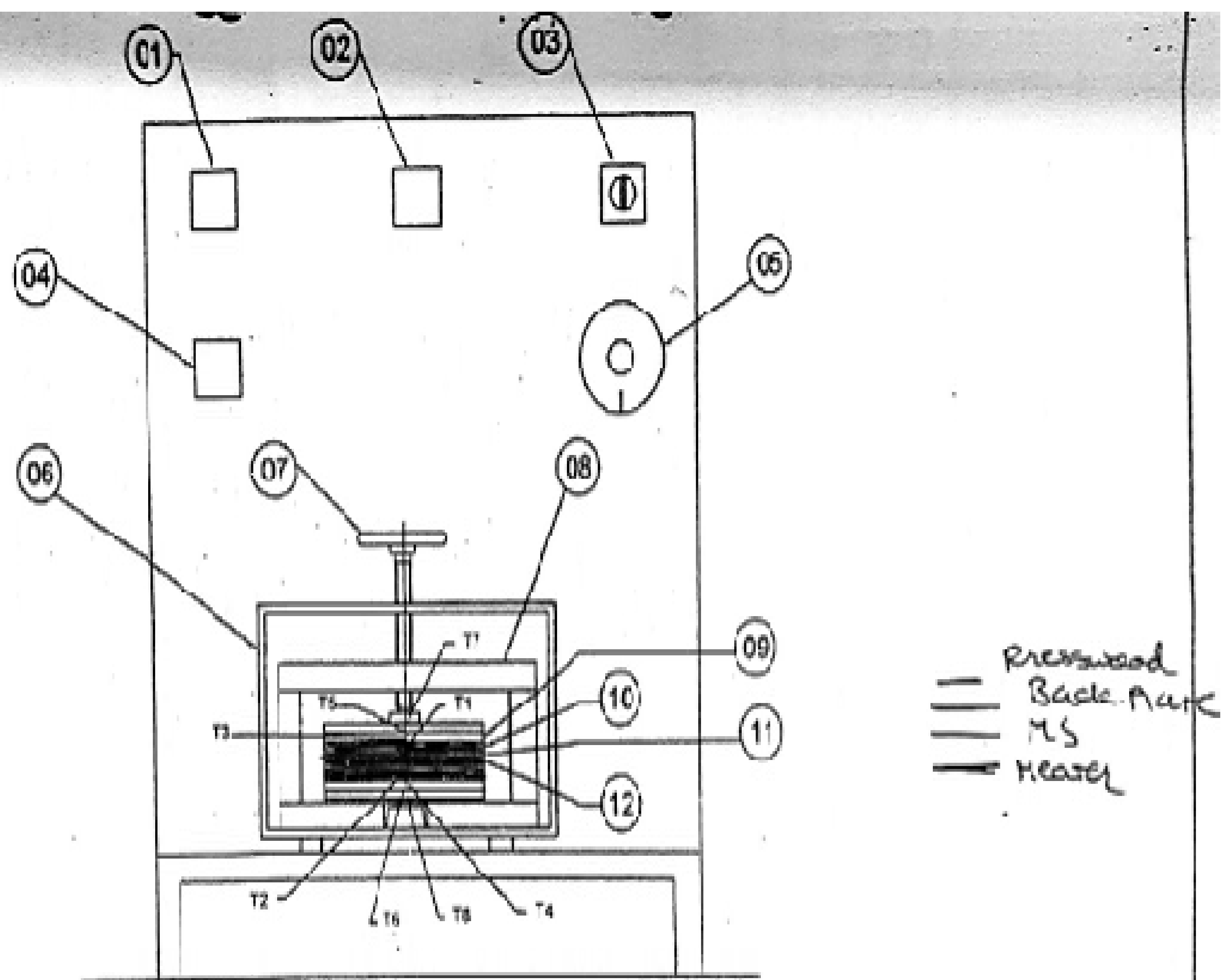
9. RESULTS:

Materials	Thermal conductivity(K) w/m°c	Thermal resistance (R_{th}) °c/w.

10. CONCLUSION:-

1) Thermal conductivity of the composite wall = -----------------w/m°c.

2) Thermal resistance of the composite wall = -------------------°c/w



01 AMMETER 02 TEMP. INDICATOR 03 ON OFF SWITCH 04 VOLT METER 05 DIMMER STAT

06 CABINET 07 HAND WHEEL AND SCREW 08 FRAME 09 PRESS WOOD PLATE 10 BAKELITE PLATE

11 C. I. PLATE 12 HEATER T1 TO T8 THERMOCOUPLES

Schematic Layout for

HEAT TRANSFER THROUGH COMPOSITE WALLS APPARATUS

Supersonic Electronics
Miraj

EXPERIMENT-2

AIM: To measure thermal conductivity of insulating powder.

1. INTRODUCTION:

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

2. THE APPARATUS:-

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

3. SPECIFICATIONS:-

1. Inner Sphere - 100 Mm O. D. , Halved Construction.
2. Outer Sphere - 200 Mm I. D., Halved Construction.
3. Heater - Mica Flat Heater, Fitted Inside Inner Sphere.
4. Controls - A) Main Switch - 30 A , B) Dimmerstat - 0-230 Volts, 2a Capacity.
5. Measurements -A) Voltmeter - 0 - 200 Volts B) Ammeter - 0 - 1 Amp. C) Multichannel Digital Temperature Indicator Calibrated For Cr / A1 Thermocouples.

4. EXPERIMENTAL PROCEDURE:-

1. Keep dimmerstat knob at ZERO position and switch ON the equipment.
2. Slowly rotate the dimmerstat knob, so that voltage is applied across the heater. Let the temperatures 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.

5. THEORY:-

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

Let, r_i = radius of inner sphere, m

r_0 = radius of outer sphere, m.

T_i = average inner sphere surface temp. ^{0}c.

T_o = average outer sphere surface. ^{0}c.

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

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

where, k = thermal conductivity of insulating powder.

$$\therefore \frac{q}{4\pi k} \times \frac{dr}{r^2} = -dT$$

Integrating between, r_i to r_o and T_i to T_o, we get

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

$$\text{or} \quad \frac{q}{4\pi k} \times \left(\frac{1}{r_i} - \frac{1}{r_o}\right) = (T_i - T_o)$$

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

From The measured values of q, Ti and To thermal conductivity of insulating powder can be determined as,

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

6. OBSERVATIONS:-

Sr. No.	Volt (V)	AMP (I)	Q=V/ I	Thermo couple Reading TEMPERATURES ^0C										T_i	T_0	K W / mk
				T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}			

7. CALCULATIONS-

1. Heater input = Q = V x I watts
2. Average inner sphere surface temperature

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

3. Average outer sphere surface temperature

$$T_o = \frac{T_5 + T_6 + T_7 \ldots\ldots + T_{10}}{6} \; {}^oc$$

4. Inner sphere radius = 50 mm = 0.05 m

5. Outer sphere radius = 100 mm = 0.1 m.

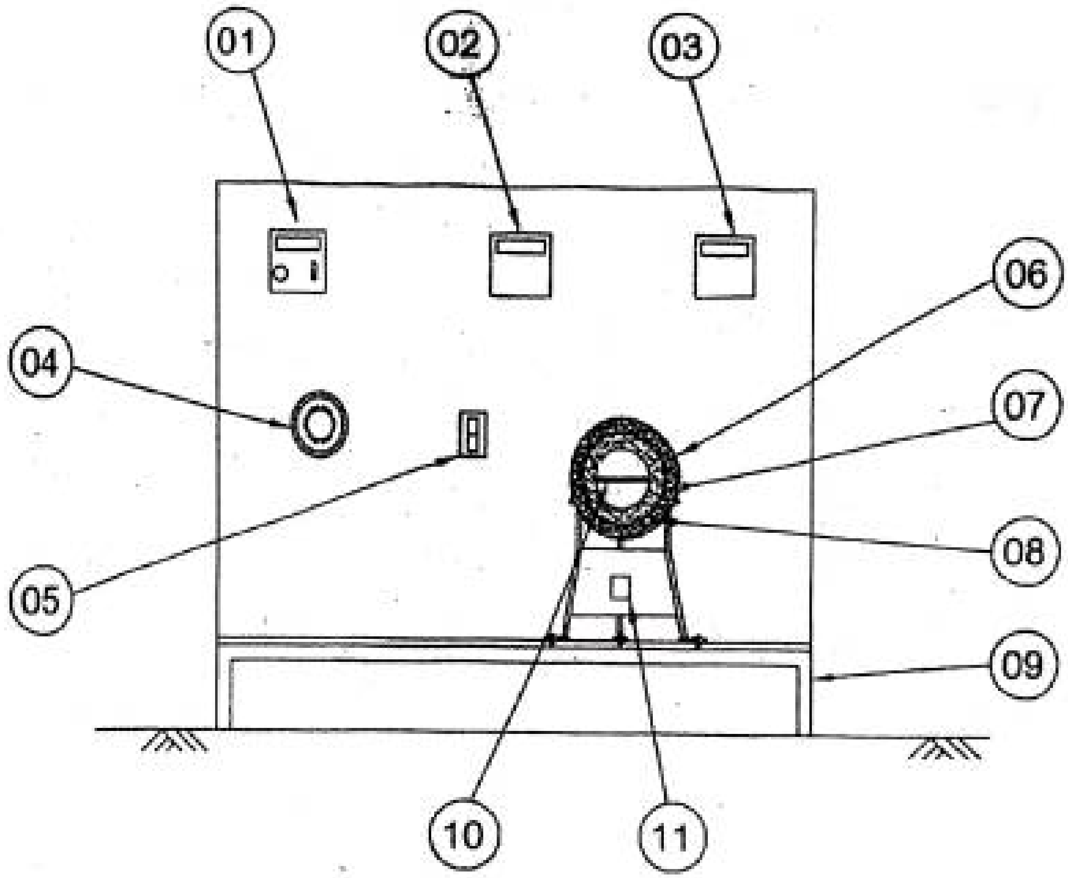
$$\text{now, } k = \frac{q \; (r_o - r_i)}{4\pi \cdot r_i \,.\, r_o \; (T_i - T_o)} \quad W / m.k$$

$$\text{at} \quad \frac{T_i + T_o}{2} \; {}^oc$$

PRECAUTIONS:-

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

8. CONCLUSION:-



01 TEMP. INDICATOR 02 AMMETER 03 VOLTMETER 04 DIMMER ST

05 ON OFF SWITCH 06 OUTER SPHERE 07 INNER SPHERE 08 INSULATING POW

09 FRAME 10 HEATER 11 THERMOCOUPLE SOCKET

THERMAL CONDUCTIVITY OF INSULATING POWDER

Supersonic Elec

EXPERIMENT-3

AIM: To calculate the thermal conductivity of lagged pipe.

