COMPUTERIZED CONCENTRIC DOUBLE PIPE HEAT EXCHANGER

INTRODUCTION:

Heat exchangers are devices in which heat is transferred from one fluid to another. The fluids may be in direct contact with each other or separated by a solid wall. Heat Exchangers can be classified based on its principle of operation and the direction of flow. The temperature of the fluids change in the direction of flow and consequently there occurs a change in the thermal head causing the flow of heat.

The temperatures profiles at the two fluids in parallel and counter flow are curved and has logarithmic variations. LMTD is less then the arithmetic mean temperature difference. So, it is always safer for the designer to use LMTD so as to provide larger heating surface for a certain amount of heat transfer.

DESCRIPTION OF THE APPARATUS:

The apparatus consists of **concentric tubes**. The inner tube is made of **copper** while the outer tube is made of **Stainless Steel**. **Insulation** is provided with **mica sheet** and **asbestos rope** for effective heat transfer.

Provision has been made for **hot water generation** by means of geyser.

Change - Over Mechanism is provided to change the direction of flow of cold water in a single operation.

ACRYLIC Rotameters of specific range is used for direct measurement of water flow rate.

Thermocouples are placed at appropriate positions which carry the signals to the temperature indicator. A **data logger indicator** is provided to measure the temperature.

The whole arrangement is mounted on an **Aesthetically designed self sustained sturdy frame** made of **NOVAPAN board control panel**. The control panel houses all the indicators, accessories and necessary instrumentations.

EXPERIMENTATION:

AIM:

To determine the effectiveness of concentric Double pipe heat exchanger

PROCEDURE:

1. Switch ON mains and the CONSOLE.
2. Start the flow on the hot water side.
3. Start the flow through annulus also.
4. Set the exchanger for parallel or counter flow using the change over mechanism.
5. Switch ON the heater of the geyser.
6. Set the flow rate of the hot water (say 1.5 to 4 Lpm) using the rotameter of the hot water.
7. Set the flow rate of the cold water (say 3 to 8 Lpm) using the rotameter of the cold water.
8. Wait for sufficient time to allow temperature to reach steady values.
9. Note down the Temperatures 1 to 4 using the Scanner.
10. Note down the flow rates of the water and tabulate.
11. Now, change the direction of flow for the same flow rates and repeat the steps 9 to 11.
12. Repeat the experiment for different flow rates of water.

PROCEDURE : COMPUTERIZED

TAKING READINGS – COMPUTERIZED

1. Switch on the panel.

2. Switch on the computer.

3. Open the **“ HEAT TRANSFER Software”** from the installed location a welcome screen will be displayed

4. Follow the below steps to operate through software
   a. Once the software is opened, the main screen will be displaced

   b. Now, press **“START”** button, and the small screen will opened
   c. Enter the parameters listed for particular test under study.

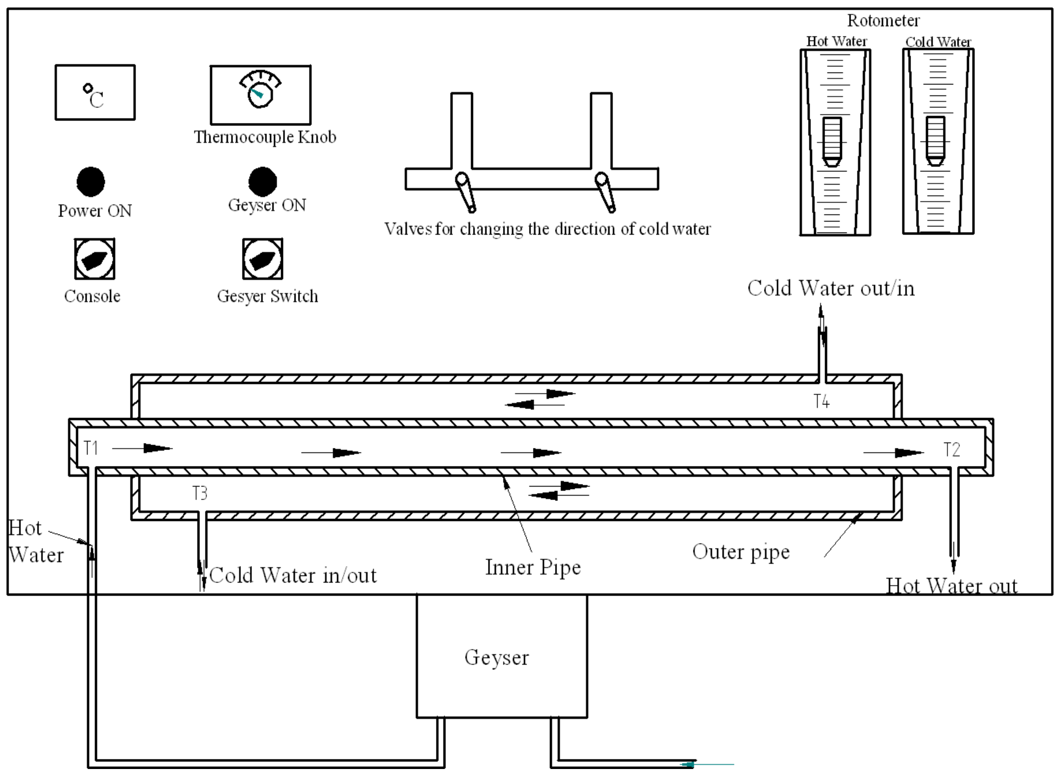
5. Start the flow on the hot water side.
6. Start the flow through annulus also.
7. Set the exchanger for parallel or counter flow using the change over mechanism.
8. Switch ON the heater of the geyser.
9. Set the flow rate of the hot water (say 1.5 to 4 Lpm) using the rotameter of the hot water.
10. Set the flow rate of the cold water (say 3 to 8 Lpm) using the rotameter of the cold water.
11. Wait for sufficient time to allow temperature to reach steady values.

12. The software starts displaying the calculated values which can be cross verified based on the formulae give after.

13. Click the **“store”** button to store the value can be viewed anytime later.

14. After completion of the Experiment to press the stop button
15. Finally switch of the gyser.

EXPERIMENTAL SET UP:



Experimental Setup of Heat Exchanger

OBSERVATIONS:

Sl. No.	Flow Direction	Temperatures °C				Flow rate, LPM	
		T1	T2	T3	T4	Hot water, H	Cold Water, C
1							
2							
3							
4							

5							

NOTE:
T3 = Cold Water Inlet Temperature (In Case Of Parallel Flow)
Cold Water Outlet Temperature (In Case Of Counter Flow)
T4 = Cold Water Outlet Temperature (In Case Of Parallel Flow)
Cold Water Inlet Temperature (In Case Of Counter Flow)
T1 = Hot Water Inlet Temperature.
T2 = Hot Water Outlet Temperature.

CALCULATIONS:

1. HEAT TRANSFER RATE ,Q

$$Q = \frac{Q_H + Q_C}{2} \text{ Watts}$$

WHERE,

Q_H = heat transfer rate from hot water and is given by:

= $m_H \times C_{PH} \times (T1 - T2)$ W

Where,

m_h = mass flow rate of hot water = H/60 kg/sec.

C_{PH} = Specific heat of hot water from table at temp. (T1+T2)/2

Q_C = heat transfer rate from cold water and is given by:

= $m_C \times C_{PC} \times (T4 - T3)$ W (for parallel flow)

= $m_C \times C_{PC} \times (T3 - T4)$ W (for counter flow)

Where,

m_C = mass flow rate of cold water = C/60 kg/sec.

C_{PC} = Specific heat of hot water from table at temp. (T3+T4)/2

2. LMTD – Logarithmic mean temperature difference:

$$\Delta T_M = \frac{\Delta T_I - \Delta T_O}{\ln(\Delta T_I / \Delta T_O)}$$

Where,

$\Delta T_I = (T_1 - T_3)$ for parallel flow

$\Delta T_I = (T_1 - T_4)$ for counter flow

$\Delta T_O = (T_2 - T_4)$ for parallel flow

$\Delta T_O = (T_2 - T_3)$ for counter flow

NOTE: The suffix H = HOT WATER

C = COLD WATER

I = INLET

O = OUTLET

3. OVERALL HEAT TRANSFER CO-EFFICIENT:

$$U = \frac{Q}{A \times \Delta T_M} \quad W/m\,°K$$

Where,

Q = heat transfer rate

$A = \pi \times D_O \times L$ m^2 where, $D_O = 0.02m$ & $L = 1m$.

ΔT_M = LMTD.

4. EFFECTIVENESS OF HEAT EXCHANGER, E

EXPERIMENTAL:

$$E_{EXP} = \frac{(T_{CO} - T_{CI})}{(T_{HI} - T_{CI})} \quad \text{IF } C_{MAX} > C_{MIN}$$

$$E_{EXP} = \frac{(T_{HI} - T_{HO})}{(T_{HI} - T_{CI})} \quad \text{IF } C_{MAX} < C_{MIN}$$

THEORETICAL:

$$E_{TH} = \frac{1 - e^{-NTU\,(1 + R)}}{(1 + R)} \quad \text{For PARALLEL FLOW}$$

$$E_{TH} = \frac{1 - e^{-NTU\,(1 - R)}}{1 - Re^{-NTU\,(1 - R)}} \quad \text{For COUNTER FLOW}$$

Where,

$C_{MAX} = m_H \times C_{PH}$

$C_{MIN} = m_C \times C_{PC}$

$R = C_{MIN} / C_{MAX}$

NTU = No. of Transfer units is given by

$$= \frac{U \times A}{C_M}$$

C_M = minimum of C_{MIN} & C_{MAX}

Other notations have their usual meaning.

5. **PERCENTAGE OF ERROR, %ERROR**

$$\%ERROR = \frac{E_{TH} - E_{EXP}}{E_{TH}} \times 100$$

PRECAUTIONS:

1. Check all the electrical connections.
2. Do not run the equipment if the voltage is below 180V.
3. Do not attempt to alter the equipment as this may cause damage to the whole system.

