LABORATORY MANUAL

III Year B. Tech II- Semester

MECHANICAL ENGINEERING

AY: 2025-26

HEAT TRANSFER LAB

Prepared by:
Dr. Y. Dilip Kumar
Associate Professor

MALLAREDDYCOLLEGEOFENGINEERING&TECHNOLOGY
DEPARTMENTOFMECHANICALENGINEERING

(Autonomous Institution-UGC, Govt.of India)
Secunderabad-500100,TelanganaState,India.
www.mrcet.ac.in

MRCET CAMPUS

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(AUTONOMOUS INSTITUTION - UGC, GOVT. OF INDIA)

Affiliated to JNTUH; Approved by AICTE, NBA-Tier 1 & NAAC with A-GRADE | ISO 9001:2015

Maisammaguda, Dhulapally, Komaplly, Secunderabad - 500100, Telangana State, India

LABORATORY MANUAL & RECORD

Name:...

Roll No:.......... Branch:...

Year:........... Sem:..

MRCET CAMPUS

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(AUTONOMOUS INSTITUTION - UGC, GOVT. OF INDIA)

Affiliated to JNTUH; Approved by AICTE, NBA-Tier 1 & NAAC with A-GRADE | ISO 9001:2015

Maisammaguda, Dhulapally, Komaplly, Secunderabad - 500100, Telangana State, India

Certificate

Certified that this is the Bonafide Record of the Work Done by

Mr./Ms...Roll.No..................of

B.Tech year .... Semester for Academic year 2025-2026

in..Laboratory.

Date: Faculty Incharge HOD

Internal Examiner External Examiner

INDEX

S.No	Date	Name of the Activity/Experiment	Grade/ Marks	Faculty Signature

VISION

To become an innovative knowledge center in mechanical engineering through state-of-the-art teaching-learning and research practices, promoting creative thinking professionals.

MISSION

The Department of Mechanical Engineering is dedicated for transforming the students into highly competent Mechanical engineers to meet the needs of the industry, in a changing and challenging technical environment, by strongly focusing in the fundamentals of engineering sciences for achieving excellent results in their professional pursuits.

QUALITY POLICY

- ✓ To pursuit global Standards of excellence in all our endeavors namely teaching, research and continuing education and to remain accountable in our core and support functions, through processes of self-evaluation and continuous improvement.
- ✓ To create a midst of excellence for imparting state of art education, industry-oriented training research in the field of technical education.

(R22A0387) HEAT TRANSFER LAB

Course Objectives:

- The primary objective of this course is to provide the fundamental knowledge necessary
- To understand the behavior of thermal systems.
- This course provides a detailed experimental analysis,
- Including the application and heat transfer through solids, fluids, and vacuum.
- Convection, conduction, and radiation heat transfer in one and two dimensional steady and unsteady systems are examined

- LIST OF EXPERIMENTS:

1. Composite Slab Apparatus – Overall heat transfer co-efficient.
2. Heat transfer through lagged pipe.
3. Heat Transfer through a Concentric Sphere
4. Thermal Conductivity of given metal rod.
5. Heat transfer in pin-fin.
6. Experiment on Transient Heat conduction.
7. Heat transfer in forced convection apparatus.
8. Heat transfer in natural convection.
9. Parallel and counter flow heat exchanger.
10. Emissive apparatus.
11. Stefan Boltzmann's Apparatus.
12. Critical Heat flux apparatus.
13. Study of heat pipe and its demonstration.

Note: Total 10 experiments are to be conducted. Course

Course Outcomes:

- Perform experiments to determine the thermal conductivity of a metal rod
- Conduct experiments to determine convective heat transfer coefficient for free and forced convection and correlate with theoretical values.
- Estimate the effective thermal resistance in composite slabs
- Determine surface emissivity of a test plate
- Estimate performance of effectiveness of fin
- Calculate temperature distribution of study and transient heat conduction through plane wall, cylinder and fin using numerical approach

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

www.mrcet.ac.in

Department of Mechanical Engineering

INDEX

EXPERIMENT NO. 1

HEAT TRANSFER THROUGH COMPOSITE WALL

INTRODUCTION:

In engineering applications, we deal with many problems. Heat Transfer through composite walls is one of them. It is the transport of energy between two or more bodies of different thermal conductivity arranged in series or parallel. For example, a fastener joining two mediums also acts as one of the layers between these mediums. Hence, the thermal conductivity of the fastener is also very much necessary in determining the overall heat transfer through the medium. An attempt has been made to show the concept of heat transfers through composite walls.

AIM: To determine

1. The overall thermal conductance (C) for a composite wall and to compare with theoretical value.
2. Temperature distribution across the width of the composite wall.

APPARATUS

a. Mains on indicator
b. Console On switch for activation of the control panel.
c. Scanner for measurement of
   - **i.** Temperatures at various locations of the slab.
   - **ii.** Input Voltage.
   - **iii.** Input Current.
d. Heater regulator to regulate the input voltage.