1. INTRODUCTION:

The costs involved in insulting either heated or refrigerated equipment, air-conditioned rooms, pipes, ducts, tanks, and vessels are of a magnitude to warrant careful consideration of the type and quantity of insulation to be used.
Economic thickness is defined as the minimum annual value of the sum of the cost of heat loss plus the cost of insulation, or, in more general terms, as the thickness, of a given insulation that will save the greatest cost of energy while paying for itself within an assigned period of time. At low values of thickness, the amortized annual cost of insulation is low, but the annual cost of heat energy is
Additional thickness adds to the cost of insulation but reduces
the loss of heat energy, and therefore, its cost. At some value of insulation thickness, the sum of the cost of insulation and the cost of heat loss will be a minimum, curve C raises because the increased cost insulation is no longer offset by the reduced cost of heat loss.

2. DESCRIPTION - :

The apparatus consists of three concentric pipes mounted on suitable stand. The inside pipe consists of a heater, which is wound with nichrome wire on the insulation between first two cylinders the insulating material with which lagging is to be done is filled compactly. Between second and third pipe another material used for lagging is filled. The thermocouples are attached to the surface of pipe approximately to measure the temperatures. The input to the heater is varied through a dimmerstat and measured on voltmeter and ammeter. The experiments can be conducted at various values of input and calculations can be made accordingly. Similarly the experiments can be made for double or single lagging by removing appropriate pipes.

3. SPECIFICATIONS - :

1.PIPES
i) GI pipe (inside) ϕ 50 mm Dia. (O.D.)
ii) GI pipe (middle) ϕ100 mm. (mean dia.)
iii) GI pipe (outer) ϕ 150 mm. (I.D.)
iv) Length of pipes 1000 mm.
2.HEATER-Nichrome wire heater (cartridge type) placed centrally having suitable capacity 400 watts,
3.CONTROL PANEL comprising of –
i) Single phase Dimmerstat 0 – 230 volts . . . 1 No.
ii) Voltmeter 0 – 100 / 200 v. . . . 1 No.
iii) Ammeter 0 – 2 Amps. . . . 1 No.
4.TEMPERATURE INDICATOR WITH THERMOCOUPLES - :
Range 0 – 300^{0}c using chrome, alumel thermocouples – 1 No. s
Service required – A. C. single phase 230v electric supply.

4. EXPERIMENTS TO BE CARRIED OUT - :

a) To determine heat flow rate through the lagged pipe and compare it with the heater input for known value of thermal conductivity of lagging material.
b) To determine the thermal conductivity of the lagged pipe
c) To plot the temperature distribution across the lagging material.

5. LIMITES AND PRECAUTIONS - :

1. Keep dimmerstat to zero position before start.
2. Increase voltage gradually.

3. Keep the assembly undisturbed while testing.
4. Do not increase voltage above 100 volts.
5. Operate selector switch of temperature indicator gently.

6. PROCEDURE - :

1. Start the supplies of heater and by varying dimmerstat adjust the input for desired value (Range 60 to 100 watts) by using voltmeter and ammeter.
2. Take readings of all the 6 thermocouples at an interval of 5 minutes until the steady state is reached.
3. Note down steady readings in observation table.

7. OBSERATION TABLE:-

1. Inside pipe (O.D.) D1 = ϕ 50 mm
2. Middle pipe (Mean dia) D2 = ϕ 100 mm
3. Outer pipe (I.D.) D3 =ϕ 150 mm

Sr.No.	Voltmeter	Ammeter	Thermocouple Readings					
			T_1	T_2	T_3	T_4	T_5	T_6
1.								
2.								
3.								
4.								

MEAN READINGS - :

$$T\ (\text{inside}) = \frac{T_1 + T_2}{2}$$

$$T\ (\text{middle}) = \frac{T_3 + T_4}{2}$$

$$T\ (\text{outer}) = \frac{T_5 + T_6}{2}$$

8. CALCULATIONS:-

r_i = Radius of inner pipe.
r_o = Radius of outer pipe.
r_m = Mean radius of middle pipe.
L = Length of the pipe assume it as unity.
K = Thermal conductivity Kcal / hr. m^{0}C or w / m – k .

ASSUMPTIONS:-

The pipe is so long as compared with diameter that heat flows in radial direction only in middle half length.

Actual heat input is equal to

a) Actual heat input is equal to

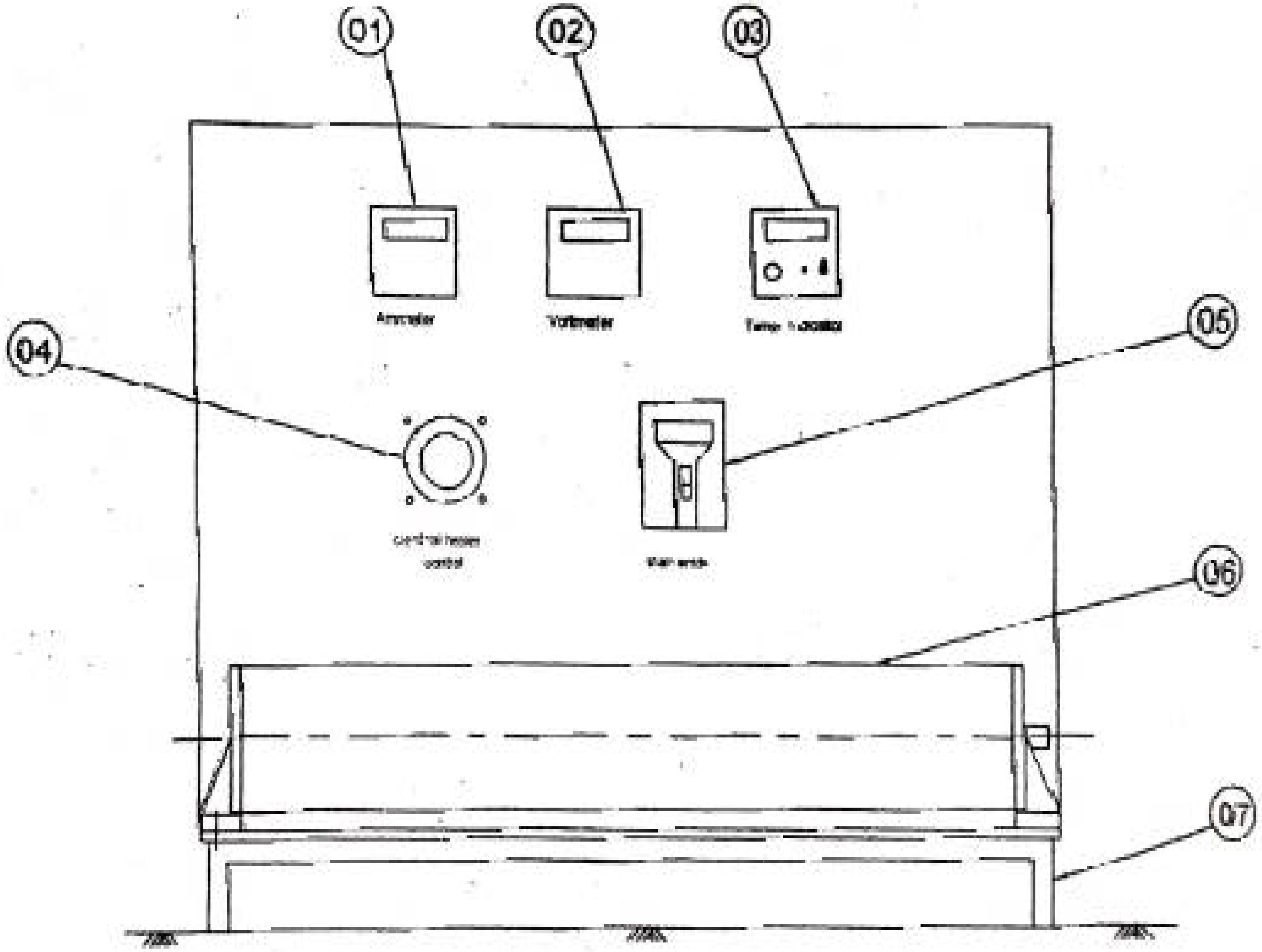
q = V x I Watts

b) Now from known value of heat flow rate, value of combined thermal conductivity of lagging material can be calculated.

$$Q = \frac{2\pi LK (T_1 - T_0)}{\log_e (r_o / r_I)}$$

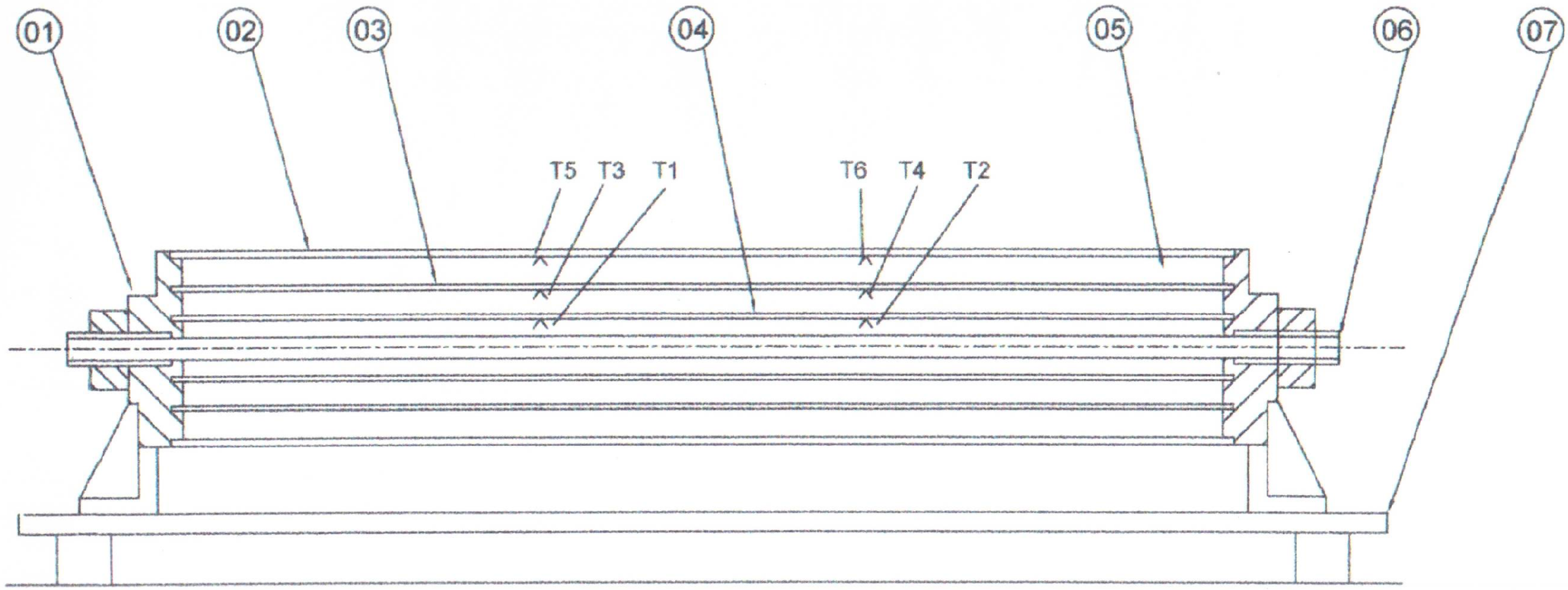
$$K = \frac{q \log_e (r_o / r_I)}{2\pi L (T_i - T_0)}$$