RESULTS and CONCLUSION:

The effectiveness and overall coefficient of heat exchanger is ___

VIVA QUESTIONS:

1. What are the applications of heat exchanger?
2. What is fouling and fouling factor?
3. Draw the temperature v/s length of heat exchanger graph for parallel flow and counter flow arrangements
4. Define effectiveness of heat exchanger
5. Define capacity rate and capacity ratio
6. Why effectiveness of counter flow heat exchanger is more than that of parallel flow heat exchanger

COMPUTERIZED COOLING LOAD ON WET BULB TEMPERATURE

1. Aim:

Analysis the effect of cooling load on wet bulb temperature

2. Fundamental principles:

Consider a droplet of water inside the tower. This droplet will be surrounded by a thin film of air. As air flows past the droplet heat is transferred in three ways.

- By radiation from the surface of the droplet. This is a very small proposition of the total amount of heat flow and it is usually neglected.
- By conduction and convection between water and air, the amount of heat transferred will depend on the temperature of air and water. This is a significant portion of the total quantity.
- By evaporation, this is the far most important effect. Cooling take place as molecules of water diffuse from the surface into the surrounding air. These molecules are then replaced by others from the liquid (evaporation) and the energy required for this is taken from the remaining liquid.

The evaporation that occurs when air and water are in contact is caused by the difference in pressure of water vapour at the surface of the water and in the air. These vapour pressures are functions of the water temperature and the degree of saturation of air respectively.

In a cooling tower the water and air streams are generally opposed so that cooled water leaving the bottom of the pack is in contact with the entering air. Similarly hot water entering the pack is in contact with warm air leaving the pack.

Evaporation will take place throughout the pack. It should be noted at the top of the pack air is nearly saturated and it is compensated for high water temperature and consequently high Vapour pressure.

The amount of evaporation which takes place depends on a no of factors including the total surface area the water presents to the air and the amount of air flowing. If the air flow mix is high greater cooling can be achieved. This is because as the air flow increases the effect of water on it will become less and the partial pressure difference throughout the pack will be increased.

The difference between the temperature of the water leaving a cooling tower and the local wet bulb temperature is an indication of the effectiveness of the cooling tower.

3. Performance of cooling tower depends on:

- Cooling range
- Ambient wet bulb temperature
- Air flow rate
- Water flow rate
- Water Temperature
- Volume of packing

4. Specification:

Type	Mechanical Draught
Packing type	Perforated aluminum corrugated sheets
Blower	0.5 Hp, centrifugal blower ,2800 rpm,240 v, single phase
Water heater Power	4 Kw
Orifice diameter	20mm
Coefficient of discharge of orifice	0.61
Orifice constant	0.7

5. Operating terms of a cooling tower

Casing or shell	This is the structure which encloses the heat transfer process and also acts as a support for other items.
Cooling range	This is the difference between the water temperature entering and leaving the tower.
Cooling load	This is the rate at which heat is removed from the water.

Table 1. Operating performance of cooling tower

Drift or carry over	Droplets of water which are entrained by the air stream leaving the tower.
Approach to wet Bulb	The difference between the temperature of the water leaving the tower and the wet bulb temperature of the air entering
Packing or Fill	The material over which the water flows as it falls through the tower, so that a large surface area is presented to the air stream.
Air inlet and outlet	The position at which air enters and leaves the tower.
Fan	The fan is provided to move the required amount of air through the water to be cooled.
Water inlet	This is the point at which water enters the tower.

6. Observation

- **Water flow rate** (L) = **Lpm**
- **Air flow orifice manometer** (x) = **m**
- **Entering hot water temperature at top** (T_1) = **^{0}c**
- **Leaving water temperature at bottom** (T_2) = **^{0}c**
- **Air temperature at inlet**

Dry bulb temperature (t_{d1}) (T_3) = **^{0}c**
Wet bulb temperature(t_{w1}) (T_4) = **^{0}c**

- **Air temperature at exit**

Dry bulb temperature (t_{d2}) (T_5) = **^{0}c**
Wet bulb temperature(t_{w2}) (T_6) = **^{0}c**

- **Water temperature distribution**

in tower from top

Station 1 (Tw1) (T_7) = ^{0}c
Station 2 (Tw2) (T_8) = ^{0}c
Station 3 (Tw3) (T_9) = ^{0}c
Station 4 (Tw4) (T_{10}) = ^{0}c
Station 1 (Tw5) (T_{11}) = ^{0}c

- **Air temperature distribution**

in tower from top

Station 1 Dry bulb temperature (t_d) (T_{12}) = ^{0}c
Wet bulb temperature(t_w) (T_{13}) = ^{0}c
Station 2 Dry bulb temperature (t_d) (T_{12}) = ^{0}c
Wet bulb temperature(t_w) (T_{13}) = ^{0}c
Station 3 Dry bulb temperature (t_d) (T_{12}) = ^{0}c
Wet bulb temperature(t_w) (T_{13}) = ^{0}c
Station 4 Dry bulb temperature (t_d) (T_{12}) = ^{0}c
Wet bulb temperature(t_w) (T_{13}) = ^{0}c
Station 5 Dry bulb temperature (t_d) (T_{12}) = ^{0}c
Wet bulb temperature(t_w) (T_{13}) = ^{0}c

7. Formula used

- **To find tower characteristic**

1. **Water flow rate from Rota meter (L)** = 0.675 **LPM**

Velocity of air = $c_d\sqrt{2gh_a/1-k^4}$ **m/s**

Where

$h_a = \frac{x(\rho_w - \rho_a)}{\rho_a}$

$\rho_w = density\ of\ water$

$= 1000\ kg/m^3$

ρ_a = density of air

$= 1.18 kg/m^3$

$x = manometer\ differnce\ in\ m$

$K = \frac{diameter\ of\ orifice}{diameter\ of\ pipe}$

$= \frac{0.2}{0.26}$

$= 0.769$

2. **Volumetric flow rate of air (G)** = $velocity \times cross\ sectioal\ area$ kg/hr

3. **L/G ratio** =

standard characteristic table

T 0_c	**h water (h_w) Kcal/Kg**	**h air (h_a) Kcal/Kg**	**Δ h (h_w - h_a)**	**1/ Δh**
T_2 +0.1(T_1- T_2)	**h_{w1}**	**h_1 +0.1(L/G) (T_1- T_2)**		
T_2 +0.4(T_1- T_2)	**h_{w2}**	**h_1 +0.4 (L/G) (T_1- T_2)**		
T_1 -0.4(T_1- T_2)	**h_{w3}**	**h_2 -0.4 (L/G) (T_1- T_2)**		
T_1 -0.1(T_1- T_2)	**h_{w4}**	**h_2 -0.1 (L/G) (T_1- T_2)**		

Note :

h_1 is found out from psychometric chart. Knowing the wet bulb temperature of entering air.

Then:

$h_2 = h_1 + (L/G)(T_1 - T_2)$

h_{water} is obtained from;

$$h_w = m_w \times c_p \times (T) \qquad Kw$$

where:

m_w	=	Mass flow rate of water in	Lpm
c_p	=	Specific heat capacity	J kg^{-1} K^{-1}

- **Tower characteristic**

$$\frac{\text{Kav}}{\text{L}} = \frac{\text{T}_1 - \text{T}_2}{4} \boldsymbol{\Sigma} \frac{\mathbf{1}}{\boldsymbol{\Delta h}}$$

Make up water calculation

a) Water inlet flow rate = Lpm

Water outlet flow rate = Lpm

Rate of water evaporated:

[Water inlet flow rate × density of water] - [Water outlet flow rate × density of water]

Mass flow rate of air m_a = [volumetric flow Rate of air × density of air] kg/min

or

$$m_a = 0.0137\sqrt{x/v_b}$$

where:

x = Airflow orifice manometer m

v_B= Specific volume m^3/Kg

c) Moisture pitched up by air = m_a ($h_2 - h_1$)

Where:
Humidity of inlet air h_1 = from psychometric chart
Humidity of outlet air h_2 = from psychometric chart

Energy balance chart using psychometric chart

station	Water bulb temperature	Dry bulb temperature	Wet bulb temperature	humidity	Enthalpy KJ/kg
Bottom					
5					
4					
3					
2					
1					
Top					

Effectiveness

$$ef = \frac{\textbf{inlet of hot water temperature} - \textbf{outlet water temperature}}{\textbf{inlet of hot water temperature} - \textbf{wet bulb temperature of inlet air}}$$

8. Procedure:

- Switch on the console
- Leave the water to the heater
- Adjust the water flow rate by means of Rota meter.
- Note down the water inlet flow rate.
- Switch on the heater.
- Switch on the blower
- Adjust the blower speed by varying knob position.
- Note down the manometer reading in U tube manometer.
- Note down the temperature (T_1 to T_{11}) until it achieve steady state.
- Keep the dry and wet bulb thermocouple (T_{12} and T_{13}) for each station.
- At every 5 minute intervals note down the reading.

- By means of measuring jar and stop watch note down the water outlet flow rate at the bottom of the tower.
- Switch off the heater and blower.

9. Safety precaution:

- **Don't switch on the heater without water supply.**

10. Results and Conclusions.

Effects of cooling load on wet bulb temperature must be explained.

11. Graph:

Plot a graph with ordinate as

1.'water entry temperature t5' K and 2. 'Water exit temperature t6' K and absicca as 'Cooling load' kW Plot another graph with ordinate as 'Approach to Wet Bulb temperature' K and absicca as 'Cooling Load'

COMPUTERIZED HEAT BALANCE SHEET ON IC ENGINE

Objective- To prepare heat balance sheet on Single-Cylinder Diesel Engine.

APPARATUS USED: - Single-Cylinder Diesel Engine (Constant Speed) Test Rig, Stop

Watch and Digital Tachometer.

THEORY:-

The thermal energy produced by the combustion of fuel in an engine is not completely utilized for the production of the mechanical power. The thermal efficiency of I. C. Engines is about 33 %. Of the available heat energy in the fuel, about 1/3 is lost through the exhaust system, and 1/3 is absorbed and dissipated by the cooling system.

It is the purpose of heat balance sheet to know the heat energy distribution, that is, how and where the input energy from the fuel is is distributed.

The heat balance sheet of an I. C. Engine includes the following heat distributions:

a. Heat energy available from the fuel brunt.

b. Heat energy equivalent to

output brake power. c. Heat

energy lost to engine cooling

water.

d. Heat energy carried away by

the exhaust gases. e.

Unaccounted heat energy

loss.

FORMULE USED :-

(i) Torque, $T = 9.81 \times W \times R_{Effective}$ N-m.