THEORY

The apparatus consists of three slabs of Mild Steel, Bakelite and Aluminum materials of thickness 25, 20 & 12mm respectively clamped in the center using screw rod. At the center of the composite wall a heater is fitted. End losses from the composite wall are minimized by providing thick insulation all rounds to ensure unidirectional heat flow.

PROCEDURE: MANUAL MODE

1. Symmetrically arrange the plates and ensure perfect contact between the plates.
2. Give necessary electrical connections to the instruments.

3. Switch ON mains and the CONSOLE.
4. Set the heater regulator to the known value.
5. Wait for sufficient time to allow temperature to reach steady values.
6. Note down the Temperatures, voltage and current using the Data logger.
7. Calculate the overall conductance using the formulae given below.
8. Repeat the experiment for different heat input.

OBSERVATIONS:

Sl. No.	Temperatures °C						Heater Input	
	T1	T2	T3	T4	T5	T6	V	I
1								
2								
3								
4								
5								

PROCEDURE: COMPUTERIZED

1. Symmetrically arrange the plates and ensure perfect contact between the plates.
2. Give necessary electrical connections to the instruments.
3. Switch ON mains and the CONSOLE.
4. Set the heater regulator to the known value.
5. Wait for sufficient time to allow temperature to reach steady values.
6. Turn on the computer switch on the panel.
7. Switch on the computer.
8. Open the " HEAT TRANSFER Software" from the installed location a welcome screen will be displayed
9. Follow the below steps to operate through software
    a. Login using the given password into the software
    b. Screen will display the concept of the equipment. Now login to the experiment by clicking the "Click to login" button on the screen.

c. Give required username for the experiment to be conducted.

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

e. Now, press **"START"** button, and the small screen will be opened for any messages and also Specifications to be entered.

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

g. Now, set the heater regulator to known valve.

h. Wait for sufficient time to allow temperature to reach steady values.

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

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

11. After completion of the Experiment, press the **"STOP"** Button.

12. To view the stored data follow the procedure in Annexure.

CALCULATIONS ARE BASED ON THE BELOW FORMULAE:

1. HEAT FLUX (q)

$$q = \frac{V * I}{A}, W/m^2$$

Where,

V = voltmeter reading, volts

I = ammeter reading, amps

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

2. AVERAGE TEMPERATURES:

$T_A = T_1$

$T_B = (T2 + T3)/2$

$T_C = (T4 + T5)/2$

$T_D = T6$

Where,

T_A = Average inlet temperature to Aluminum.

T_B = Average outlet temperature from Aluminum/

Average inlet temperature of MS

T_C = Average outlet temperature to MS/

Average inlet temperature to Bakelite.

T_D = Average outlet temperature to Bakelite.

3. THERMAL CONDUCTANCE: PRACTICAL:

$$C = \frac{Q}{T_A - T_D}, \quad \frac{W}{m.K}$$

Where,

Q = heat input in watts

$(T_A - T_D)$ = Temperature difference as calculated.

THEORETICAL:

$$C = \frac{1}{\frac{L_1}{K_1} + \frac{L_2}{K_2} + \frac{L_3}{K_3}}, \quad \frac{W}{m}.K$$

K_1	=	205	W/m-K
K_2	=	25	W/m-K
K_3	=	0.08	W/m-K
L_1	=	12 mm	L_2 = 25 mm L_3 = 20 mm

4. OVERALL THERMAL CONDUCTIVITY OF THE SLAB, K

$$K = \frac{Q \; X \; B}{T_A - T_B} \; W/m^0K$$

Where, B = thickness of the plates on one side = 0.057m

PRECAUTIONS

- ❖ This is general equipment for study in undergraduate level, for consideration of higher level studies you can add any extra parameter required. For adding the parameters call the supplier.
- ❖ Don't run the equipment if the voltage is less than 180V.
- ❖ Don't alter the equipment without the supervision of the supplier.

RESULTS:

The overall thermal conductance (C) for a composite wall is………….

Temperature distribution across the width of the composite wall is …………

ADVANTAGES

- ✓ Light Weight
- ✓ High Strength
- ✓ Corrosion Resistance
- ✓ High-Impact Strength

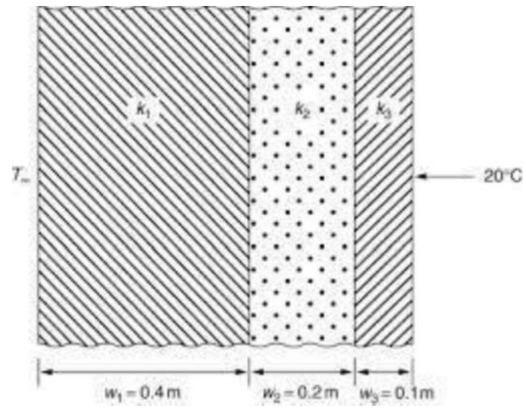
LIMITATIONS

- Composites are more brittle than wrought metals and thus are more easily damaged.
- Repair at the original cure temperature requires tooling and more costly.

APPLICATIONS

- ✓ Automotive industry
- ✓ Aerospace industry

✓ Insulated steam pipe carrying high temperature and high pressure.