9. CONCLUSION:-



01 AMMETER 02 VOLTMETER 03 TEMP. INDICATOR 04 DIMMER STAT

05 MAIN SWITCH 06 MAIN UNIT 07 FRAME



01 BRACKET 02 OUTER PIPE 03 MIDDLE PIPE 04 INSIDE PIPE

05 LAGGING MATERIAL 06 HEATER 07 BASE PLATE T1 TO T6 THERMOCOUPLES

HEAT TRANSFER THROUGH LAGGED PIPE

Supersonic Electronics
Miraj

Experiment-4

AIM: To calculate the critical radius of insulation for a cylinder.

1. INTRODUCTION:

Thermal conductivity is one of the important properties of the materials and its knowledge is required for analyzing heat conduction problems. Physical meaning of the thermal conductivity is how quickly it passes through a given materials, thus, the determination of this property is of considerable engineering significance, there are various methods of determination of thermal conductivity but it is suitable for finding out the thermal conductivities of the material in the powdered form.

2. DESCRIPTION - :

The apparatus consists of one metal cylinder in which heater is fitted. The insulating material (asbestos belt) as lagging material is covered around the cylinder. Again the total assembly is insulated by glass wool & aluminum foil. The heat supplied to inner cylinder through heating coil by using a by a dimmerstat & is measured by Voltmeter & Ammeter. Cromial alumel thermocouples are used to measure the temperatures, thermocouples 1 to 5 are embedded on metal cylinder and thermocouples 6 to 10 are embedded on the external side of insulating material. Position 1 to 10, are as shown on change over switch of temperature indicator. Under steady state condition, the temperatures 1 to 10 are rated and also the voltmeter and ammeter readings are recorded. These readings, in turn enables as to find out the thermal conductivity of the insulating powder packed between two shells like assume the insulating powder as are isotropic material and the value of thermal conductivity to be constant. The apparatus assume one dimensional radial heat conduction across the powdered layer and thermal conductivity can be determined as above under steady state condition.

3. Specification:

- Pipe No.1 GI pipe φ33mm insulating material asbestos rope 3 mm thick outer total φ36 mmx 360 mm long.
- Pipe No.2 GI pipe φ33mm insulating material asbestos rope 6 mm thick outer total φ39 mmx 360 mm long.
- Pipe No.3 GI pipe φ33mm insulating material asbestos rope 9 mm thick outer total φ42 mmx 360 mm long.
- Pipe No.4 GI pipe φ33mm insulating material asbestos rope 12 mm thick outer total φ45 mmx 360 mm long.
- Voltmeter and ammeter
- Digital Temperature indicator

4. EXPERIMENTS TO BE CARRIED OUT - :

To find out heat transfer rate and total resister for critical radius of insulation for a cylinder.

5. LIMITES AND PRECAUTIONS - :

- Plug properly in wall socket and press the switch gently to avoid the spark.
- Do not touch the hot sphere for half an hour
- Operate the meter control carefully for safety of instrument.

6. PROCEDURE - :

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

7. OBSERATION TABLE:-

SR NO	VOLTAGE	CURRENT	T1	T2	T3	T4	T5	T6	T7	T8

8. CALCULATIONS:

Heat input (q) : q = V I ....(Watts) Where,V = Input voltage. I = Input Ampere.
Mean Temperature of Cylinder (Ta) :
Ta =(T1 + T2 + T3 + T4 + T5)/5
Mean Temperature of Insulating Material at external side (Tb):
Tb =(T6 + T7 + T8 + T9 + T10)/4
Heat Transfer Co-efficient of Insulating Material: qh = DL (Ta -Tb)
Critical Radius of Insulating Material R = K/h
Where,
R = Critical radius h = Heat Transfer Co-efficient. K = Thermal conductivity of Material(0.2 Watt/mtr0 K) (Asbestos)

9. RESULTS:

	1	**2**	**3**
Ti			
To			
q			

10. CONCLUSIONS:

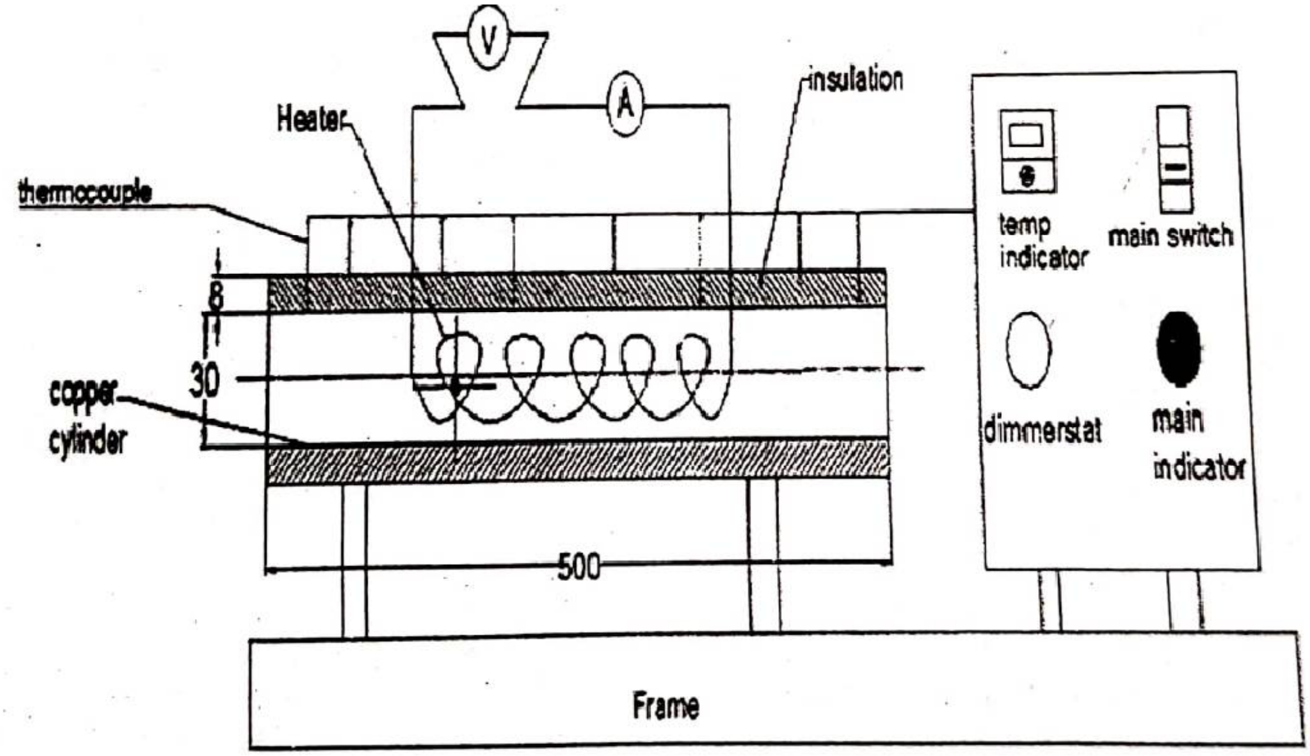


Fig. Critical Radius Apparatus

Experiment-5

AIM: To determine heat transfer coefficient in unsteady state heat conduction.

1. INTRODUCTION:

When a body is subjected to heating or cooling, irrespective of the material it requires a certain time to attain steady state. Hence the other way of expressing is that the unsteady process will occur till it attains the steady process. In an unsteady process the temperature will change with respect to time. Although, temperature of the body is generally expressed as the function of 3 different axis and time,it is not easy to solve. Unsteady state heating or cooling can be categorized as:

i) PERIODIC HEAT FLOW: where the temperature within the system undergoes periodic changes which may be regular or irregular.
ii) NON – PERIODIC HEAT FLOW: where the temperature at any point within the system changes non – linearly with respect to time.

Unsteady state heat flow is very common in all heating or cooling problems at the beginning of the system. Hardening by quenching, cooling of IC engine cylinders, and heating of boiler tubes are common examples of unsteady state heat flow.

2. DESCRIPTION OF APPARATUS:

The apparatus consists of a hot water bath provided with electrical heater, so that water can be heated up to desired temperature. A test piece with a thermocouple at the centre is immersed in the water bath and its temperature is measured at fixed interval of time. The unit is provided with timer, which whistles every five seconds. The hot test piece is then cooled in atmospheric air. Thus heat transfer co-efficient during heating and cooling process can be calculated.

3. SPECIFICATION :

a) Test piece- 25 dia X 50 long copper and m.c.-1 each
b) Hot water bath with electric heater
c) Switch for heater
d) Digital temperature indicator for bath and test piece temperature
e) A timer to indicate temperature at 5 seconds interval.