; Where $R_{Effective} = (D + d)/2$ or $(D + t_{Belt})/2$ m, and

W (Load) = $(S_1 - S_2)$ Kg,

(ii) Brake Power, $BP = (2\pi N T) / 60,000$ KW

; Where N = rpm, T = Torque N-m,

(iii) Fuel Consumption, $m_f = (50\ ml \times 10^{-6} \times \rho_{Fuel}) / (t)$ Kg/Sec

Here; 1 ml = 10^{-3} liters, and 1000 liters = 1 m^3
So 1 ml = 10^{-6} m^3

(iv) Heat energy available from the fuel brunt, $Q_s = m_f \times C.V. \times 3600$ KJ/hr

(v) Heat energy equivalent to output brake power, $Q_{BP} = BP \times 3600$ KJ/hr

(vi) Heat energy lost to engine cooling water, $Q_{CW} = m_w \times C_w (t_{wo} - t_{wi}) \times 3600$
KJ/hr

(vii) Heat energy carried away by the exhaust gases, $Q_{EG} = m_{fg} \times C_{fg} (t_{fg} – t_{air}) \times 3600$
KJ/hr

; Where $m_{fg} = (m_f + m_{Air})$ Kg/Sec,
And $m_{Air} = C_d A_o \sqrt{2 g \Delta h \rho_{Air} \rho_{Water}}$ Kg/ Sec

; Where Cd (Co-efficient of Discharge) = 0.6,
ρ Air = (Pa x 102) / (R x Ta) Kg/ m3,
Ao (Area of Orifice) = (π do2)/ 4 m2,
P1 = 1.01325 Bar, R = 0.287 KJ/Kg . K, Ta = (ta + 273) K,
ta = Ambient Temperature OC
(viii) Unaccounted heat energy loss, QUnaccounted = Qs – { QBP + QCW + QEG } KJ/hr

PROCEDURE:

1. Before starting the engine check the fuel supply, lubrication oil, and availability of cooling water.
2. set the dynamometer to zero load and run the engine till it attain the working temperature and steady state condition.
3. Note down the fuel consumption rate, Engine cooling water flow rate, inlet and outlet temperature of the engine cooling water, Exhaust gases cooling water flow rate, Air flow rate, and Air inlet temperature.
4. Set the dynamometer to 20 % of the full load, till it attains the steady state condition.

   Note down the fuel consumption rate, Engine cooling water flow rate, inlet and outlet temperature of the engine cooling water, Exhaust gases cooling water flow rate, Air flow rate, and Air inlet temperature.
5. Repeat the experiment at 40 %, 60 %, and 80 % of the full load at constant speed.
6. Disengage the dynamometer and stop the engine.
7. Do the necessary calculation and prepare the heat balance sheet.

OBSERVATIONS:-

Engine Speed, N	= 1500	rpm
No. of Cylinders, n	= Single	
Calorific Value of Fuel, C.V.	= 38,000	KJ/Kg

Specific Heat of Water, C_w = 4.187 KJ/Kg . K

Specific Heat of Exhaust Flue Gases, C_{fg} = 2.1 KJ/Kg . K

Gas Constant, R = 0.287 KJ/Kg . K

Ambient Temperature, t_a = ^{O}c

Atmospheric Pressure, P_a = 1.01325 Bar

Orifice Diameter, d_o = 25×10^{-3} M

Co-efficient of Discharge, C_d = 0.6

Density of fuel (Diesel), ρ_{Fuel} = 810 to 910 Kg/m^3

Density of Water, ρ_{water} = 1,000 Kg/m^3

Brake Drum Diameter, D = 181.5×10^{-3} M

Rope Diameter, d = M

Or Belt thickness, t_{Belt} = M

RESULT TABLE :-

Sl. No.	Engine Speed, N (rpm)	Brake Power, BP (KW)	Fuel Consumption, mf (Kg/hr)	Air Flow Rate, mair (Kg/hr)	Exhaust Gas Flow Rate, mfg (Kg/hr)
1.	1500				
2.	1500				
3.	1500				
4.	1500				

HEAT BALANCE SHEET :-

Heat Energy Supplied	KJ/hr	% age	Heat Energy Consumed (Distribution)	KJ/hr	% age
Heat energy available from the fuel brunt			(a) Heat energy equivalent to output brake power.		
			(b) Heat energy lost to engine cooling water.		
			(c) Heat energy carried away by the exhaust		
			(d) Unaccounted heat Energy Loss.		
Total	____	100 %	To	__________	100 %

RESULTS AND CONCLUSION:-

Draw the heat balance sheet.

Precautions:-

- Conduct yourself in a responsible manner at all times in the laboratory.
- Always work in a well-ventilated area.
- No unauthorized experiments are to be performed. If you are curious about trying a procedure not covered in the experimental procedure, consult with your laboratory instructor.
- Keep your hands, other body parts and clothing away from moving parts of engine
- Before engine start, check that you removed all tools and cloths from the area near the engine
- Report any accident (spill, breakage, etc.) or injury (cut, burn, etc.) to the teacher immediately, no matter how trivial it seems. Do not panic

- Always wash your hands before leaving lab.
- Learn where the safety and first-aid equipment is located. This includes fire extinguishers, fire blankets, and eye-wash stations.
- Experiments must be personally monitored at all times. Do not wander around the room, distract other students, startle other students or interfere with the laboratory experiments of others.

COMPUTERISED MEASUREMENT OF SURFACE EMISSIVITY

<u>INTRODUCTION</u>:

Radiation is one of the modes of heat transfer, which does not require any material medium for its propagation. All bodies can emit radiation & have also the capacity to absorb all or a part of the radiation coming from the surrounding towards it. The mechanism is assumed to be electromagnetic in nature and is a result of temperature difference. Thermodynamic considerations show that an ideal radiator or black body will emit energy at a rate proportional to the fourth power of the absolute temperature of the body. Other types of surfaces such as glossy painted surface or a polished metal plate do not radiate as much energy as the black body , however the total radiation emitted by these bodies still generally follow the fourth power proportionality. To take account of the gray nature of such surfaces, the factor called emmissivity (ε), which relates the radiation of the gray surface to that of an ideal black surface, is used. The emissivity of the surface is the ratio of the emissive power of the surface to the emissive power of the black surface at the same temperature. Emissivity is the property of the surface and depends upon the nature of the surface and temperature.

DESCRIPTION OF THE APPARATUS:

The setup consists of a **200mm dia two copper plates** one surface blackened to get the effect of the black body and other is platened to give the effect of the gray body. Both the plates with **mica heaters** are mounted on the ceramic base covered with chalk powder for maximum heat transfer. Two Thermocouples are mounted on their surfaces to measure the temperatures of the surface and one more to measure the enclosure/ambient temperature. This complete arrangement is fixed in an **acrylic chamber** for visualization. Temperatures are indicated on the digital temperature indicator with channel selector to select the temperature point. Heater regulators are provided to control and monitor the heat input to the system with voltmeter and ammeter for direct measurement of the heat inputs. The heater controller is made of complete aluminium body having fuse.

With this, the setup is mounted on an aesthetically designed frame with control panel to monitor all the processes. The control panel consists of mains on indicator, Aluminium body heater controllers, change over switches, digital Data logger is used to measure the temperature, voltage and current of the Black body and grey body and other necessary instrumentation. The whole arrangement is on the single bench considering all **safety and aesthetics factors**.

AIM:

The experiment is conducted to determine the emissivity of the gray surface body and black body surface body.

PROCEDURE:

1. Give necessary electrical connections and switch on the MCB and switch on the console on to activate the control panel.

2. Switch On the heater of the black body and set the voltage (say 30V) using the heater regulator

3. Switch On the heater of the Gray body and set the voltage (say 30V) using the heater regulator.

4. Observe temperatures of the black body and test surface in close time intervals and adjust power input to the test plate heater such that both black body and test surface temperatures are same.

NOTE: This procedure requires trial and error method and one has to wait sufficiently long (say 2hours or longer) to reach a steady state.

5. Wait to attain the steady state.

6. Note down the temperatures at different points and also the voltmeter and ammeter readings.

7. Tabulate the readings and calculate the surface emmissivity of the non – black surface.

PROCEDURE : COMPUTERIZED

TAKING READINGS – COMPUTERIZED

16. Switch on the panel.

17. Switch on the computer.

18. Open the **" HEAT TRANSFER Software"** from the installed location a welcome screen will be displayed

19. Follow the below steps to operate through software

    d. Once the software is opened, the main screen will be displaced

    e. Now, press **"START"** button, and the small screen will opened

    f. Enter the parameters listed for particular test under study.

    g. the software starts displaying the calculated values which can be cross verified based on the formulae give after.

20. Switch On the heater of the black body and set the voltage (say 30V) using the heater regulator

21. Switch On the heater of the Gray body and set the voltage (say 30V) using the heater regulator.

22. Observe temperatures of the black body and test surface in close time intervals and adjust power input to the test plate heater such that both black body and test surface temperatures are same.

23. Wait to attain the steady state.

24. Click the **"store"** button to store the value can be viewed anytime later.

25. After completion of the Experiment to press the stop button

EXPERIMENTAL SET UP:

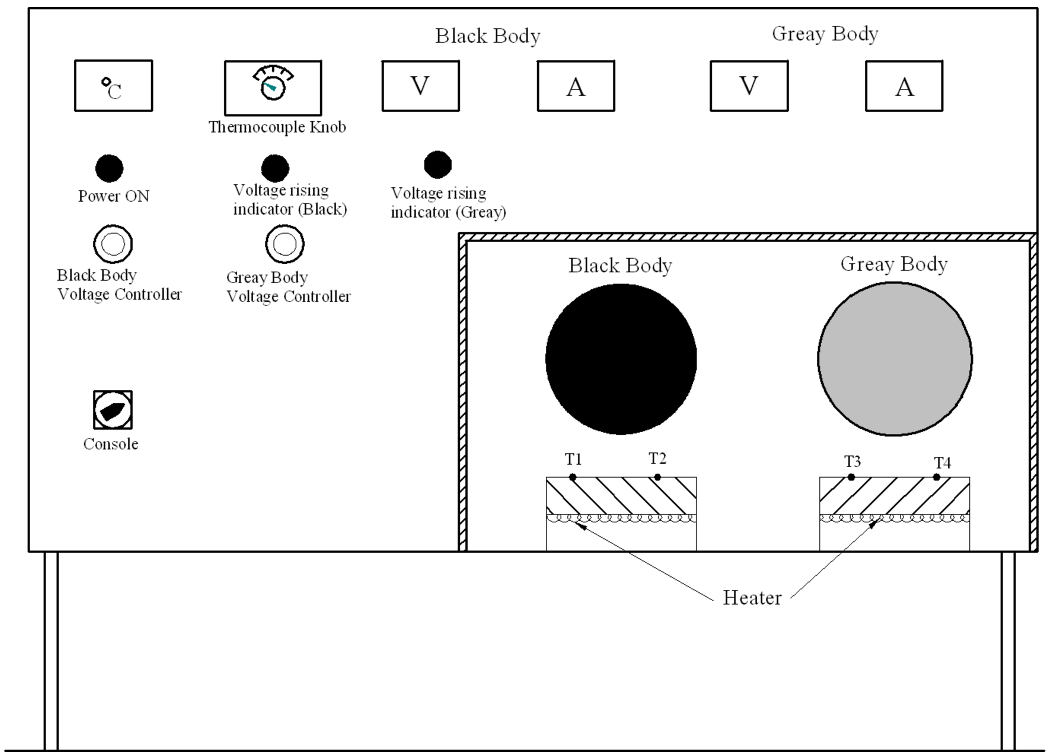


Fig: Line diagram of surface emissivity

<u>OBSERVATIONS</u>:

Sl. No.	Heater input				Temperature, °C				
	Black body		Gray body						
	Voltage, 'v' volts	Current 'I' amps	Voltage 'v' volts	Current 'I' amps	T_1	T_2	T_3	T_4	T_5
1									

2									
3									
4									
5									

CALCULATIONS:

1. HEAT INPUT TO THE BLACK BODY, Q_B

   Q_B = V x I Watts.

2. HEAT INPUT TO THE GRAY BODY, Q_G

   Q_G = V x I Watts.

3. EMMISSIVITY OF THE GRAY BODY, ε_G

$$\varepsilon_G = 1 - \frac{0.86 \times (Q_B - Q_G)}{\sigma \times A \times (T^4 - T_A^4)}$$

σ = Stefen Boltzmann constant = 5.67×10^{-8} W/ m^2 k^4.

Q_G = Heat input to the gray body.

Q_B = Heat input to the black body.

A = Area of plates = $(\pi d^2/4)$ m^2, d = 0.2m

T = (T1+T2+T3+T4)/4

T_A = enclosure temperature = T5

0.86 = constant , which takes into account various factors such as radiation shape factor, effect of conduction and free convection losses and other factors(such as non uniformities in enclosure temperature) which cause deviations from the typical radiation heat transfer experiment.

4. RESULT , ε_G

The emmissivity of the gray body is ε_G = ________.

NOTE;

IF YOU FIND THE ABOVE METHOD TO BE MORE TEDIOUS, USE **ALTERNATE PROCEDURE AND CALCULATIONS**.

ALTERNATE PROCEDURE:

1. Give necessary electrical connections and switch on the MCB and switch on the console on to activate the control panel.
2. Switch On the heater of the Gray body and set the voltage (say 45V) using the heater regulator and digital voltmeter.
3. Switch On the heater of the Black body and set the voltage or current (say higher than gray body) using the heater regulator and digital voltmeter.
4. Wait to attain the steady state.
5. Note down the temperatures at different points and also the voltmeter and ammeter readings.
6. Tabulate the readings and calculate the surface emmissivity of the non – black surface.

ALTERNATE OBSERVATIONS:

Sl. No.	Heater input				Temperature, °C				
	Black body		Gray body						
	Voltage, 'v' volts	Current 'I' amps	Voltage 'v' volts	Current 'I' amps	T_1	T_2	T_3	T_4	T_5
1									
2									
3									
4									
5									

ALTERNATE CALCULATIONS:

1. HEAT INPUT TO THE BLACK BODY, Q_B

$$Q_B = V \times I \quad \text{Watts.}$$

2. HEAT INPUT TO THE GRAY BODY, Q_G

$$Q_G = V \times I \quad \text{Watts.}$$

3. EMMISSIVITY OF THE GRAY BODY, ε_G

$$\varepsilon_G = \frac{Q_G\,(T_B^4 - T_A^4)}{Q_B\,(T_G^4 - T_A^4)}$$

Q_G = Heat input to the gray body.

Q_B = Heat input to the black body.

A = Area of plates = ($\pi d^2/4$) m^2, d = 0.2m

T_B = Temperature of black body = (T1+T2)/2

T_G = T(T3+T4)/2

T_A = Ambient temperature = T5

4. RESULT AND CONCLUTIONS

The emmissivity of the gray body is ε_G = ________.

VIVA QUESTIONS:

1. Explain the mechanism of radiation heat transfer
2. What are the characteristics of radiation heat transfer?
3. Define mano- chromatic emissivity, total emissivity, normal total emissivity
4. Define intensity of radiation
5. What do you mean by greenhouse effect?
6. What is radiation shield? What is its effect on heat transfer?
7. What is the range of values for the emissivity of a surface?

PRECAUTIONS:

4. Check all the electrical connections.
5. Do not run the equipment if the voltage is below 180V.
6. Make sure that heater regulator is at the minimum position before switching on the console.
7. After finishing the experiment open the acrylic door to remove the heat from the chamber.
8. Do not attempt to alter the equipment as this may cause damage to the whole system.

COMPUTERISED STEFAN BOLTZMAN'S APPARATUS

INTRODUCTION:

The most commonly used relationship in radiation heat transfer is the Stefan Boltzman's law which relates the heat transfer rate to the temperatures of hot and cold surfaces.

$$q = \sigma A (T_H^4 - T_C^4)$$

Where,

q = rate of heat transfer, watts

σ = Stefan Boltzman's constant = 5.669×10^{-8} watts/m² °K^4

A = Surface area, m²

T_H = Temperature of the hot body, °K

T_C = Temperature of the cold body, °K

The above equation is applicable only to black bodies 9for example a piece of metal covered with carbon black approximates this behavior) and is valid only for thermal radiation. Other types of bodies (like a glossy painted surface or a polished metal plate) do not radiate as much energy as the black body but still the total radiation emitted generally follow temperature proportionality.

<u>DESCRIPTION OF THE APPARATUS</u>:

The apparatus consists of

Copper hemispherical enclosure with insulation.

SS jacket to hold the hot water.

Over head water heater with quick release mechanism and the thermostat to generate and dump the hot water.
Thermostat to supply the regulated power input to the heater.

Thermocouples at suitable position to measure the surface temperatures of the absorber body.

PID Indicator is used to measure the temperatures.

Control panel to house all the instrumentation.

With this the whole arrangement is mounted on an aesthetically designed self-sustained frame with a separate control panel.

EXPERIMENTATION:

AIM:

- To verify the Stefan Boltman's Law

PROCEDURE:

1. Fill water slowly into the overhead water heater.
2. Switch on the supply mains and console.
3. Switch on the heater and regulate the power input using the heater regulator. (say 60 – 85 °C)
4. After water attains the maximum temperature, open the valve of the heater and dump to the enclosure jacket.
5. Wait for about few seconds to allow hemispherical enclosure to attain uniform temperature – the chamber will soon reach the equilibrium. Note the enclosure temperature.
6. Insert the Test specimen with the sleeve into its position and record the temperature at different instants of time using the stop watch.
7. Plot the variation of specimen temperature with time and get the slope of temperature versus time variation at the time t = 0 sec
8. Calculate the Stefan Boltzman's constant using the equations provided.

9. Repeat the experiment 3 to 4 times and calculate the average value to obtain the better results.

PROCEDURE : COMPUTERIZED

TAKING READINGS – COMPUTERIZED

26. switch on the panel.
27. Switch on the computer.
28. Open the **" HEAT TRANSFER Software"** from the installed location a welcome screen will be displayed
29. Follow the below steps to operate through software

h. Once the software is opened, the main screen will be displaced On the main screen press **"PORT"** button and select the USB port connected,

i. Now, press **"START"** button, and the small screen will opened

j. Enter the parameters listed for particular test under study.

k. Now, set the temp by using thermostat regulator to known valve.

l. Now press "START BUTTON" on the screen so the software automatically starts recording the temperatures and other values.

m. Switch on the heater and regulate the power input using the heater regulator. (say 60 – 85 °C)

n. After water attains the maximum temperature, open the valve of the heater and dump to the enclosure jacket.

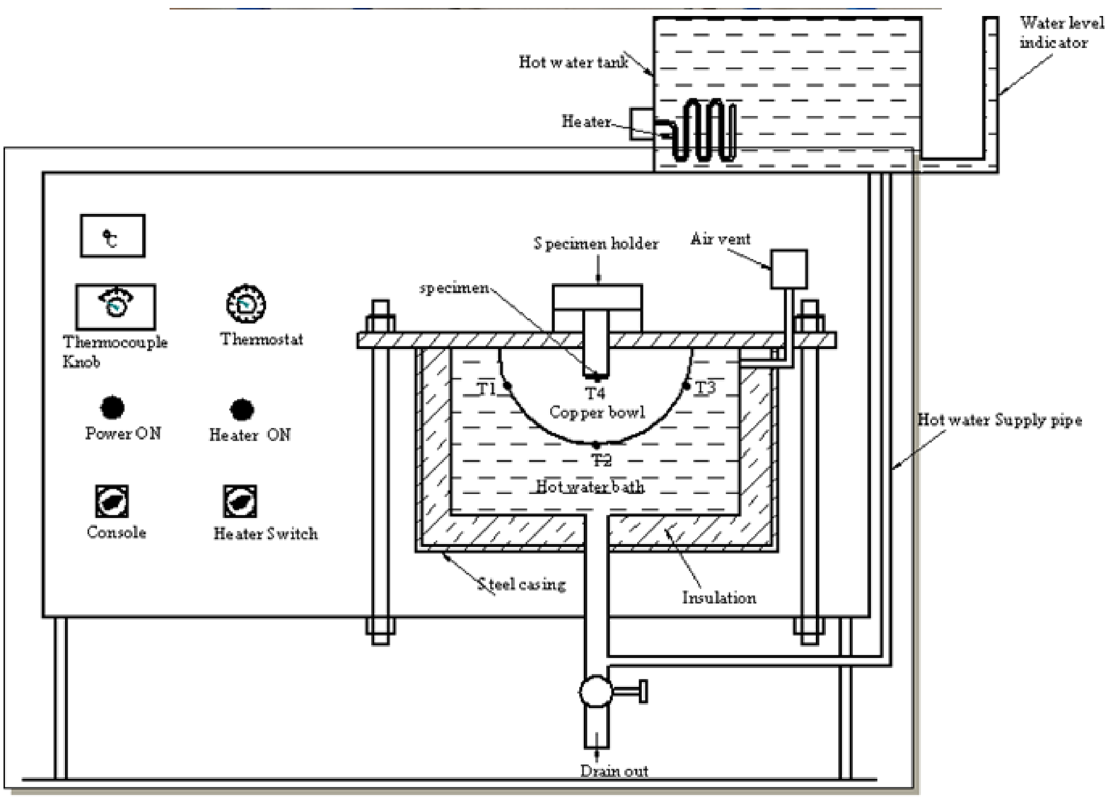
o. Wait for about few seconds to allow hemispherical enclosure to attain uniform temperature – the chamber will soon reach the equilibrium. Note the enclosure temperature.