VIVA-VOCE QUESTIONS

1. Define a black surface.
2. What is the range of values for the emissivity of a surface?
3. What are the conditions to be satisfied for the application of a thermal circuit?
4. Thermal conductivity of air with rise in temperature.
5. Unit of thermal conductivity in S.I. units is--
6. Cork is a good insulator because it has --
7. What is Sensible?
8. When heat is Transferred by molecular collision, it is referred to as heat transfer by
9. Thermal conductivity of solid metals with rise in temperature.
10. How is natural convection different from forced convection?

Reference:

1. Heat and Mass transfer by Arora & Domkundwar.
2. Chemical Engineers' Handbook, by Robert H. Perry / Cecil H. Chilton Publication: McGraw – Hill Book Company (6th edition).

EXPERIMENT NO. 2

CRITICAL HEAT FLUX APPARATUS

1. INTRODUCTION:

Boiling and Condensation are the specific convection processes which is associated with change of phase. The co – efficient of heat transfer are correspondingly very high when compared to natural conventional process while the accompanying temperature difference are small (quite).

However, the visualization of this mode of heat transfer is more difficult and the actual solutions are still difficult than conventional heat transfer process.

Commonly, this mode of heat transfer with change of phase is seen in Boilers, condensers in power plants and evaporators in refrigeration system.

AIM:

1. To observe the formation of pool boiling and
2. To draw the graph of heat flux Vs. Bulk Temperature up to Burnout (Critical) condition.

APPARATUS

1. The apparatus consists of a specially designed Glass Cylinder.
2. An arrangement above the Cylinder in the form of Bakelite plate is provided to place the main **Heater** and the Ni-chrome wire heater arrangement.
3. The base is made of MS and is powder coated with Rubber cushion to place the Glass cylinder.
4. **Heater regulator** to supply the regulated power input to the heater.
5. **Digital Voltmeter and Ammeter** to measure poser input ot the heater.
6. **Thermocouples** at suitable position to measure the temperatures of body and the air.
7. **Digital Temperature Indicator** with channel selector to measure the temperatures.

THEORY

The apparatus consists of cylindrical glass container housing and the test heater (Ni-chrome wire). Test heater is connected also to mains via a dimmer. An ammeter is connected in series while a voltmeter across it to read the current and voltage. The glass container is kept on a stand, which is fixed on a metallic platform. There is provision of illuminating the test heater wire with the help of a lamp projecting light from back and the heater wire can be viewed through a lens. This experimental set up is designed to study the pool-boiling phenomenon up to critical heat flux point. The pool boiling over the heater wire can be visualized in the different regions up to the critical heat flux point at which the wire melts. The heat flux from the wire is slowly increased by gradually increasing the applied voltage across the test wire and the change over from natural convection to nucleate boiling can be seen

PROCEDURE:

1. Fill in the Glass Cylinder with Distilled Water above the heater level.
2. Connect the Ni-chrome Wire (Test Wire) of suitable length.
3. Keep the heater regulator to the minimum position.
4. Connect the power cable to 1Ph, 220V, 10 Amps with earth connection.
5. Switch on the Mains On to activate the control panel.
6. By using the Main Heater heat the water to the known temperature and switch off the same.
7. Now, using the Dimmer provided start heating the Test Wire by slowly rising the Current till the wire breaks.
8. Meanwhile, record the temperature, voltage and Current till the wire breaks
9. Repeat the above experiment by replacing the Test Wire and for Different Temperatures of Water.

OBSERVATIONS

Sl. No.	Temperatures °C			Heater Input	
	T1	T2	T3	V	I
1					
2					
3					
4					
5					

CALCULATIONS:

1. **Surface Area of the Wire, A**

   A = π DL m^2

Where d = diameter of Test Wire.

L = Length of Test Wire.

2. **Heat Input, Q**

   Q = V x I Watt

Where,

V = Voltage in Volts.

I = Current in Amps.

3. **Heat Flux, q**

$$q = \frac{Q}{A} \; W/m^2$$

4. **Heat Transfer Co - efficient, h**

   Where,

$$h = 1.54q^{0.75} \; W/m^2k$$

q = Heat Flux

5. **Temperature Excess, ΔT**

$$\Delta T = \sqrt{\frac{h}{5.58}} \quad K$$

TABULAR COLUMN

Sl No	Heat Flux, q	Temperature Excess, ΔT

PRECAUTIONS

1. Clean the tank regularly after every use.
2. Do not run the equipment if the voltage is below 180V.
3. Check all the electrical connections before running.
4. Do not attempt to alter the equipment as this may cause damage to the whole system.

RESULTS:

- Draw the Graph of **q** vs. **ΔT** and
- Compare **ΔT** with the experimental Values i.e.,

  (Difference of Water Temperature and the Test Wire/Boiling Temperature)

ADVANTAGES

- ✓ The critical heat flux for ignition is the lowest thermal load per unit area capable of initiating a combustion reaction on a given material.