4. EXPERIMENTATION PROCEDURE:

a) Take the fluid water in the tank.
b) Heat the fluid to the required temperature, say 50^{0}C in case of water.
c) Note down the initial temperature of rod and hot fluid.
d) Immerse the rod in hot fluid bath for heating.
e) Note down the core and outer surface temperature of the rod at every 5 or 10 seconds till it attains fluid temperature.
f) Take out the rod from hot fluid and cool it in atmospheric air or in cold water.
g) Note down the temperature at every 5 or 10 second till it reaches atmospheric condition.
h) Repeat the experiment for different temperatures of fluid.

5. OBSERVATIONS: -

a) Test piece - Copper/M.S. [To – T_2 on selector switch]
b) Hot Bath temp. = ^{0}C. [Tf – T_1 on selector switch]
c) Ambient temperature. = ^{0}C. [Ta – on selector switch]
d) Density of Specimen = 8800 Kg /m^3
e) C_p = 381 J/Kg K

f) Specimen Size = 25mm×50 mm
g) Initial Temperature of specimen = T_o
h) Temperature of surrounding bath : T_f

Sr. No.	Heating Process			Cooling Process		
	Time Sec	Temp. of Test Piece	h w / m^2 K	Time Sec	Temp. of Test Piece	h w / m^2 K
1	0 [Initial]	To =		[0 Initial]		
2		T1 =				
3		T2 =				
4		T3 =				
N		Tn =				

6. THEORY : -

Let the initial temperature of body be t_o and surface area of body be A m^2.
When a body of volume 'V' is immersed in surrounding of temperature T_f, then at any instant of time t, rate of chance of internal energy of body is equal to heat transfer rate from the surroundings.

Hence,

$$\rho V_a C_p \frac{dT}{dt} = h A (T - T_f)$$

if $\varphi = (T - T_f)$ then

$$\rho V C_p \frac{d\varphi}{dt} = - h A \varphi$$

Integrating and using initial condition,
at $t = 0$, $\varphi = (T_o - T_f) = \varphi_o$, then

$$\frac{\varphi}{\varphi_o} = e^{\left[\frac{- h At}{\rho C_p V} \right]}$$

For a cylinder of radius R and length L,

$$\frac{\varphi}{\varphi_o} = e^{\left[\frac{-2h (L + R) t}{\rho C_p R L} \right]}$$

The equation can be expressed in terms of two dimensionless parameters, called Biot number (Bi) and Fourier number (Fo)

$$Bi = \frac{hL}{K} \quad \text{and} \quad Fo = \frac{\propto T}{L^2}$$

Where,

K = Thermal Conductivity,

L = Characteristic dimension,

$\propto$ = Thermal diffusivity

$$\propto = \frac{K}{\rho\ C_p}$$

For the cylinder, R is characteristic dimension,

$$\therefore \frac{\varphi}{\varphi_o} = e^{[-2 (Bi)(Fo)(1 + L/R)^{-1}]}$$

$$Log_e = \frac{T - T_F}{T_1 - T_F} = \left[\frac{-G.L.R}{K} . \frac{\propto t}{R^2}\right]$$

$$\therefore h = \left[\frac{K.R.}{G \propto t}\right] . \quad Log_e = \left(\frac{T - T_F}{T_1 - T_F}\right) \quad W / m^2\ K \quad \text{-----------} \quad (1)$$

7. CALCULATIONS: -

Initial temperature of body = T_1 = ^{0} C.
Temperature of water bath (or surrounding)= T_f = ^{0} C.
Specimen size = dia. 50 mm x 80 mm. Long
Hence,

a) Volume of specimen,

$$V = \frac{\pi}{4} D^2 \ x \ L$$

$$= 2.45 \times 10\text{-}5 \ m^3$$

b) Surface area of specimen,

$$A = 2 [\pi / 4 \ D^2] + \pi D L$$

$$= 4.9 \times 10 \text{-}3 \ m^2$$

$$\varphi_o = (T_o - T_f)$$

c) After 5 seconds,

$\varphi_5 = (T1 - T_f)$, $\varphi_{10} = (T1 - T_f)$ $\varphi_{15} = (T1 - T_f)$------- $\varphi_n = (Tn - T_f)$

Now,

$$\frac{\varphi}{\varphi_o} = e^{\left[\frac{-2h (L + R) t}{\rho\ C_p R L}\right]}$$

φ -2h (L + R) t

$$\therefore \text{Log}_e \left[\frac{\varphi}{\varphi_o} \right] = \left[\frac{e}{\rho \, C_p R L} \right]$$

$$h = \frac{\rho \, C_p R L \, \text{Log}_e [\varphi / \varphi_o]}{2 (L + R) t}$$

ρ = Mass density of specimen
= 7800 kg / m^3 for m.s.
= 8800 kg / m^3 for copper
Cp = Specific heat of specimen
= 452 J / kg K (0.1 k cal / kg m ^0C) for m.s.
= 381 J / kg K (0.09 k cal / kg m ^0C) for copper.
R & L = Radius and Length of specimen.
t = time in hours.

The above calculations are made by neglecting the internal temperature gradients of the specimen. However, there is criterian for neglecting temperature gradient, which is ; Bi < 0.1 which can be readily verified, because

$$Bi = \frac{hL}{K}$$

Hence, for cylinder, R is characteristic dimension

$$\therefore \; Bi = \frac{hR}{K}$$

$$\text{Fourier number;} \quad F_o = \frac{\propto t}{R^2}$$

Where, $\propto$ is thermal diffusivity
Now, We have

$$\text{Log}_e = \left(\frac{T - T_F}{T_1 - T_F} \right) = e^{-(G . B_i F_o)}$$

Where for cylinder's dimensionless quantity ' G' =2

$$\therefore h = \left[\frac{K.R.}{G \propto t} \right] . \text{Log}_e = \left(\frac{T - T_F}{T_1 - T_F} \right) \quad W / m^2 \, K$$

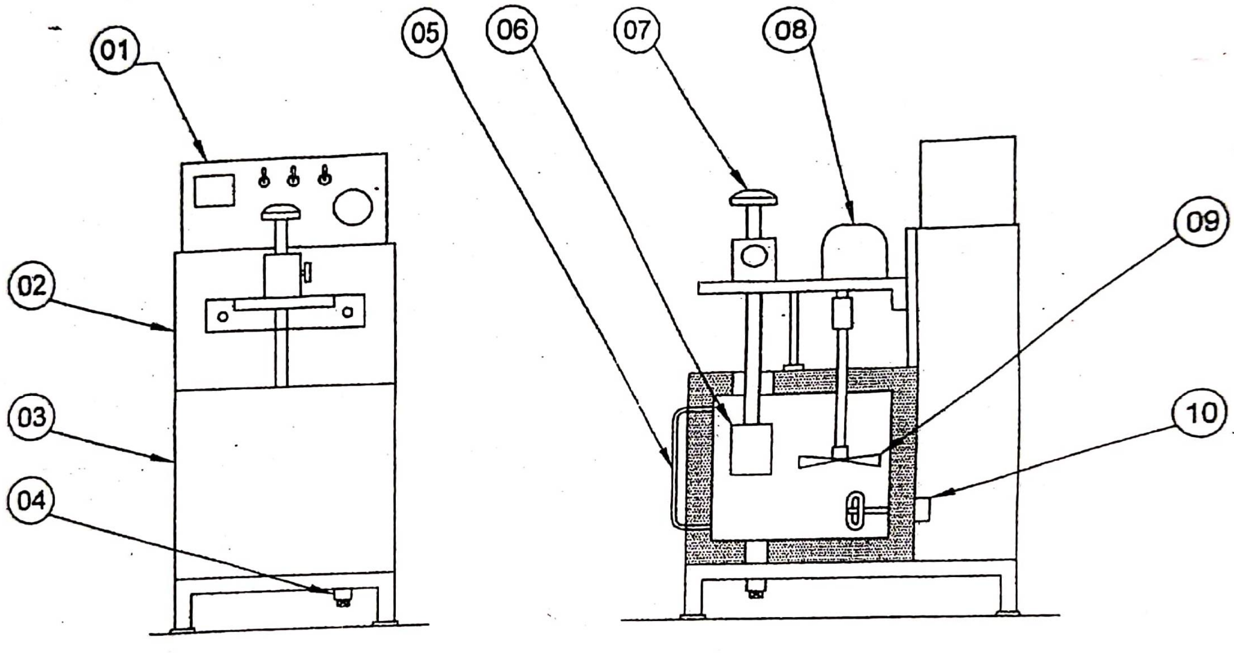
8. CONCLUSION: -

a) Average heat transfer coefficient for heating is ---------

b) Average heat transfer coefficient for cooling is ------

9. PRECAUTIONS

- Operate all the switches and controls gently.
- Do not heat water above 90 ^{0} C.



01 CONTROL PANEL 02 CONTROL PANEL 03 INSULATED WATER TANK 04 DRAIN
05 LEVEL INDICATOR 06 TEST PIECE 07 TEST PIECE 08 STIRRER MOTOR
09 STIRRER 10 HEATER

Fig. Transient Heat Conduction Apparatus

Experiment-6

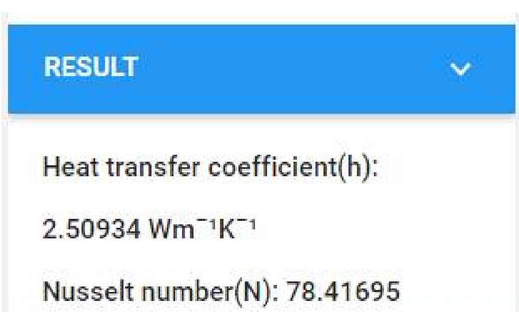
AIM: To determine heat transfer coefficient of given test cylinder.

LAB NAME: Physical Science/ Virtual Heat & Thermodynamics Lab (IIT Bombay-VLab)

1. EXPERIMENT PROCEDURE:

1) Experiment is performed on VLAB IIT Bombay portal on the link : htv.au.vlabs.ac.in/heatthermodynamics/Heat_Transfer_by_Natural_Convection/experiment.html
2) Select the material of test cylinder on the screen
3) Select the width of wooden box
4) Select the height of wooden box
5) Select the diameter of cylinder
6) Select the length of cylinder
7) Select the thickness of cylinder
8) "On", power button
9) Get the result for three different material

2. SCREEN LAYOUT:



3. OBSERVATION TABLE:

Sr No	**Material**	width of wooden box in cm	height of wooden box in cm	diameter of cylinder in cm	length of cylinder in cm	thickness of cylinder in cm
1	Iron					
2	Aluminum					
3	Copper					

4. RESULT TABLE:

Sr No	**Material**	Heat Transfer Coefficient	Nusselt Number
1	Iron		
2	Aluminum		
3	Copper		

5. CONCLUSION:

Experiment result shows that heat transfer coefficient of _________ cylinder is higher than other material.