p. Also, the software starts displaying the calculated values which can be cross verified based on the formulae give there after.

q. Enter the **STORE BUTTON** to store the values.

r. Press report button to see the stored values

s. finally thermostat you kept at 0 *C



Experimental Diagram

OBSERVATIONS:

Enclosure Temperature, Te =

Initial Temperature of the specimen, Ts =

Time, t	Specimen Temperature, Ts
5	

10	
15	
20	
25	
30	

CALCULATIONS:

STEFAN BOLTMAN'S CONSTANT IS CALCULATED USING THE RELATION:

$$\sigma = \frac{m\, Cp\, (dTa/dt)_{t=0}}{A_D\,(T_e^4 - T_S^4)}$$

Where,

m = mass of the test specimen = 0.0047Kg
Cp = Specific heat of the specimen = 410 J/Kg °C
T_e = Enclosure temperature, °K
T_S = Initial temperature of the specimen, °K
(dTa/dt) = calculated from graph.
A_D = Surface area of the test specimen

= $\pi d^2/4$

where d = 0.015m

RESULTS AND CONCLUSIONS

Stefan Boltzmann"s value is calculated and verified with Stefan Boltzmann"s constant equations

□2 □4

Thus, Stefan–Boltzmann"s law is proved which states that the total intensity radiated over all wavelengths increases as the temperature increases of a black body which is proportional to the fourth power of the thermodynamic temperature.

PRECAUTIONS:

9. Check all the electrical connections.
10. Do not run the equipment if the voltage is below 180V.
11. Do not switch on the heater without water in the overhead tank.
12. Do not turn the heater regulator to the maximum as soon as the equipment is started.
13. Do not attempt to alter the equipment as this may cause damage to the whole system.

VERIFY KIRCHOFF'S LAW OF SURFACE EMISSIVITY

INTRODUCTION:

All substances at all temperature at all temperature emit thermal radiation. Thermal radiation is an electromagnetic wave and does not require any material medium for propagation. All bodies can emit radiation and have also the capacity to absorb all or a pare of the radiation coming from the surrounding towards it. An idealized black surface is one, which absorbs all the incident radiation with reflectivity and transmissivity equal to zero. The radiant energy per unit time per unit area from the surface of the body is called, as the emissivity of the surface is the ratio of the emissive power of the surface to the emissive power of a black surface at the same temperature. It is noted by E.

$$\text{Thus } E = + \frac{e}{E_b}$$

For black body absorptivity = 1 and by the knowledge of Kirchoff's Law emissivity of the black body becomes unity. Emissivity being a property of the surface depends on the nature of the surface and temperature. It is obvious from the Stefan Boltzmann's Law that the prediction of emissive power of a surface requires knowledge about the values of its emissivity and therefore much experimental research in radiation has been concentrated on measuring the values of emissivity as function of surface temperature. The present experimental set up is designed and fabricated to measure the property of emissivity of the lest test plate surface at various temperatures.

Kirchoff's Law

Kirchoff’s Law states that the emissivity of a surface is equal to its absorptance, where the absorptance (α) of a surface is the ratio of the radiant power absorbed to the radiant power incident on the surface.

$$\int_T \alpha(\lambda, T)d\lambda = \int_T \varepsilon(\lambda, T)d\lambda$$

$$\alpha = \varepsilon$$

DESCRIPTION OF THE APPARATUS:

The setup consists of a **200mm dia two copper plates** one surface blackened to get the effect of the black body and other is platened to give the effect of the gray body. Both the plates with **mica heaters** are mounted on the ceramic base covered with chalk powder for maximum heat transfer. Two Thermocouples are mounted on their surfaces to measure the temperatures of the surface and one more to measure the enclosure/ambient temperature. This complete arrangement is fixed in an **acrylic chamber** for visualization. Temperatures are indicated on the digital temperature indicator with channel selector to select the temperature point. Heater regulators are provided to control and monitor the heat input to the system with voltmeter and ammeter for direct measurement of the heat inputs. The heater controller is made of complete aluminium body having fuse.

With this, the setup is mounted on an aesthetically designed frame with control panel to monitor all the processes. The control panel consists of mains on indicator, Aluminium body heater controllers, change over switches, digital Data logger is used to measure the temperature, voltage and current of the Black body and grey body and other necessary instrumentation. The whole arrangement is on the single bench considering all **safety and aesthetics factors**.

AIM:

The experiment is conducted to verify the kirchoffs law of the gray surface body and black body surface body.

PROCEDURE:

8. Give necessary electrical connections and switch on the MCB and switch on the console on to activate the control panel.
9. Switch On the heater of the black body and set the voltage (say 30V) using the heater regulator
10. Switch On the heater of the Gray body and set the voltage (say 30V) using the heater regulator.
11. Observe temperatures of the black body and test surface in close time intervals and adjust power input to the test plate heater such that both black body and test surface temperatures are same.

NOTE: This procedure requires trial and error method and one has to wait sufficiently long (say 2hours or longer) to reach a steady state.

12. Wait to attain the steady state.

13. Note down the temperatures at different points and also the voltmeter and ammeter readings.

14. Tabulate the readings and calculate the surface emmissivity of the non – black surface.

PROCEDURE : COMPUTERIZED

TAKING READINGS – COMPUTERIZED

30. Switch on the panel.

31. Switch on the computer.

32. Open the **" HEAT TRANSFER Software"** from the installed location a welcome screen will be displayed

33. Follow the below steps to operate through software

t. Once the software is opened, the main screen will be displaced

u. Now, press **"START"** button, and the small screen will opened

v. Enter the parameters listed for particular test under study.

w. the software starts displaying the calculated values which can be cross verified based on the formulae give after.

34. Switch On the heater of the black body and set the voltage (say 30V) using the heater regulator

35. Switch On the heater of the Gray body and set the voltage (say 30V) using the heater regulator.

36. Observe temperatures of the black body and test surface in close time intervals and adjust power input to the test plate heater such that both black body and test surface temperatures are same.

37. Wait to attain the steady state.

38. Click the **"store"** button to store the value can be viewed anytime later.

39. After completion of the Experiment to press the stop button

EXPERIMENTAL SET UP:

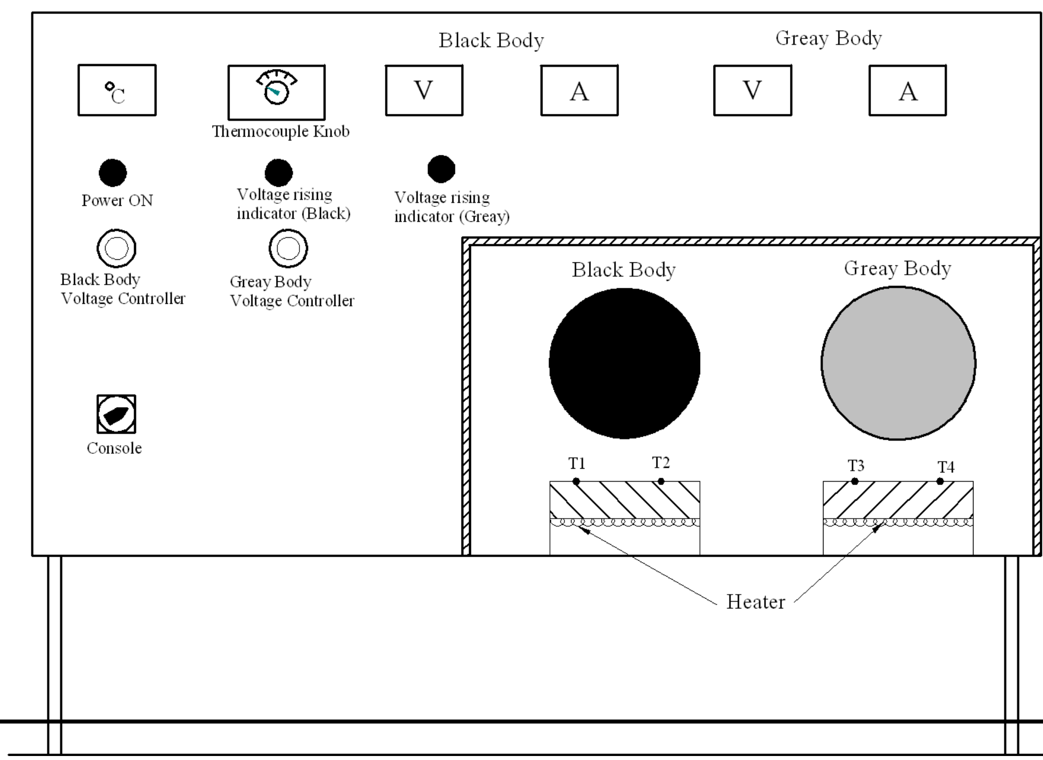


Fig: Line diagram of surface emissivity

OBSERVATIONS:

Sl. No.	Heater input				Temperature, °C				
	Black body		Gray body						
	Voltage, 'v' volts	Current 'I' amps	Voltage 'v' volts	Current 'I' amps	T_1	T_2	T_3	T_4	T_5
1									
2									
3									
4									
5									

CALCULATIONS:

5. HEAT INPUT TO THE BLACK BODY, Q_B

Q_B = V x I Watts.

6. HEAT INPUT TO THE GRAY BODY, Q_G

Q_G = V x I Watts.

7. EMMISSIVITY OF THE GRAY BODY, ε_G

$$\varepsilon_G = 1 - \frac{0.86 \times (Q_B - Q_G)}{\sigma \times A \times (T^4 - T_A^4)}$$

σ = Stefen Boltzmann constant = 5.67 X 10^{-8} W/ m^2 k^4.