LIMITATIONS

- Erosion caused by pitting around the liner, cylinder head and coolant pump.
- The critical heat flux for ignition is the lowest thermal load per unit area capable of initiating a combustion reaction on a given material.

APPLICATIONS

- Chemical Process Industry
- Energy (kilns, boiler, cross flow heat exchangers, solar panels)

VIVA-VOCE QUESTIONS

1. What is meant by boiling?
2. List the various types of boiling.
3. What is pool boiling or nucleate boiling?
4. What is a critical heat flux?
5. What is its importance?
6. What are the two separate processes of nucleate boiling?
7. What is saturated boiling?
8. Define overall heat transfer coefficient.
9. What is a gray surface?
10. What do you understand by stability criterion for the solution of transient problems?

EXPERIMENT NO. 3

MEASUREMENT OF SURFACE EMMISSIVITY

AIM: The experiment is conducted to determine the emissivity of the non- black surface and compare with the black body.

APPARATUS:

The setup consists of a 200 mm diameter two copper plates one surface blackened to get the effect of the black body and other is patented 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 aluminum body having fuse.

THEORY:

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.

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 emissivity of the non – black surface.

PROCEDURE: 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

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

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

   Enter the parameters listed for particular test under study.

   the software starts displaying the calculated values which can be cross verified based on the formulae give after.
5. Switch On the heater of the black body and set the voltage (say 30V) using the heater regulator
6. Switch On the heater of the Gray body and set the voltage (say 30V) using the heater regulator.
7. 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.
8. Wait to attain the steady state.
9. Click the **"store"** button to store the value can be viewed anytime later.
10. After completion of the Experiment to press the stop button

OBSERVATIONS:

Sl. No.	Heater input				Temperature, ℃				
	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

$$\in_G = 1 - \frac{0.86*(Q_B - Q_G)}{\sigma*A*(T_S^4 - T_A^4)}$$

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.

NOTE:

If you find the above method to be more tedious, use alternate procedure and calculations.

ALTERNATE PROCEDURE:

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

1. Switch On the heater of the Gray body and set the voltage (say 45V) using the heater regulator and digital voltmeter.
2. 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.
3. Wait to attain the steady state.
4. Note down the temperatures at different points and also the voltmeter and ammeter readings.
5. Tabulate the readings and calculate the surface emissivity of the non- black surface.

ALTERNATE OBSERVATIONS:

Sl. No.	Heater input				Temperature, ℃				
	Black body		Gray body						
	Voltage V volts	Current'I' amps	Voltage'v Volts	Current'I' amps	T1	T2	T3	T4	T5
1									
2									
3									
4									

1. HEAT INPUT TO THE BLACK BODY, Q_B

$$Q_B = V * I \text{ Watts.}$$

2. HEAT INPUT TO THE GRAY BODY, Q_G

$$Q_G = V * I \text{ Watts.}$$

3. EMMISSIVITY OF THE GRAY BODY, ε_G

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

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 = T_5

PRECAUTIONS:

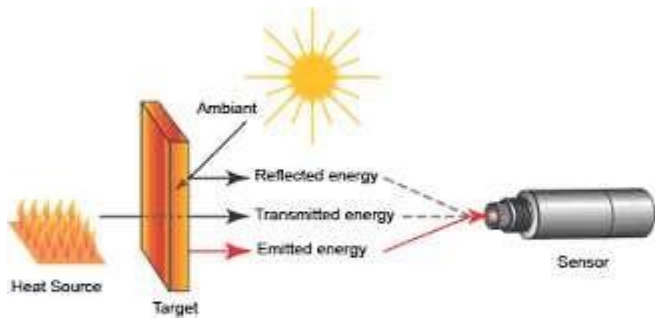
1. Check all the electrical connections.
2. Do not run the equipment if the voltage is below 180V.
3. Make sure that heater regulator is at the minimum position before switching on the console.
4. After finishing the experiment open the acrylic door to remove the heat from the chamber.
5. Do not attempt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

RESULT :

The emissivity of the gray body is ε_G =__________.

APPLICATIONS

6. Chemical Process Industry
7. Energy (kilns, boiler, cross flow heat exchangers, solar panels)



VIVA-VOCE QUESTIONS

1. Why metals are good conductors of heat?
2. Heat flows from one body to other when they have ---
3. List the various types of boiling.
4. Thermal conductivity of wood depends on
5. The rate of energy emission from unit surface area through unit solid angle, along a normal to the surface, is known as
6. What is Thermal diffusivity?
7. What is a critical heat flux?
8. Define overall heat transfer coefficient.
9. What is a gray surface?
10. What do you understand by stability criterion for the solution of transient problems?

Reference:

1) Heat and Mass transfer by Arora & Domkundwar
2) Chemical Engineers' Handbook, by
   Robert H. Perry / Cecil H. Chilton
   Publication: McGraw – Hill Book Company (6th edition)

EXPERIMENT NO. 4

HEAT TRANSFER THROUGH FORCED CONVECTION

AIM: To determine convective heat transfer coefficient in forced convection.