Experiment-7

AIM :- To measure the Emissivity of given test plate

1. INTRODUCTION:-

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

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

The fraction of incident energy, reflected by the surface is called reflectivity (ρ). The fraction of incident energy, absorbed by the surface is called absorptivity (α) and the fraction of incident energy transmitted through body is called transmissivity (τ)

The surface which absorbs all the incident radiation is called a black surface.

For a black surface , $\rho + \alpha + \tau = 1$

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

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

$$\varepsilon = \frac{e}{eb}$$

2.THE APPARATUS:-

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

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

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

3. SPECIFICATION:

1) Two aluminium plates identical in all dimension, one coated with lamp black.(Dia.160mm).
2) Mica Heater
3) Heating coils.
4) Voltmeter,Ammeter.
5) Dimmerstat
6) Thermocouples
7) Multichannel digital Temperature indicator.

4. EXPERIMENTAL PROCEDURE:-

1) Blacken one of the plates with the help of lamp black (Normally this is Blackened at the works, but if blackening is wiped out, then blackening is necessary)
2) Keep both the dimmer knobs at ZERO position.

3) Insert the supply pin-top in the socket (which is properly earthed) and switch 'ON' the mains supply.
4) Switch ON the mains switch on the panel.
5) Keep the meter selector switch (toggle switch) at the black plate side position.
6) Adjust dimmer of black plate, so that around 110 - 120 volts are supplied to black plate.
7) Now, switch the meter selector switch on other side.
8) Adjust test plate voltage slightly less than that of black plate (say 100 -110 volts)
9) Check the temperatures (after, say 10 minutes) and adjust the dimmers so that temperatures of both the plates are equal and steady. Normally, very minor adjustments are required for this.
10) Note down the readings after the plate temperatures reach steady state.

5.OBSERVATIONS:-

Plate	I n put		Surface Temp.0C
	V	I	
Test Plate			T1 =
Black plate			T2 =

Enclosure temp. – T3 = ^{0}C

6. CALCULATIONS:-

1) Enclosure Temp.

$TE = T3$ ^{0}C

$= (T3 + 273.15)$ K

2) Plate surface temp.

$T = T1 = T2 =$ 0C

$TS = (T + 273.15)$ K

3) Heat input to black plate,

$Wb = V \times I$ watts

4) Heat input to test plate,

$WT = V \times I$ watts

5) Surface area of plates

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

= 0.0447 m2

Where, D = dia. of plates = 0.16 m. and ,t = thickness of plates = 0.009 m.

6) For black plate,

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

Where,

W_{CVb} = Convection losses

W_{Cdb} = Conduction losses

W_{Rb} = Radiation losses

Similarly, for test plate,

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

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

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

Subtracting equation (ii) from (i) we get,

$$W_b - W_T = W_{Rb} - W_{RT}$$
$$= [\sigma \cdot A \cdot \varepsilon_b \; (T_S^4 - T_E^4)] - [\sigma \cdot A \cdot \varepsilon_T \; (T_S^4 - T_E^4)]$$
$$= \sigma \cdot A \cdot (T_S^4 - T_E^4)\,(\varepsilon_b - \varepsilon)$$

as emissivity of black plate is 1,

$$W_b - W_T = \sigma \cdot A \cdot (T_S^4 - T_E^4)\,(1 - \varepsilon)$$

Where,

ε = Emissivity of test plate

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

7) We have to calculate Emissivity E

For this, we have,

$$q_b = \sigma A\,(T^4_s - T^4_d) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

&

$$q_T = \sigma E A\,(T^4_s - T^4_d) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where,

q_b = Heater input to test black plate = VI

q_T = Heater input to test plate = VI

σ = Stefan Boltzman Const.

= 5.667 x 10^{-8} $W/m^2 K^4$

E = Emissivity of Test Plate.

A = Area of plate where Dia. of plate = ϕ 160

T_5 = Surface Temp.

T_a2 = Ambient Temp. = T_3

Finally, from (1) & (2), we have -

$$E = \frac{q_T}{q_b} \quad \text{..................} (3)$$

[Note - Emissivity of oxidized aluminum plate i.e. test plate is normally within the range of 0.3 to 0.7.]

7. CONCLUSION:-

The emissivity of test plate was found to be ------ at the temperature of ------ K

8. PRECAUTIONS:-

1) Black plate should be perfectly blackened.
2) Never put your hand or papers over the holes provided at the top of enclosure.
3) Keep at least 200mm distance between the back side of unit and the wall.
4) Operate all the switches and knobs gently.

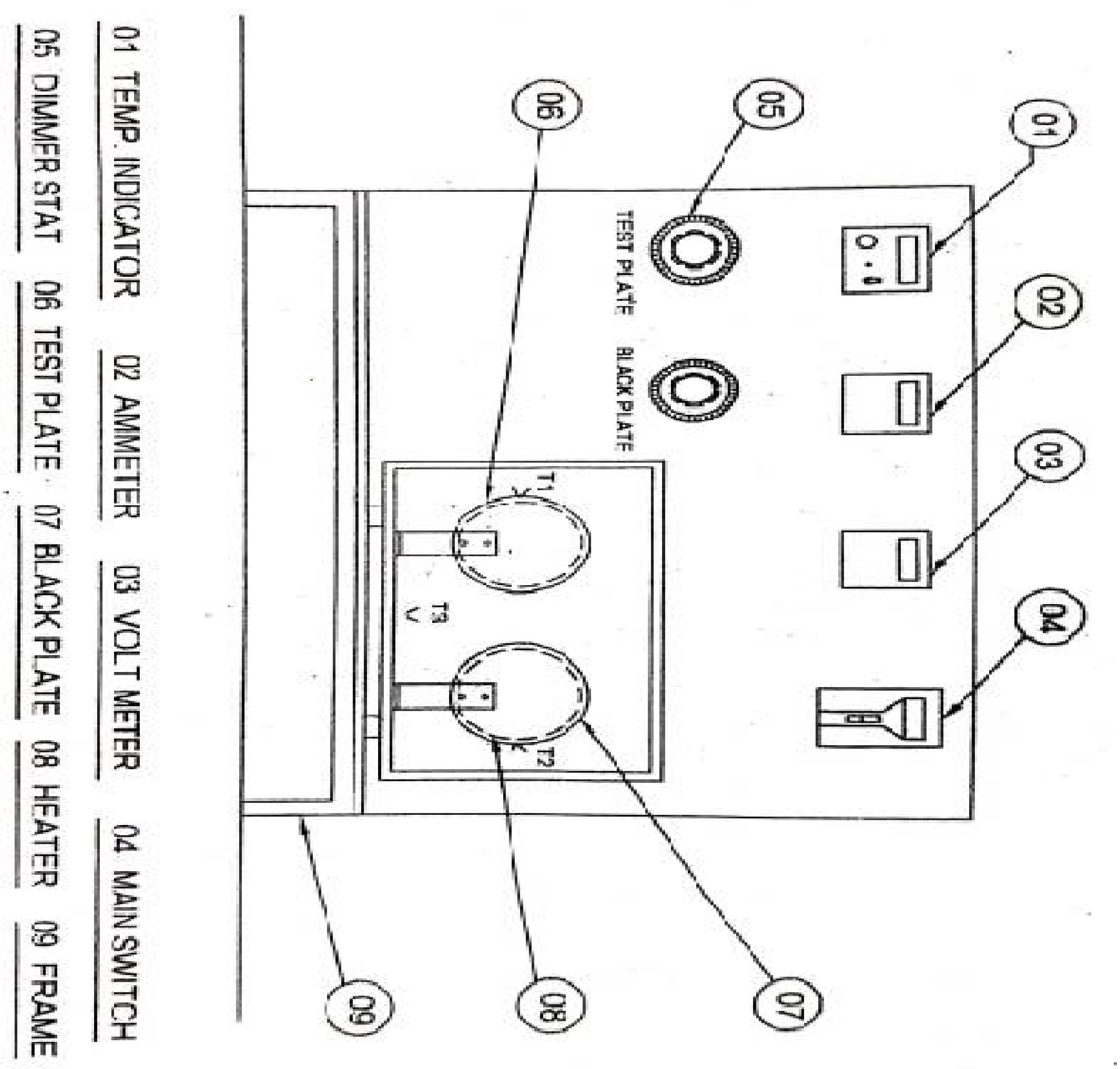


Fig.Emmisivity Measurement Apparatus

Experiment-8

AIM: To measure the value of Stefan Boltzmann constant on Stefan Boltzmann apparatus.

1. INTRODUCTION

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

$$e \propto T^4$$

$$\text{or} \quad e = \sigma . \varepsilon . T^4$$

Where, e = emissive power of surface.

T = absolute temperature.

σ = Stefan Boltzmann Constant

& ε = Emissivity of the surface

Value of Stefan Boltzmann constant is taken as

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

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

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

2. THE APPARATUS:

The apparatus consists of a water heated jacket of hemispherical shape. A copper test disc is fitted at the center of jacket. The hot water is obtained from a hot water tank, fitted to the panel, in which water is heated by an electric immersion heater. The hot water is taken around the hemisphere, so that hemisphere temperature rises. The test disc is then inserted at the center. Thermocouples are fitted inside hemisphere to average out hemisphere temperature. Another thermocouple fitted at the center of test disc measures the temperature of test disc. A timer with a small buzzer is provided to note down the disc temperatures at the time intervals of 5 sec.

3. SPECIFICATIONS - :

1. Hemisphere Diameter=200 mm
2. HEATER -1.5 KW immersion heater
3. Jacket disc-250mm
4. Test Disc Size-20 mm dia × 1.5 mm thickness
5. Test Disc Material – Copper
6. Timer- Built in timer for temperature readings at 5 seconds interval
7. Digital Temperature Indicator-0-300°c

4. EXPERIMENTAL PROCEDURE

1) See that water inlet cock of water jacket is closed and fill up sufficient water in the heater tank.
2) Put 'ON' the heater.
3) Blacken the test disc with the help of lamp black & let it cool.
4) Put the thermometer and check water temperature.
5) Boil the water and switch 'OFF' the heater.
6) See that drain cock of water jacket is closed and open water inlet cock.
7) See that there is sufficient water above the top of hemisphere (A piezometer tube is fitted to indicate water level)
8) Note down the hemisphere temperatures (i.e. up to channel 1 to 5)
9) Note down the test disc temperature (i.e. channel No. 6)
10) Start the timer. Buzzer will start ringing. At the start of timer cycle, insert test disc into the hole at the bottom of hemisphere.
11) Note down the temperature of disc, every time the buzzer rings. Take at least 4-5 readings.