Q_G = Heat input to the gray body.

Q_B = Heat input to the black body.

A = Area of plates = ($\pi d^2/4$) m^2, d = 0.2m

T = (T1+T2+T3+T4)/4

T_A = enclosure temperature = T5

0.86 = constant , which takes into account various factors such as radiation shape factor, effect of conduction and free convection losses and other factors(such as non uniformities in enclosure temperature) which cause deviations from the typical radiation heat transfer experiment.

8. RESULT , ε_G

The emmissivity of the gray body is ε_G = ________.

NOTE;

IF YOU FIND THE ABOVE METHOD TO BE MORE TEDIOUS, USE **ALTERNATE PROCEDURE AND CALCULATIONS**.

ALTERNATE PROCEDURE:

7. Give necessary electrical connections and switch on the MCB and switch on the console on to activate the control panel.

8. Switch On the heater of the Gray body and set the voltage (say 45V) using the heater regulator and digital voltmeter.
9. Switch On the heater of the Black body and set the voltage or current (say higher than gray body) using the heater regulator and digital voltmeter.
10. Wait to attain the steady state.
11. Note down the temperatures at different points and also the voltmeter and ammeter readings.
12. Tabulate the readings and calculate the surface emmissivity of the non – black surface.

ALTERNATE OBSERVATIONS:

Sl. No.	Heater input				Temperature, °C				
	Black body		Gray body						
	Voltage, 'v' volts	Current 'I' amps	Voltage 'v' volts	Current 'I' amps	T_1	T_2	T_3	T_4	T_5
1									
2									
3									
4									
5									

ALTERNATE CALCULATIONS:

5. HEAT INPUT TO THE BLACK BODY, Q_B

Q_B = V x I Watts.

6. HEAT INPUT TO THE GRAY BODY, Q_G

Q_G = V x I Watts.

7. EMMISSIVITY OF THE GRAY BODY, ε_G

$$\varepsilon_G = \frac{Q_G\,(T_B^4 - T_A^4)}{Q_B\,(T_G^4 - T_A^4)}$$

Q_G = Heat input to the gray body.

Q_B = Heat input to the black body.

A = Area of plates = $(\pi d^2/4)$ m^2, d = 0.2m

T_B = Temperature of black body = (T1+T2)/2

T_G = T(T3+T4)/2

T_A = Ambient temperature = T5

8. RESULT AND CONCLUTIONS

The emmissivity of the gray body is ε_G = ________.

VIVA QUESTIONS:

8. Explain the mechanism of radiation heat transfer
9. What are the characteristics of radiation heat transfer?
10. Define mano- chromatic emissivity, total emissivity, normal total emissivity
11. Define intensity of radiation
12. What do you mean by greenhouse effect?
13. What is radiation shield? What is its effect on heat transfer?
14. What is the range of values for the emissivity of a surface?

PRECAUTIONS:

14. Check all the electrical connections.
15. Do not run the equipment if the voltage is below 180V.
16. Make sure that heater regulator is at the minimum position before switching on the console.
17. After finishing the experiment open the acrylic door to remove the heat from the chamber.
18. Do not attempt to alter the equipment as this may cause damage to the whole system.

COMPUTERISED CONDENSATION OF FILM and DROP WISEAPPARATUS

INTRODUCTION:

Condensation is the process of change of state free vapour to liquid. Condensation occurs on a surface when the vapour saturation temperature is higher than the temperature of surface. The temperature of the condensate so formed will be less than the saturation temperature of the vapour and becomes sub-cooled. More vapour starts condensing on the exposed surface or on the previous condensate, since the temperature of the previous condensate is lower.

The phenomenon of condensation heat transfer is more complex, which involves change of phase and additional characteristics / variables that control the condensation process.

There are two basic types of condensation - Film Condensation and Dropwise Condensation.

a) Film Condensation :

When the condensate tends to "wet" the surface, then it is called "film condensation". In this process, the liquid condensate distributes itself as a continuous thin film on the cooled surface. This happens when the surface tension between the liquid and the solid material is sufficiently small for example, condensation of steam on a clean metallic surface, when the surface is clean and grease / oil free.

In film condensation, heat transfer from the vapour to the cooling surface takes place through the condensate film formed on the surface. As the new condensate formed joins the film existing on the surface, the film thickness increases. The heat is transferred from the vapour to the condensate by convection and further from condensate to the surface by conduction. This combined mode of heat transfer by conduction and convection reduce the rate of heat transfer in film condensation process. Hence, the rate of heat transfer is lower in film condensation (as compared to dropwise condensation).

b) Dropwise Condensation :

When the condensate does not wet the surface, it forms the droplets on the surface, it is known as “dropwise condensation”. When the surface tension is large, the condensate coalesces into a multitude of droplets of different sizes. With time, each droplet grows as more vapour condenses on its exposed surface. The formation of each droplet is initiated at a point of surface imperfection (pit, scratch, etc.) and such sites are called “nucleation sites”. At some time, the tangential pull of gravity, or sheer force exerted by the vapour stream, dislodges the droplet and carries it downstream. The moving droplet devours the smaller droplets in its path, thereby creating a clean trail ready for the generation of new droplets of smaller sizes. This surface renewal process occurs periodically as the droplets accumulate and grow in size. Since the condensation rate is the highest in the absence of condensate on the surface, the periodic cleaning performed by the large drops renews finite size regions of the surface for the restart of the condensation. This surface renewal process is the main reason why dropwise condensation is a highly effective heat transfer mechanism. The heat transfer coefficient is roughly ten times greater than the corresponding condensation in the form of thin film.

In the design of condensers, whose function is to cool a vapour stream and to convert it into liquid, there is a great advantage to promote the breakup of the condensate into droplets. This can be achieved by :

a) Coating the solid surface with an organic substance like wax, oil, oleic acid, etc.

b) Injecting non-wetting chemicals into the vapour, which get deposited on the surface of the condenser.

c) Coating the surface with a polymer of low surface energy like teflon, silicone, etc. or with a noble metal like gold, silver, etc.

The mechanism of dropwise condensation is complex because of its intermittent time dependent character, effect of surface tension (due to drop size and shape) and the uncertainty associated with the location of nucleation sites and the time when the largest droplet will start its downstream movement. Hence, a unifying theory of dropwise condensation has not been developed.

DESCRIPTION OF THE APPARATUS:

The apparatus consists of

Heat exchanger tube made of **copper** which is placed inside the **GLASS CHAMBER** of dimension φ100 x 200mm.

Steam Generator with necessary fittings and accessories to generate and supply the steam.

Rotameter to directly measure the flowrate of the water into the condensate tube.

Thermocouples at suitable position to measure temperatures of body and the air.

Data logger to measure the temperatures.

Control panel to house all the instrumentation.

With this the whole arrangement is mounted on an aesthetically designed self-sustained frame with a control panel.

EXPERIMENTATION:

AIM:

TO determine the heat flux and surface coefficient of film wise and drop wise condensation at constant pressure.

PROCEDURE:

1. Fill water slowly into the water tank and steam generator.
2. Switch on the supply mains and console.
3. Switch on the heater of steam generator to generate the steam.
4. Once the steam is generated follow the steps below.
5. Open the inlet valve and allow the cold fluid to flow through the condenser.
6. Adjust the flowrate of cold fluid to minimum.
7. *Open the steam inlet valve and keep steam pressure constant (say 0.2kg/cm^2) throughout the experiment.
8. After cold fluid temperature becomes steady state, note down the inlet temperature, out let temperature and flowrate of cold fluid and also note down the volume of condensate collected at the given time interval(say 1min).
9. Keeping steam pressure constant take 4 – 5 readings for different cold fluid flow rate from minimum to maximum.
10. Repeat the experiment at another constant steam pressure Say, (0.3kg/cm^2).

PROCEDURE : COMPUTERIZED

TAKING READINGS – COMPUTERIZED

40. switch on the panel.

41. Switch on the computer.

42. Switch on the heater of steam generator to generate the steam

43. Open the **“ HEAT TRANSFER Software”** from the installed location a welcome screen will be displayed

44. Follow the below steps to operate through software

    x. Once the software is opened, the main screen will be displaced

    y. Now, press **“START”** button, and the small screen will opened

    z. Enter the parameters listed for particular test under study.

45. Once the steam is generated follow the steps below.

46. Open the inlet valve and allow the cold fluid to flow through the condenser.

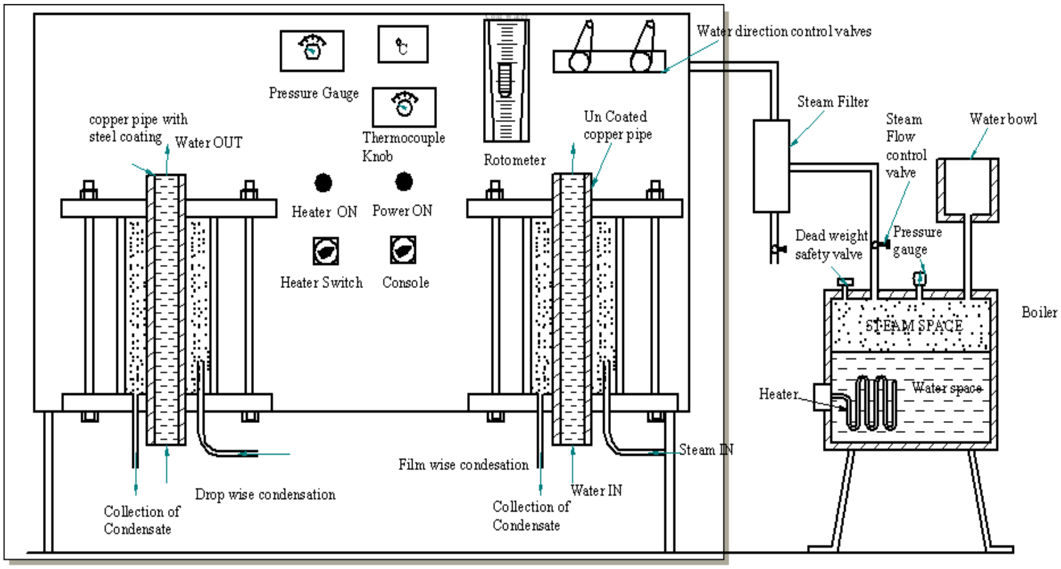
47. Adjust the flowrate of cold fluid to minimum.