APPARATUS:

The apparatus consists of Heat exchanger tube made of copper which is thermally insulated outside to prevent heat transfer losses to the atmosphere. Band heaters of 500-watt capacity. Heater regulator to supply the regulated power input to the heater. Data logger is used to measure the Temperature, Voltage, current and Air flow rate Thermocouples at suitable position to measure the temperatures of body and the air.

THEORY:

Heat transfer can be defined as the transmission of energy from one region to another as a result of temperature difference between them. There are three different modes of heat transfer; namely,

HEAT CONDUCTION : The property which allows the passage for heat energy, even though its parts are not in motion relative to one another.

HEAT CONVECTION : The capacity of moving matter to carry heat energy by actual movement.

HEAT RADIATION : The property of matter to emit or to absorb different kinds of radiation by electromagnetic waves.

PROCEDURE : MANUAL MODE

1. Switch on the MCB and then console on switch to activate the control panel.
2. Switch on the blower unit first and adjust the flow of air using wheel valve of blower to a desired difference in manometer.
3. Switch on the heater and set the voltage (say 80V) using the heater regulator.

4. Wait for reasonable time to allow temperatures to reach steady state.
5. Measure the voltage, current and temperatures from T_1 to T_6 at known time interval.
6. Calculate the convective heat transfer co-efficient using the procedure given.
7. Repeat the experiment for different values of power input to the heater and blower air flow rates.

OBSERVATIONS:

SL No.	Manometer Reading, mm of water	HEAT INPUT		Air temp, °C		TEMPERATURE, °C			
						SURFACE			
	H	V	I	T4	T5	T1	T2	*T3*	*T4*
1.									
2.									
3.									
4.									

Where : V = Voltage, volts and I = Current, amps

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

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

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

   Enter the parameters listed for particular test under study.

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

5) Switch on Blower And adjust the air Flow rate By using the Valve See the Air flow rate in Indicator.
6) Switch on the heater and set the voltage (say 40V) using heater regulator.
7) Wait for sufficient time to allow temperature to reach steady values.
8) Repeat the experiment for different heat inputs and also for horizontal position with different heat inputs.
9) Wait to attain the steady state.
10) Click the **"store"** button to store the value can be viewed anytime later.
11) After completion of the Experiment to press the stop button.

CALCULATIONS:

PRACTICAL

1. $$\mathbf{h = \frac{Q}{A(T_i - T_0)}}$$

where, Q = heat given to the heater = V x I watts.

A = Area of the tube surface = π d L

d = 0.036m and L = 0.5m

Ti = mean temperature = (T1+T2+T3+T4)/4

To = (T5+T6)/2

THEORETICAL

$$\mathbf{h = \frac{(0.023 * Pr^{0.4} * Re^{0.8} * k)}{D}}$$

Where, $\mathrm{Re} = \frac{\rho V D}{\mu}$ $\mathrm{Pr} = \frac{\mu C_p}{K}$

where ,
D = inner diameter of the tube = 0.036

$$V = \frac{\text{mass flow rate of air}}{\text{Flow area}} \ {}^{m}/_{s}$$

Mass flow rate of air is calculated as follows:

$$= 0.62 \times a \times \sqrt{2gH}$$

Where,

$$a = \frac{\pi D^2}{4}$$ d= 0.015

$$H = \frac{h}{1.293}\, m\ of\ air\ column$$

Flow area is calculated as follows:

$$= \frac{\pi D^2}{4}$$ D= 0.036m

All the properties of air should be taken at (Ti + To)/2 from the data hand book.

PRECAUTIONS

1) Don't run the equipment if the voltage is less than 180V.
2) 230V, 1ph with neutral and proper earthing to be provided.
3) Don't alter the equipment without the supervision of the supplier.

RESULT:

Draw the graph of 'h' versus 'Tm' for theoretical and practical calculations and compare the results.

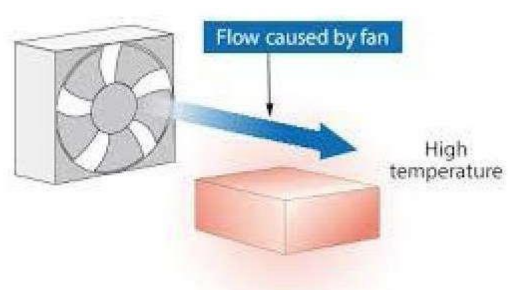
LIMITATIONS

1. Maximum Load is limited to 150V.
2. This is general equipment for study in undergraduate level, for consideration of higher level studies you can add any extra parameter required. For adding the parameters call the supplier.

APPLICATIONS

1. Thermal insulators are materials specifically designed to reduce the flow of heat by limiting conduction, convection, or both.

2. Thermal resistance is a heat property and the measurement by which an object or material resists to heat flow (heat per time unit or thermal resistance) to temperature difference.



VIVA-VOCE QUESTIONS

1. What are the modes of heat transfer?
2. Heat flows from one body to other when they have ---

3. List the various types of boiling.
4. Thermal conductivity of wood depends on
5. Write Fourier law of heat conduction
6. What is Thermal diffusivity?
7. What is a critical heat flux?
8. Define overall heat transfer coefficient.
9. What is meant by heat transfer process?
10. What do you understand by stability criterion for the solution of transient problems?