5. OBSERVATIONS:

Hemi sphere Temperature.(^0C)	Time Interval (Sec)	Test disc Temperature.(^0C) T5
T1 =	05	
T2 =	10	
T3 =	15	
T4 =	20	
Water Bath T6 =	25	

6. CALCULATIONS:

Area of test disc, A = 3.14×10^{-4} m^2 (d = 20 mm)
Weight of test disc, m = 3 gm = 3×10^{-3} kg.
Plot a graph of temp. rise of test disc with time as base and find out its slope at origin.
Hemisphere temp.

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

Initial Test disc , $T_D = T_6 + 273.15$ k

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

$$q = \sigma \cdot \varepsilon \cdot A \ (T_H^4 - T_D^4)$$

where, q = heat gained by disc / sec.

$$= m \cdot \rho \cdot \left(\frac{dT}{dt}\right)$$

σ = Stefan Boltzmann constant
m = Mass of test disk = 5×10^{-3} kg.
ε = Emissivity of test disc = 1
A = Area of disc
ρ = Specific heat of copper = 381 J / Kg ^0C

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

Theoretical value of σ is 5.667×10^{-8} W / m^2 K^4 .In the experiment, this value may deviate due to reasons like convection, temp. Drop of hemisphere, heat losses, etc.

7. RESULT:

8. PRECAUTIONS:-

a) Never put 'ON' the heater before putting water in the tank.
b) Put 'OFF' the heater before draining the water from heater tank.
c) Drain the water after completion of experiment.
d) Operate all the switches and controls gently.

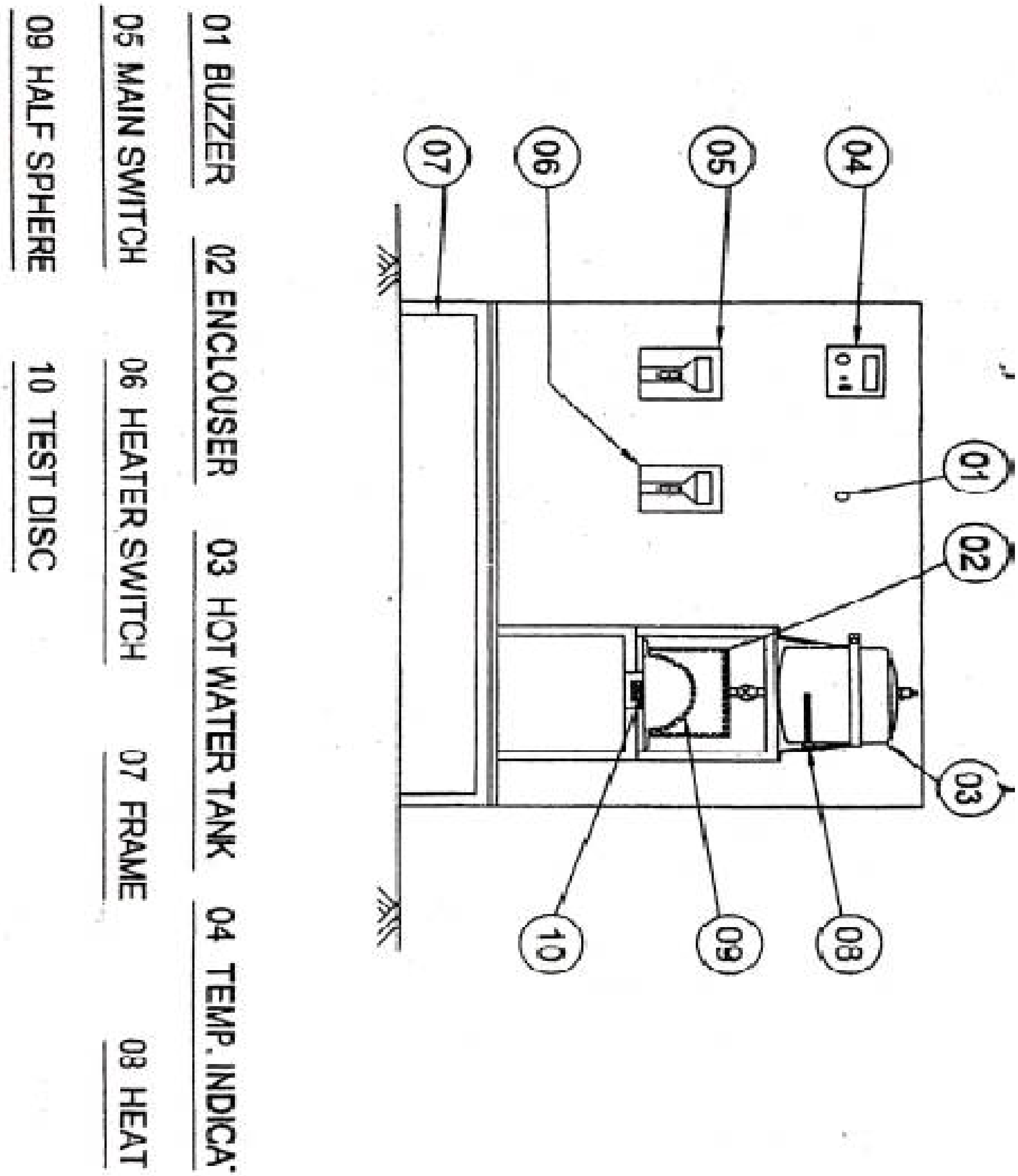


Fig. Stefan Boltzmann Apparatus

Experiment-9

AIM: - To determine effectiveness of concentric tube heat exchanger.

1. INTRODUCTION -

Heat exchangers are the devices in which the heat is transferred from one fluid to another. Exchange of heat is required at many industrial operations as well as chemical processes. Common examples of heat exchangers are the radiator of a car, condenser of a refrigeration unit or cooling coil of an air conditioner.

HEAT EXCHANGERS ARE OF BASICALLY THREE TYPES –

i) Transfer type - in which both fluids pass through the exchanger and heat gets transferred through the separating walls between the fluids ,

ii) Storage type - in this, firstly the hot fluid passes through a medium having high heat capacity and then cold fluid is passed through the medium to collect the heat. Thus hot and cold fluids are alternately passed through the medium,

iii) Direct contact type - in this type, the fluids are not separated but they mix with each other and heat passes directly from one fluid to the other.

Transfer type heat exchangers, the two fluids are kept separate and they do not mix as they flow through it. Heat is transferred

Transfer type heat exchangers are the type most widely used. In transfer type heat exchangers, three types of flow arrangements are used, viz. parallel, counter or cross flow. In parallel flow, both the fluids flow in the same direction while in counter flow, they flow in the opposite direction. In cross flow, they flow at right angles to each other.

2. DESCRIPTION OF APPARATUS :-

The apparatus consists of two concentric tubes in which fluids pass. The hot fluid is hot water which is obtained from an electric geyser. Hot water flows through the inner tube, in one direction. Cold fluid is air which is supplied by a centrifugal blower by flowing through the annulus. Control valves are provided so that direction of air can be kept parallel or opposite to that of hot water. Thus, the heat exchanger can be operated either as parallel or counter flow heat exchanger. The temperatures are measured with thermometers. Thus, the heat transfer rate, heat transfer coefficient, L.M.T.D. and effectiveness of heat exchanger can be calculated for both parallel and counter flow.

3. SPECIFICATIONS -

1) Heat exchanger - a) Inner tube - Φ 16 mm O.D.,copp
b) Outer tube - Φ 50 mm NB G.
c) Length of heat exchanger is - 1.0 m.
2) Electric heater - 3 kw capacity to supply hot water.
3) Blower:centrifugal blower to force the air driven by single phase electric motor
4)Orifice with water manometer to measure the air flow.Orifice 14mm
5) Measuring cylinder 1 liter to measure water flow
6) Valves for flow and direction control..
7) Temperature Indicator to measure temperatures of hot and cold water
8)Copper fin size OD Φ16 mm X 16 mm length,6 nos.

4. EXPERIMENTAL PROCEDURE -

1) Start the water supply. Adjust the supply @ 2 lit/min and switch "ON" the geyser.
2) Start the blower, close the two diagonal gate valves and open the other diagonal gate valves in such a way that the air flows in the parallel of the hot water.
3) The temperatures will start rising. Wait till all the temperatures become steady and then note down the temperatures, manometer reading and water flow.
4) Different readings may be taken by changing the water and air flow.

5. OBSERVATION TABLE:

SR No	Water flow time for 1 lit,in sec	Manometer Difference (m of water ,hw)	HOT WATER TEMPERATURES		AIR TEMPERATURES	
			Thi=T1 ^oC	Tho=T2 ^oC	Tci=T3 ^oC	Tco=T4 ^oC

6. CALCULATIONS -

1) Hot water inlet temp. t_{hi} = ^oC

Hot water outlet temp. t_{ho} = ^oC.

2) Hot water flow rate, m_h -

Let time required for 1 lit. of water be xh sec.

Mass of 1 lit. water =

$\therefore m_h = 1 / x_h$ kg/s.

3) Heat given by hot water (inside heat transfer rate)

$$qh = m_h \cdot cp \cdot (t_{hi} - t_{ho})$$

Where, cp = Specific heat of water = 4200 J/kg . K .