48. Open the steam inlet valve and keep steam pressure constant (say $0.2 kg/cm^2$) throughout the experiment.

49. The software starts displaying the calculated values which can be cross verified based on the formulae give after.

50. After cold fluid temperature becomes steady state, note down the inlet temperature, out let temperature and flow rate of cold fluid and also note down the volume of condensate collected at the given time interval(say 1min).
51. Keeping steam pressure constant take 4 – 5 readings for different cold fluid flow rate from minimum to maximum.
52. Click the **“store”** button to store the value can be viewed anytime later.
53. After completion of the Experiment to press the stop button

54. Finally switch of the steam generator.



CONDENSATION APPARATUS

- **NOTE THAT WHILE DOING SO FOLLOWING THE PRECAUTIONS BELOW**

    1. Intially, close the valve on the top of the condenser unit
    2. Start the steam and then open the valve at the top of the condenser unit and close it as soon as the steam is filled.
    3. Also make sure to open the water connection of the condesor unit to which the steam is released and close the steam valve of other unit.

OBSERVATIONS:

Sl. No.	Steam pressure. 'P' kg/cm^2	Cold fluid temperature °C		Flow rate of cold fluid 'W' Lpm	Volume of condensate collected at given time interval, 'Vc' kg
		t_1	t_2		

CALCULATIONS:

1. MASS FLOW RATE OF COLD FLUID

$$M_W = \frac{W}{60} \text{ Kg/s}$$

where,

W = Cold fluid flow rate, lpm

2. HEAT CARRIED AWAY BY COLD FLUID

$$Q_C = M_W \times C_{PW} \times \Delta T_W \text{ Watt.}$$

Where,

M_W = mass flow rate of cold fluid, Kg/s.
C_{PW} = Specific heat of cold fluid, KJ/Kg - °K.
ΔT_W = Cold fluid temperate difference, $(t_2 - t_1)$ °K

3. MASS FLOW RATE OF CONDENSATE FLUID

$$M_C = \frac{Vc}{T}$$

Where,

M_C = mass flow rate of condensate, Kg/s.
V_C = volume of condensate collected, Kg
T = Time interval, sec.

4. HEAT LOST BY THE STEAM

$$Q_S = \frac{M_C \times \lambda}{1000} \text{ Watt.}$$

Where,

M_C = mass flow rate of condensate, Kg/s.
λ = obtained from steam table for given pressure, kJ/Kg.

5. OVERALL HEAT TRANSFER CO – EFFICIENT

$$U_O = \frac{Q_C}{A \times \Delta t_{LMTD}} \text{ K.}$$

Where,

Q_C = heat carried away by water, Watt.

A = Area occupied by the inner tubes, m^2.

= π D_O x L x N where, D_O = outer dia of inner tube
L = Length of the tube
N = No. of tubes.

Δt_{LMTD} = Logarithmic mean temp. difference.

$$= \frac{(T_S - t_1) - (T_S - t_2)}{\ln \frac{(T_S - t_1)}{(T_S - t_2)}}$$

where, T_S = Temp. obtained from steam tables at given pressure.

Find C_P , μ , ρ and K. @ $T_{avg} = \frac{(t1 + t2)}{2}$ from hand book.

6. COLD FLUID HEAT TRANSFER CO - EFFICIENT:

$$h_I = 0.023 \times (Re) \quad \times (Pr) \quad \times (K/D_I) \qquad W/m^2 - °K.$$

Where,

Re = Reynolds number.

$= \dfrac{\rho V D_I}{\mu}$ **where, D_I = inner dia of the inner tube = 36mm.**

V = Velocity of the cold fluid,

$$= \frac{M_W}{\rho \times A_T}$$

$A_T = \dfrac{\pi \times D_I^{\,2}}{4}$ m^2.

ρ = density of the fluid, kg/m^3.

μ = viscosity of fluid, Cp.

Pr = Prandlt Number.

$$= \frac{\mu \times C_P}{K}$$

55. STEAM SIDE HEAT TRANSFER CO - EFFICIENT

$$h_S = 0.943 \left[\frac{K^3 \rho^2 g \lambda}{\mu L \Delta T}\right] \qquad W/m^2 - °K.$$

Where,

$\Delta T = (T_S - T_W)$ °K.

where, $T_W = \dfrac{T_S + T_{C\,avg}}{2}$

L = Length of the condenser = 0.18 m.

$T_{C\,avg} = (t1 + t2)/2$

TABULATE THE READING

HEAT LOST BY STEAM ‘Qs’ watt	LOGARITHM TEMP. MEAN DIFFERENCE **’ΔtLMTD’** °K.	OVERALL HEAT TRANSFER CO-EFFICIENT ‘UO’ W/m² - °K.	$\frac{1}{UO}$	VELOCITY OF THE COLD FLUID ‘V’, m/s	$\frac{1}{V^{0.8}}$	RENOLDS NUMBER, Re	PRANDLT NUMBER, Pr	COLD FLUID SIDE HEAT TRANSFER CO-EFFICIENT, ‘hl’	STEAM SIDE HEAT TRANSFER CO – EFFICIENT, ‘hS’ W/m² -

HEAT CARRIED AWAY BY COLD FLUID, ‘Q_C’ watt				
Sl. No				

PRECAUTIONS:

19. Check all the electrical connections.
20. Do not run the equipment if the voltage is below 180V.
21. Do not give continuous steam without running the cold water.
22. Run the water in the condensate tube for about 5 min after the experiment.
23. Do not run the equipment if the voltage is below 180V.
24. Check all the electrical connections before running.
25. Before starting and after finishing the experiment the steam valve should be in shut position.
26. Do not attempt to alter the equipment as this may cause damage to the whole system.

RESULTS AND CONCLUTIONS:

The two types of condensation process is studied and found the overall heat transfer coefficient, steam side film coefficient and cold fluid heat transfer coefficient.

VIVA QUESTIONS:

1. What is the surface conditions required for drop-wise condensation?
2. What is the significance of Nusselt theory?
3. Define overall heat transfer coefficient
4. Define steam side film coefficient
5. Define cold fluid heat transfer coefficient
6. What is Physical state of heat exchanging fluid?

BOLING POINT APPARATUS

AIM:

To study the Boiling Heat Transfer phenomenon for pool boiling of water.

Specifications:

Glass Column: Size - 90mm OD,

Height - 250 mm

THEORY:

Boiling heat transfer is a mode of heat transfer that occurs because of vaporization. Vaporization is a process in which a substance is changed from the liquid to the vapour state.

Pool boiling takes place when a liquid is confined in a container and a heater is submerged in the liquid.

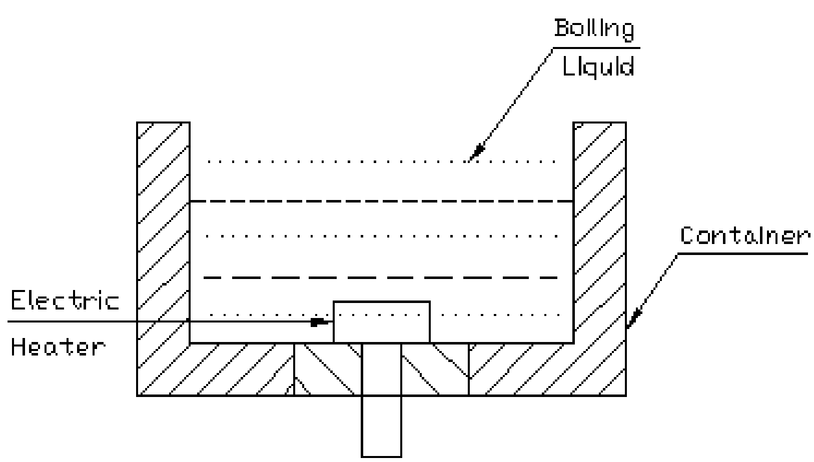


Fig.1 Pool Boiling with an electric heater for constant energy input.

Initially as q'' and Δt sat are increased, the liquid is heated by convection. The liquid must be superheated to some degree before bubbles form on the heater surface. As the liquid is heated, it becomes less dense and rises to the surface where vapourization takes place. Therefore, the cooling process on the heat is one of natural convection. On the boiling curve, Fig-2, the natural convection region from 1-2 appears as a straight line on a semi-log plot.

At point 2 the liquid superheat has increased to a point where vapour bubbles begins to form; this point on the curve is referred to as the 'Onset of Nuclear Boiling'(ONB). Careful observation of the heating surface will show that the bubbles appear at a few preferred locations. As the bubbles detach from the heated surface, they forma column of bubbles moving toward the free surface of the liquid. Line 2-3 is the knee of the boiling curve and represents a region of changing heat transfer coefficient.

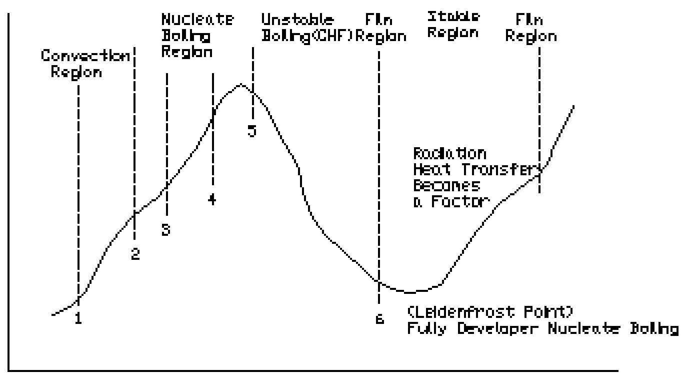


Fig2 Boiling Curve Showing Regimes of log(tw-ts) Boiling Heat Transfer.

Fig.2 Boiling Curve showing regimes of boiling heat transfer.

When point 3 is reached, a sufficient number of nucleation sites will have been activated to establish fully developed nucleate boiling. The line 3-4 representing this region will once again be straight but its slope will be much greater than in the convection region. This means that very large heat transfer rates are possible with relatively small temperature differences. The characteristically high heat transfer coefficient hb of nucleate boiling is obtained.

As heat flux is increased further, more nucleation sites are activated and a large amount of vapour forms on the heater surface. This causes the heat transfer coefficient to decrease from point 4 to 5 - Point 4 is known as the departure from nucleate boiling (DNB).