Reference:

1) Heat and Mass transfer by Arora & Domkundwar
2) Chemical Engineers' Handbook, by
   Robert H. Perry / Cecil H. Chilton

EXPERIMENT NO. 5

HEAT PIPE DEMONSTRATION

AIM:

To determine the axial heat flux in a heat pipe using water as the working fluid with that of a solid copper with different temperatures.

APPARATUS:

The apparatus consists of a Solid Copper Rod of diameter (d) 25mm and length (L) 500mm with a Source at one end and condenser at another end. Similarly, Hollow copper pipe without wick and with wick (SS mesh of 180microns) with same outer dia and length is provided.

Thermocouples are fixed on the tube surface with a phase angle of 90° on each pipe.

Control panel instrumentation consists of:

a. Digital Temperature Indicator with channel selector.
b. Digital Voltmeter & Ammeter for power measurement.
c. Heater regulator to regulate the input power.

THEORY:

One of the main objectives of energy conversion systems is to transfer energy from a receiver to some other location where it can be used to heat a working fluid. The heat pipe is a novel device that can transfer large quantities of heat through small surface areas with small temperature differences. Here in this equipment an attempt has been made to show the students, how the heat pipe works with different methods.

PROCEDURE:

1) Provide the necessary electrical connection and then CONSOLE ON switch.
2) Switch on the heater and set the voltage (say 40V) using heater regulator and the digital voltmeter.
3) Wait for sufficient time to allow temperature to reach steady values.
4) Note down the Temperatures 1 to 6 using the channel selector and digital temperature indicator.
5) Note down the ammeter and voltmeter readings.
6) Calculate the axial heat flux for all the pipes.
7) Repeat the experiment for different heat inputs and compare the results.

OBSERVATIONS:

Sl. No.	Temperatures °C						Heater Input	
	T1	T2	T3	T4	T5	T6	V	I
1								
2								
3								
4								
5								

Where : V = Voltage, volts and I = Current, amps

CALCULATIONS:

1. Calculation of heat flux, q

$$q = \frac{Q}{A} = \frac{k X \partial T}{\partial X} \; W/_{m^2}$$

where, k = Thermal conductivity of copper = 375 W/m K

dt = Temperature difference.

dx = Length b/w thermocouples.

PRECAUTIONS:

1) Check all the electrical connections.
2) Do not run the equipment if the voltage is below 180V.
3) Make sure that heater regulator is at the minimum position before switching on the console.

RESULT:

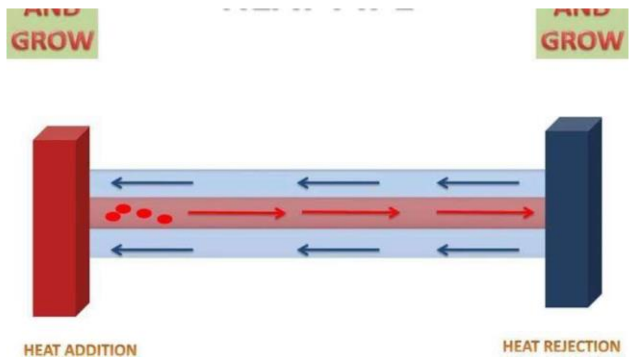
Draw the graph of 'q' versus 'Temperature difference' for different heat inputs.

LIMITATIONS:

- Most manufacturers cannot make a traditional heat pipe smaller than 3 mm in diameter due to material limitations.

APPLICATIONS:

1. Spacecraft
2. Computer systems.
3. HVAC
4. Nuclear Power Plants.



VIVA-VOCE QUESTIONS

1. What is a heat pipe?
2. Do heat pipes work against gravity?
3. What fluids are used in heat pipes?
4. Heat flows from one body to other when they have ---
5. List the various types of boiling.
6. Thermal conductivity of wood depends on
7. Write Fourier law of heat conduction
8. What is Thermal diffusivity?
9. What is a critical heat flux?
10. Define overall heat transfer coefficient.

EXPERIMENT NO. 6

HEAT TRANSFER THROUGH LAGGED PIPE

AIM:

To determine combined convective and radiation heat transfer coefficient at each zone and compare them to decide the critical thickness of insulation.

APPARATUS:

The experimental set-up consists of a copper pipe of 38mm diameter divided into four zones of 150mm each. The zone 1 is a bare pipe, and zone 2 is wound with asbestos rope to 60mm diameter, and that of zone 3 to 90mm diameter and zone 4 to 110 mm diameter. The heater of 500 watts is centered along the length of the pipe (150x4=600mm).

Heater regulator to supply the regulated power input to the heater. Digital Voltmeter and Ammeter to measure poser input at the heater. Thermocouples at suitable position to measure the temperatures of body and the air. Digital Temperature Indicator with channel selector to measure the temperatures.

Control panel to house all the instrumentation.