4) Similarly, for air, Heat collected by air (outside heat transfer rate)

$$qc = mc \cdot cp \cdot (tco - tci) \text{ watts.}$$

5)Logarithmic mean temperature difference (LMTD)

$$LMTD = \Delta Tm = \frac{Ti - To}{\ln (Ti / To)}$$

where ,

for parallel flow, for counter flow,

$Ti = t_{hi} - t_{ci}$ $Ti = t_{hi} - t_{co}$ $To = t_{ho} - t_{co}$ $To = t_{ho} - t_{ci}$

6) Overall heat transfer coefficient , U -

a) Inside overall heat transfer coefficient, Ui -

Inside diameter of tube = 0.016m

$\therefore$inside surface area of the tube,

$$Ai = \pi \cdot di \cdot l = \pi \times 0.016 \times 1.0 \text{ m}^2.$$

Now, $qh = Ui \cdot \Delta Tm \cdot Ai$ $\therefore$ $Ui = qh / (\Delta Tm \cdot Ai)$ w / m^2 ^oC

b) Outside overall heat transfer coefficient , Uo -

outside diameter of tube = 0.050 m.

outside surface area of the tube,

$$Ao = \pi \cdot do \cdot l$$

$$= \pi \times 0.050 \times 1.0$$

Similarly, $qc = Uo \cdot \Delta Tm \cdot Ao$.

$$\therefore Uo = qc / \Delta Tm \cdot Ao$$

7) Effectiveness of heat exchanger –

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

$$\varepsilon = \frac{m_h \cdot cp_h \cdot (t_{hi} - t_{ho})}{(m \cdot cp)_s \, (t_{hi} - t_{ci})}$$

$$\varepsilon = \frac{M_c \cdot cp_c \cdot (t_{co} - t_{ci})}{(m \cdot cp)_s \, (t_{hi} - t_{ci})}$$

where, $(m. cp)_s$ is the smaller of two capacity rates of m_hC_{ph} or m_cC_{pc}.

7. RESULTS

Type of flow	HEAT TRANSFER RATE		LMTD		
	Inside (Watts)	Outside (watts)	oC	Ui w /m2^{o}C	Uo w /m2^{o}C

8. PRECAUTIONS

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

9. CONCLUSION:

Experiment-10

AIM: To perform experiment on heat pipe demonstrator.

1. INTRODUCTION

The Heat pipe is a device, which transfers heat by boiling a fluid at one end and condensing it on other end of a pipe. The evaporation and condensation processes are responsible for the nearly isothermal working of the heat pipe.

2. DESCRIPTION

Heat pipe is basically consists of pipe sealed at both the ends. It is evaluated and fitted partially with distilled water. A stainless steel wire mesh is provided at inside periphery of the pipe. When heat is applied at the lower end of the heat pipe, water inside it evaporates and Vapour passes to upper end of pipe. The heat is taken by the medium surrounding upper portion of heat pipe. The Vapour condenses, giving its latent heat of evaporation to the surrounding medium. The condensed Vapour returns to bottom through the mesh packing. Thus, because of circulation of Vapour, heat pipe operates at near to isothermal operation, and conducts much heat than conventional conductors.

The apparatus consists of three pipes viz. a heat pipe copper pipe and a stainless pipe. All the pipes have same physical dimensions. Copper and stainless steel pipes serve the purpose of comparison of heat pipe performance with copper pipe as good conductor of heat and with stainless steel pipe as same material .All pipes are mounted with a band heater at one end and a water filled heat sink at other end. When heaters start heating the pipes, pipes begin to transfer the heat to heat sinks. Rapid rise of temperature of water in the heat pipe to heat sink demonstrates (apparent) thermal conductivity of heat pipe. Nearly isothermal operation of heat pipe is clearly visualized from longitudinal distribution of pipes.

3. SPECIFICATIONS - :

1. Stainless steel pipe size-25mm.O.D; 300 mm long, with both side closed, evacuated and filled with distilled water along fine stainless steel mesh inside the wall.
2. Copper and stainless steel pipe of same size as that of heat pipe one no.
3. Equal capacity heater at bottom end of each pipe.
4. Water filled heat sinks at other end of each pipe.
5. Measurement & controls
6. Dimmer stat : 4amps
7. Ammeter Selector Switch : Standard.
8. Heater : Band Heater.
9. Digital Temperature Indicator : 0-300^{0}C
   Channel with cold junction
   Compensation to measure temp.
10. Thermocouples : Chromel alumel Thermocouples.
11. Voltmeter : 0 – 230 volts.
12. Ammeter : 0-2 Amp.

4. EXPERIMENTAL PROCEDURE:-

1. Fill sufficient amount of water in three condenser tanks so that the pipe is submerged completely in water.
2. Ensure the proper earthing of unit.
3. Keep the dimmer stat at zero position & start the supply.
4. Give known slowly increase input to all the three heaters with the help of a dimmer stat.
5. Allow an initial heating period of about every 5 note down temp.
6. Note down all the temperatures along lengths of the pipes and also of the water in the tanks at the time of interval of 10 minutes.
7. Repeat the procedure at different input, but each time it is necessary to replace the water.

8. Replace the water when the pipes become cool than 45^0, otherwise removing water at high temp.of pipe may burn the seals at the bottom of heat sinks.
9. If experiment is conducted more than 30 min. time, it is merely to raise the water temperature and ultimately evaporation of water occurs. Hence it is not recommended to conduct the experiment for more than 30 minutes.

5. OBSERVATION TABLE - :

1] HEAT SINK TEMPERATURE.

Time	S.S.Pipe	Cu.Pipe	Heat Pipe
Min	0^0C heat sink	0^0C heat sink	0^0C heat sink
5			
10			
15			
20			
25			
30			

2] LONGITUDINAL TEMPERATURE DISTRIBUTION:-

Heat Pipe	Cu.Pipe	S.S.Pipe
0^0C heat sink	0^0C heat sink	0^0C heat sink
T1 =	T6 =	T11 =
T2 =	T7 =	T12 =
T3 =	T8 =	T13 =
T4 =	T9 =	T14 =
T5 =	T10 =	T15 =

6. EXPERIMENTS TO BE CARRIED OUT - :

1. To demonstrate the super thermal conducting heat pipe and to compare it's working with that of best conductor i.e Cu pipe.
2. To find and plot temperature V/s. time response of three pipes.
3. Temperature distribution along the length of three members at different time intervals can be plotted and nearly isothermal temperature distribution in a case of heat pipe can be seen.

7. GRAPHS:-

1) Plot the graph of heat sink water temperature rise up to 30 min.
2) Plot longitudinal temperature distribution of pipes.

8. PRECAUTIONS:-

1) Proper earthing is necessary.
2) Stir the water before nothing water temp.
3) Do not remove water from heat sinks till the pipes become cool.

9. CONCLUSION - :

Nearly isothermal nature of the temperature distribution clearly shows the very high values of effective thermal conductivity of the heat pipe over the conventional conductor's viz. copper and stainless steel. This can also be observed in terms of the fast temperature rise in condenser tank and the temperature gradients present on the three members.

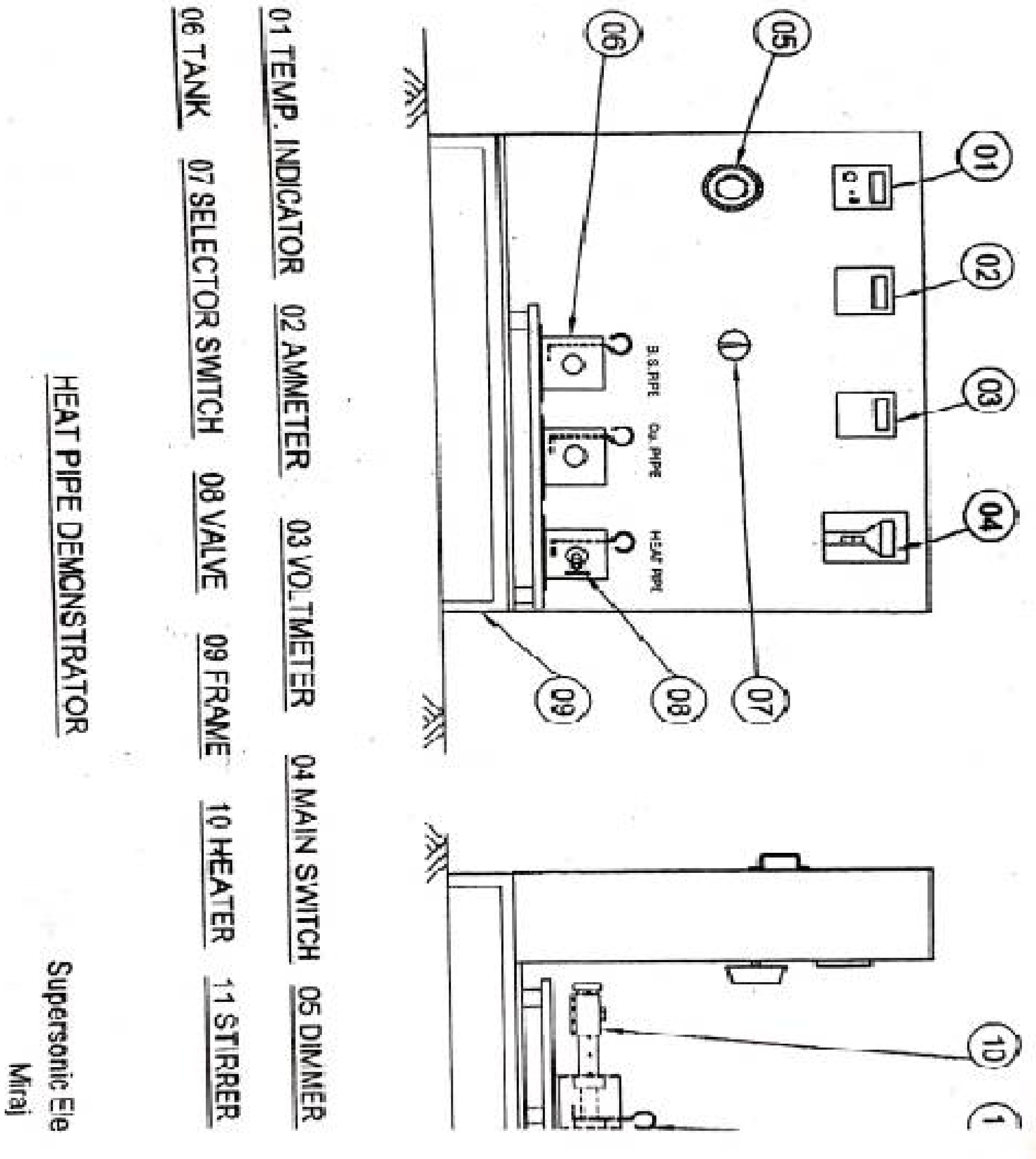


Fig.Heat Pipe Demonstrator

EXPERIMENT-11

AIM :- To find out Critical Heat Flux.