At some critical value of heat flux at point 5 a blanket of vapour forms over the entire surface of the heater and heat transfer is severely curtailed. The vapour film is unstable and it forms, collapses and reforms repeatedly. Therefore, region 5-6 referred to as one of 'Unstable film boiling'. The process cannot remove an amount of heat equal to the constant of electrical energy input. The resulting discrepancy causes a rise of internal energy of the heater with a decrease in heat flux.

NOTE : Fig.2 shows 1-5 can be drawn from critical heat flux experiment setup.
5-6 Practically it is not possible to draw this curve.
6-5 This can be drawn from 2 phase Boiling heat transfer apparatus.
1-5 & 6-5 can be drawn from 2 phase boiling heat transfer experiment.

The system is unstable and the value of t_{sat} will spontaneously jump to point 5'. If data points of line 5-6 are to be obtained it is necessary to use condensing vapor heat.

Wall temperature represented by 5' is well above the melting point of many metals. Consequently point 5 is referred to as the 'Critical heat flux point'. 'Peak heat flux point', or 'Burnout Point'.

In the range of unstable film boiling some wetting of the heater surface by the liquid can occur .This accounts for the instability of the vapour film. After a point such as 6 has been reached, the wall temperature is so high that a steam cushion appears between all liquid droplets and the heater wall and no wetting is possible. The region after point 5 is therefore one of 'Stable film boiling'. Point 6 is referred to as the 'Spheroid state' or the 'Leidunfrost Point'. Wall temperature in the stable film boiling range are at a high enough level that radiation heat transfer becomes significant, resulting in increased values of boiling heat transfer coefficients. The boiling curve of Fig. 2 is representative of all types of boiling systems.

BOILING REGIMES:

Consider that the rate of heat convection, heat transfer q for a system is expressed analytically by the Newton's equation.

$q = h \times A \times \Delta t$ --------------------(1)

Where

q = rate of heat transfer W

h = Boiling heat transfer co-efficient W/m^2 °K

A = Area of heat transfer in m^2

Δt = Temp. difference in °K

$q'' = h \Delta t_{sat}$ --------------------(2)

Where q'' = q /A = Heat flux W/ m^2

$\Delta t_{sat} = t_w - t_{sat}$

Δt_{sat} = Difference of saturation temperature of liquid and wall temperature in °K

t_w = Wall temperature in °K

t_{sat} = Saturation temperature of liquid in °K

A graph of q'' Vs Δt_{sat} is made.

EXPERIMENTAL SETUP:

The main apparatus is fitted on a MS square tube frame consisting of a glass column with a sample holding copper sump with a heater and drain valve at the bottom and a spiral condenser, with water inlet and outlet, a safety valve, and a feed valve at the top and the unit is made leak proof with necessary flange connections.

The panel consists of voltmeter, ammeter, digital temperature indicator, dimmer, thermocouple selector switch, toggle switch for pump, rotameter and a schematic diagram showing the position of the thermocouples T1, T2, T3, T4, T5. Below the table a water sump fitted with pump is provided to circulate water through the spiral condenser coil, a bypass is also provided for the pump to safe guard the motor.

SPECIFICATIONS:

1. Diameter of the copper sump, D = 100mm

OPERATION:

a) Fill the sample holding sump with sample of about 200 ml (approx.) through the feed valve provided on top of the column (ensure that the drain valve provided at the bottom is closed) and close the feed valve after filling.
b) Ensure that the dimmer is 'OFF', thermocouple selector switch at any position, the pump toggle switch is 'OFF'.
c) Connect the three pin plug top to 230V, 50, 5 Amps power supply socket with proper earthing.
d) Fill water into the water sump provided below the table.
e) Open the bypass valve fully and also open the rotameter valve.
f) Switch 'ON' the toggle switch for pump.
g) Observe water falling into the sump through by pass.
h) Slowly turn the bypass valve clock wise and observe the rotameter float to rise.
i) Set the water flow rate to any desired valve indicated by the rotameter.
j) Turn the dimmer clockwise and set the power input to the heater at minimum possible limit by observing the volt and ammeter (V x I = W) and note the readings.
k) Note down the temperatures indicated by the temperature indicator by turning the thermocouple selector switch clockwise step by step.
l) Bring back the thermocouple selector switch 1st position,
m) Increase the power input to the heater by lowest possible value (increasing pf the power input to the heater should be made at a known interval of time) record the readings,
n) Record the temperatures indicated at each step 1,2,3,4,and 5.

o) Repeat increasing of power input to the heater and recording the temperatures at an interval of time till the sample starts boiling,

p) Tabulate all the readings and calculate.

q) After the experiment is over turn the dimmer anticlockwise to 'ZERO' position. Also bring back the thermocouple selector switch to zero position allow the water circulation pump to work for some tine, switch 'OFF' the pump switch, drain the sample: by opening the drain valve and close the drain valve after draining.

EXPERIMENTAL PROCEDURE:

Open by pass valve V completely. Open Valve V slightly to pass minimum flow through Rotameter. Fill up Sump S with water and connect external water supply to sump. Switch on pump switch PS and adjust valve V for water flow rate. Now slowly start increasing the dimmerstat and note down the readings on voltmeter and ammeter until the liquid boils.

OBSERVATION TABLE :

Sl.No.	Heating pad Temp. T_1 °C	Liquid Temp T_2 °C	Vapour Temp T_3 °C	Cooling water inlet and outlet Temp. T_4& T_5 °C	Volta ge (V)	curren t (A)	Ambie nt Temp T_a °C

Where T_1, T_2, T_3, T_4, T_5 & T_a in °C

FORMULAE:

1. Heat input $q_{in} = V \times I$

2. Heat transfer area, $A = \Pi D^2/4$
   Where D = Dia. of copper bowl in m.

3. Heat Flux $q'' = q/A$ in W / m^2

4. Excess temperature, $\Delta T = T_1 - T_2$

The value of h for a boiling system changes as the system passes through different regimes. These regimes can be shown on a boiling curve.

BOILING CURVE:

The boiling curve is generally plotted in log-log coordinator with heat flux q'' Vs Wall superheat (excess temperature=T_1-T_2).An experiment on pool Boiling is shown in Fig.1.

SI. No:	AMPS – 1	VOLTS V	T1	T2	T1 -T2	V x I	q/A

At voltage > 72 volts individual bubble region starts

90 volts bubble column develops

99 volts unstable bubble appears

148 volts dropping occurs

CONCLUSIONS:

1) The unstable film boiling region curve can't be obtained practically during the course of input power controlled experiment.

Calibration Of Thermal Conductivity Unit On Concentric Sphere

INTRODUCTION:

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

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

Thermal energy in solids may be conducted in two modes. They are:

- **LATTICE VIBRATION:**
- **TRANSPORT BY FREE ELECTRONS.**

In good electrical conductors a rather large number of free electrons move about in a lattice structure of the material. Just as these electrons may transport may transport electric charge, they may also carry thermal energy from a high temperature region to low temperature region. In fact, these electrons are frequently referred as the electron gas. Energy may also be transmitted as vibrational energy in the lattice structure of the material. In general, however, this latter mode of energy transfer is not as large as the electron transport and it is for this reason that good electrical conductors are almost always good heat conductors, for eg: ALUMINIUM, COPPER & SILVER.

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

DESCRIPTION OF THE APPARATUS:

The apparatus consists of the **COPPER sphere of 150mm dia and 250mm dia concentrically placed.** Heat is provided by means of **oil bath heater** arrangement. **Thermocouples** are provided at the suitable points to measure the surface and inner temperatures. Proper **insulation** is provided to **minimize the heat loss**. The temperature is shown by means of the DATA LOGGER on the control panel, which also consists of **heater regulator** and other accessories instrumentation having good aesthetic looks and safe design.

EXPERIMENTATION:

AIM:

To calibrate the thermal conductivity unit in Spherical coordinate system on Concentric Sphere.

PROCEDURE:

1. Give necessary electrical and water connections to the instrument.
2. Switch on the MCB and console ON to activate the control panel.
3. Give input to the heater by slowly rotating the heater regulator.
4. Note the temperature at different points, when steady state is reached.
5. Repeat the experiment for different heater input.
6. After the experiment is over, switch off the electrical connections.

PROCEDURE : COMPUTERIZED

TAKING READINGS – COMPUTERIZED

56. Switch on the panel.
57. Switch on the computer.
58. Open the **" HEAT TRANSFER Software"** from the installed location a welcome screen will be displayed
59. Follow the below steps to operate through software

    aa. Once the software is opened, the main screen will be displaced bb. Now, press **“START”** button, and the small screen will opened

cc. Enter the parameters listed for particular test under study.

dd. the software starts displaying the calculated values which can be cross verified based on the formulae give after.

60. Before switch on the Heater Please check the Oil.
61. Switch on the heater and set the voltage (say 40V) using heater regulator.
62. Wait for sufficient time to allow temperature to reach steady values.

63. Repeat the experiment for different heat inputs and different heat inputs.

64. Wait to attain the steady state.
65. Click the **“store”** button to store the value can be viewed anytime later.
66. After completion of the Experiment to press the stop button

TABULAR COLUMN

SL No.	Heat Input		TEMPERATURE, °C		
			Inner	Surface	
	V volts	I amps	T1	T2	T3
1.					
2.					
3.					
4.					

CALCULATIONS:

1. ***HEAT INPUT TO THE SYSTEM, Q_I***

Heat input to the system = Heat carried away by water

$$Q = V \times I \quad \text{Watts}$$

Where,

V = Voltage

I = Current

2. ***THERMAL CONDUCTIVITY OF THE Concentric Sphere, K***

$$Q = \frac{4\pi r_2 r_1 K\left(T_1 - T_{avg}\right)}{(r_2 - r_1)} \quad \text{Watts}$$

Where,

r1 = radius of the inner sphere = 0.075m

r2 = radius of the outer sphere = 0.125m

K = Thermal conductivity of COPPER sphere

T1 = Temp. of the inner sphere

Tavg =Temp of the outer sphere

= (T2+T3)/2

PRECAUTIONS:

27. Input should be given very slowly.
28. Do not run the equipment if the voltage is below 180V.
29. Check all the electrical connections before running.
30. Before starting and after finishing the experiment the heater controller should be in off position.
31. Do not attempt to alter the equipment as this may cause damage to the whole system.

Results:

Calibration of thermal Conductivity on Concentric Sphere________