THEORY:

The costs involved in inserting 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 with in 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 high. 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 rises because the increased cost insulation is no longer offset by the reduced cost of heat loss.

PROCEDURE:

1. Switch on the MCB and then console on switch to activate the control panel.
2. Switch on the heater and set the voltage (say 40V) using the heater regulator and digital voltmeter.
3. Wait for reasonable time to allow temperatures to reach steady state.
4. Measure the voltage, current and temperatures from T_1 to T_7 at known time interval.

5. Calculate the heat transfer co-efficient using the procedure given.
6. Repeat the experiment for different values of power input to the heater.

OBSERVATIONS:

SL No.	HEAT INPUT		TEMPERATURE, °C SURFACE						
	V	I	T1	T2	T3	T4	T5	T6	T7
1.									
2.									
3.									
4.									

Where : V = Voltage, volts and I = Current, amps

T1 : Bare Point Inner Temperature

T2 : Zone I Inner Temperature

T3 : Zone I Outer Temperature

T4 : Zone II Inner Temperature

T5 : Zone II Outer Temperature

T6 : Zone III Inner Temperature

T7 : Zone III Outer Temperature

CALCULATIONS:

$$Q = \frac{2\pi L(T_{input} - T_{outlet})}{\frac{1}{K}\log_e\frac{R_{outer}}{R_{inner}} + \frac{1}{R_{outer}\ h_0}}$$

where, Q = heat given to the heater = V x I watts.

Router/inner indicates respective radius of the zones.

Tinput/outlet indicates respective temp. of the zones.

L = 0.150m

K2 = Thermal conductivity of insulation.

PRECAUTIONS:

1. Check all the electrical connections.
2. Do not run the equipment if the voltage is below 180V.
3. Make sure that heater regulator is at the minimum position before switching on the console.
4. Do not attempt to alter the equipment as this may cause damage to the whole system.

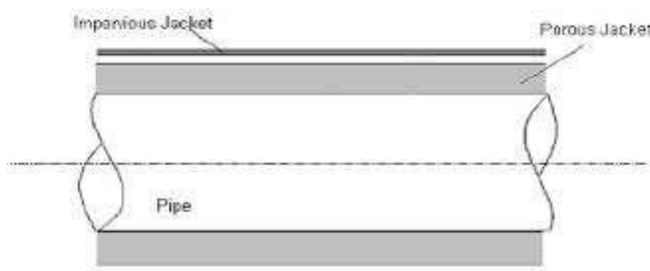
RESULT:

Draw the graph of 'h' versus 'Tm' for theoretical and practical calculations and compare the results.

APPLICATIONS:

Protection against extreme temperatures

1. Nuclear Power Plants.



VIVA-VOCE QUESTIONS

1. What is a lagged pipe?
2. Write the expansion of LMTD
3. Write the 2-limitations of Plate heat exchangers
4. Thermal conductivity of a material may be defined as the
5. Heat flows from one body to other when they have ---
6. List the various types of boiling.
7. Thermal conductivity of wood depends on
8. Write Fourier law of heat conduction
9. What is Thermal diffusivity?
10. Define overall heat transfer coefficient.

EXPERIMENT NO: 7

HEAT TRANSFER THROUGH NATURAL CONVECTION

INTRODUCTION:

There are certain situations in which the fluid motion is produced due to change in density resulting from temperature gradients. The mechanism of heat transfer in these situations is called free or natural convection. Free convection is the principal mode of heat transfer from pipes, transmission lines, refrigerating coils, hot radiators etc.

The movement of fluid in free convection is due to the fact that the fluid particles in the immediate vicinity of the hot object become warmer than the surrounding fluid resulting in a local change of density. The colder fluid creating convection currents would replace the warmer fluid. These currents originate when a body force (gravitational, centrifugal, electrostatic etc) acts on a fluid in which there are density gradients. The force, which induces these convection currents, is called a buoyancy force that is due to the presence of a density gradient within the fluid and a body force. Grashoffs number a dimensionless quantity plays a very important role in natural convection.

AIM:

To determine the natural heat transfer coefficient **'h'** from the surface of the tube in both vertical and horizontal position.

DESCRIPTION OF THE APPARATUS:

The apparatus consists of a **Chromium plated Copper tube** of diameter (d) 38mm and length (L) 500mm with a Special electrical heater along the axis of the tube for uniform heating.

Four **thermocouples** are fixed on the tube surface with a phase angle of 90°.

An arrangement to change the position of the tube to vertical or horizontal position is provided.

Front **transparent acrylic enclosure** to minimize the disturbances of the surrounding and also for safety of the tube when not in use.

Control panel instrumentation consists of:

a. Mains on, console on
b. Data logger is used to measure the Temp, Voltage and current.

c. **Heater regulator** to regulate the input power.

With this, the setup is mounted on an aesthetically designed frame with NOVAPAN Board control panel to monitor all the processes considering all **safety and aesthetics factors**.