1. INTRODUCTION

The phenomenon of boiling is characterized by different regimes. The 'SUPERSONIC' make CRITICAL HEAT FLUX APPARATUS consists of a test section in which tests wire surrounded by water of constant temperature. The surface temperature of test wire is heated by passing current through it. Due to the temperature difference between the wire surface and surroundings, the different regimes are observed till the burn out point.

2. SPECIFICATIONS: -

1) Test wire - 40 gauge; Length = 10 cm.
2) Nichrome heater - 1 Kw capacity.
3) Glass trough of sufficient capacity.
4) Table light to observe the test wire.
5) Voltmeter & Ammeter to measure input to the test wire.
6) Dimmerstat to adjust the voltage.

3. SERVICES REQUIRED: -

1) 220 V, 15 Amp. Stabilized, single phase supply.
2) Floor surface - 1 m x 1 m at working height.

4. THEORY:-

TYPES OF BOILING:

While heat is added to a liquid from a submerged solid surface which is at a temperature higher than the saturation temperature of the liquid, it is usual for a part of the liquid to change phase. This change of phase is called boiling. Boiling is of various types, the type being dependent on the temperature difference between the surface and the liquid. The different types are indicated in Fig. 8.3 which illustrates a typical experimental boiling curve obtained in a saturated pool of liquid.

The heat flux supplied to the surface is plotted against (Tw - Ts), the difference between the temperature of the surface and the saturation temperature of the liquid. It is seen that the boiling curve can be divided into three regions: (I) natural convection region, (II) nucleate boiling region, and (III) film boiling region. The region of natural convection occurs at low temperature differences (of the order of 10^{o} C or less). Heat transfer from the heated surface to the liquid in its vicinity causes the liquid to be superheated. This superheated liquid rises to the free liquid surface by natural convection, where vapour is produced by evaporation.

As the temperature difference (Tw - Ts) is increased, nucleate boiling commences. In this region bubbles begin to form at certain locations on the heated surface. Region II consists of two parts. In the first part, IIa, the bubbles formed are very few in number. These bubbles grow in size, separate from the heated surface and rise to the free surface. In the second part, IIb, the rate of bubble formation as well as the number of locations where they are formed increase.

With increasing temperature difference, a stage is finally reached when the high bubble formation rate causes them to coalesce and blanket the surface with a vapour film. This is the beginning of region III, namely, film boiling. In the first part of this region, IIIa, the vapor film is unstable; film boiling may be occurring on a portion of the heated surface area, while nucleate boiling may be occurring on the remaining area. In the second part, IIIb, a stable film covers the entire surface. The temperature difference in this region is of the order of 1000^{0} C and consequently radioactive heat transfer across the vapour film is also significant.

It will be observed from Fig. 8.3 that the heat flux does not increase in a regular manner with the temperature difference. In region I, the heat flux is proportional to (Tw - Ts) where n is slightly greater than unity (approximately 1.3). When the transition from natural convection to nucleate boiling occurs, the heat flux starts to increase more rapidly with temperature difference, the value of n increasing to about 3. At the end of region II, the boiling curve reaches a peak (Point A). Beyond this, in region IIIa, in spite of the increasing temperature difference, the head flux decreases because the thermal resistance to heat flow increases with the formation of a vapour film. The heat flux passes through a minimum (point B) at the end of region IIIa. It starts to increase again with (Tw - Ts) only when stable film boiling begins and radiation becomes increasingly significant.

It is of interest to note how the temperature of the heating surface changes as the heat flux steadily increased from zero. Up to the point A, natural convection boiling and then nucleate boiling occur and the temperature of the heating surface is obtained by reading off the value (Tw - Ts) from the boiling curve and adding to it the value of Ts. If the heat flux is increased a little beyond the value at A, the temperature of the surface shoots up to the value corresponding to the point C. It is apparent from Fig. 8.3 that the surface temperature corresponding to point C is high. For some surfaces, it is high enough to cause the material to melt. Thus in many practical situations, it is undesirable to exceed the value of heat flux corresponding to point A. This value is therefore of considerable significance in engineering and is called the critical or peak heat flux. Also it is called as 'Burn-out point'.

5. PROCEDURE :

1) Fill up the glass trough with clean & pure water.
2) Clamp the test wire within the test bolts.
3) Close the glass bowl with the test section dipped in the water.
4) Before switching on the main switch; see that,
   (a) Both the heaters are well submerged under water. &
   (b) The dimmerstat is at '0' position.
5) Now, switch 'ON' the main switch. Put the toggle switch to the 'bulk heater' position.
   (This will only raise the water temp. in the bowl.) Heat the water till 40^{o}c.
6) Now, Put the toggle switch to the 'test wire ' position.(This will glow the lamp & keeps the test wire ready for testing.) Now, slowly rotate the dimmer in clockwise direction (about 10 degrees). This increases the current in the test wire & correspondingly increases the wire surface temperature. Observe the test wire. Again increase the dimmer current and go on observing the test wire surface, till the burn-out point reaches. The pool boiling phases are observed on the wire surface till the burn-out point reaches. Note down the voltage & current at the instant of the burn-out point.

Repeat the process by increasing the bulk temperature.(Do not increase the bulk temperature above 80^{o}c)

6. OBSERVATION TABLE :

Sr. no.	Bulk Temperature (^{o}c)	Voltage (Volt)	Current (Ampere)

7. CALCULATIONS :

A] An approximate empirical equation for the Critical heat flux is given by;

$$\therefore q_{max} = 0.18 \times h_{fg} \times p_v \left[\frac{\sigma \times g \{ p_L - p_v \}}{P_v^2} \right]^{1/4}$$

Where

1) q_{max} = Critical heat flux in W / m^2

2) h_{fg} = Latent heat of evaporation J /Kg = KJ/Kg X 10^3 = J/Kg
3) p_v = Density of vapour Kg /m^3 = 1/ V_f Kg /m^3
4) p_L = Density of liquid Kg /m^3 = 1 /V_L X 10^3 kg/m^3
5) σ = Surface Tension = N/ m , = from chart value X 10^{-3} N/m

B] Experimental Critical Heat Flux =

$$\frac{Q}{A} = \frac{VI}{\pi DL}$$

=------W/M²

WHERE,

Q = V I WATTS

D = DIA.OF WIRE IN M

L = LENGTH OF WIRE IN M.

8. PRECAUTIONS :

1) Do not increase the bulk temperature above 80°c.
2) Handle the controls & switches gently.

9. CONCLUSION:

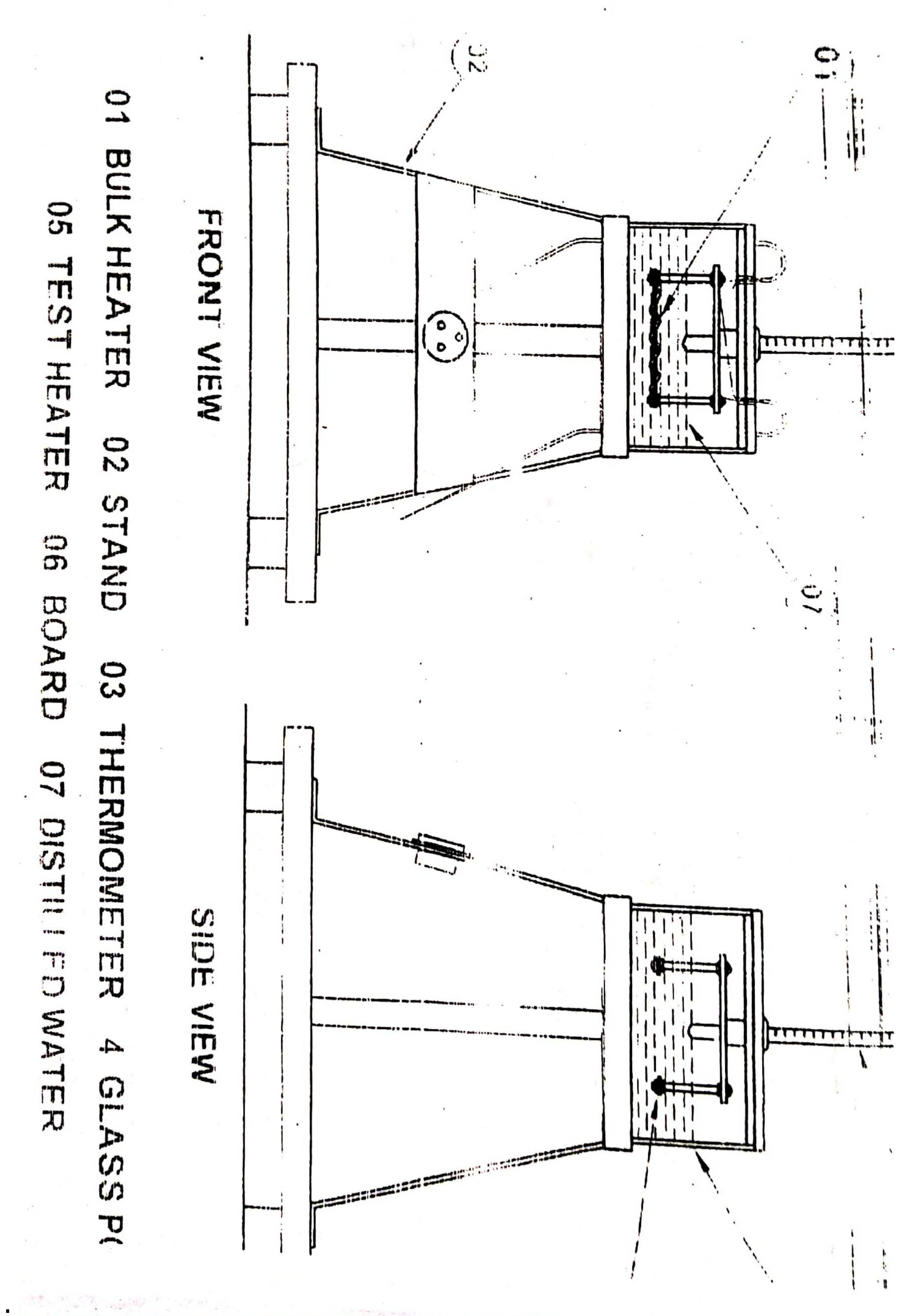


Fig. Heat Flux Apparatus