PROCEDURE : MANUAL

1. Keep the tube in the vertical position.
2. Switch on MCB and then CONSOLE ON switch.
3. Switch on the heater and set the voltage (say 40V) using heater regulator.
4. Wait for sufficient time to allow temperature to reach steady values.
5. Note down the Temperatures 1 to 4 using the Data logger
6. Note down the Voltage and Current.
7. Calculate the convection heat transfer co-efficient using the procedure given below.
8. Repeat the experiment for different heat inputs and also for horizontal position with different heat inputs.

OBSERVATIONS:

Sl. No.	Position	Temperatures °C				Heater Input	
		T1	T2	T3	T4	V	I
1							
2							
3							
4							
5							

Where : V = Voltage, volts and I = Current, amps

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
5. Once the software is opened, the main screen will be displaced
6. Now, press **“START”** button, and the small screen will opened
7. Enter the parameters listed for particular test under study.
8. the software starts displaying the calculated values which can be cross verified based on the formulae give after.
9. Switch on the heater and set the voltage (say 40V) using heater regulator.
10. Wait for sufficient time to allow temperature to reach steady values.
11. Repeat the experiment for different heat inputs and also for horizontal position with different heat inputs.
12. Wait to attain the steady state.
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

CALCULATIONS ARE BASED ON THE BELOW FORMULAE:

PRACTICAL

1. $$h = \frac{Q}{A(T_m - T_a)}$$

where, Q = heat given to the heater = V x I watts.

A = Area of the tube surface = π d L

d = 0.038 m and L = 0.5m

Tm = mean temperature = (T1+T2+T3+T4)/4

Ta = Ambient air temperature.

THEORETICAL

1. VERTICAL POSITION: for $10^4 < Gr.Pr < 10^9$

$h_v = (0.59 \times (Gr.\,Pr)^{0.25} \times k) / L$

2. HORIZONTAL POSITION: for $10^4 < Gr.Pr < 10^9$

   $h_h = (0.53 \times (Gr.\,Pr)^{0.25} \times k) / L$

Where,

$$Pr = \frac{\mu C_p}{K} \qquad Gr = \frac{L^3 \rho^2 \beta (T_m - T_a)}{\mu^2}$$

$\beta = 1/(273+Tm)$

All the properties of air should be taken at (Tm + Ta)/2 from the data hand book.

Here , L is the characteristic length and is given as:

L = L = 0.5m for vertical position.

L = d = 0.038 for horizontal position.

LIMITATIONS & PRECAUTIONS

1. Maximum Load is limited to 120V.
2. This is a general equipment for study in undergraduate level, for consideration of higher level studies you can add any extra parameter required. For adding the parameters call the supplier.
3. Don't run the equipment if the voltage is less than 180V.
4. 230V, 1ph with neutral and proper earthing to be provided.
5. Don't alter the equipment without the supervision of the supplier.

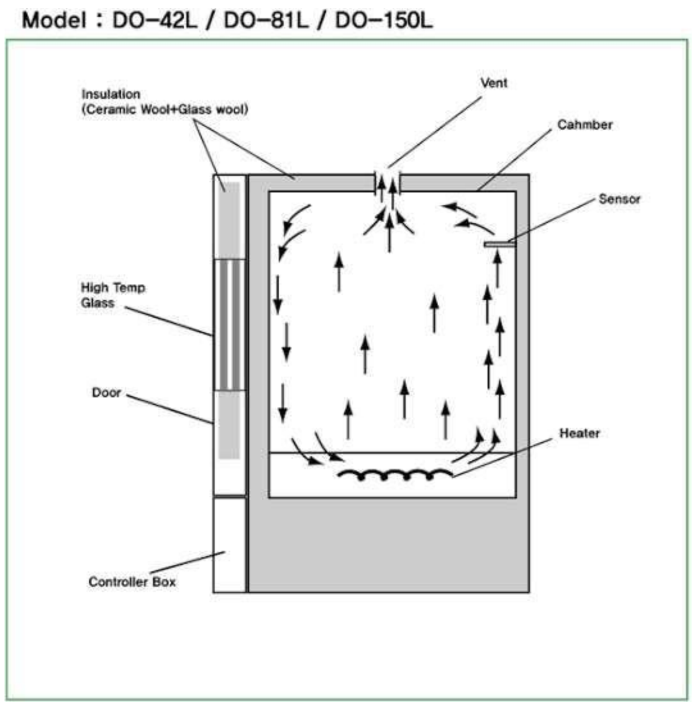
RESULT:

Draw the graph of 'h' versus 'Tm' for vertical and horizontal positions of the tube actually and theoretically calculated and compare the results.

APPLICATIONS:

1. The cooling of transmission lines.
2. The electrical transformers.
3. The cooling of rectifiers.
4. The heating of rooms by using radiators.

5. The heat transfer from hot pipes surrounded by cooler air.
6. The heat transfer from ovens surrounded by cooler air.
7. Cooling of reactor core (in nuclear power plants) and carried out the heat generated by nuclear fission.



VIVA-VOCE QUESTIONS:

1. What is free convection?
2. What is forced convection?
3. What are the applications of free convection?
4. What are the applications of forced convection?
5. What is difference between forced convection and free convection?
6. What is laminar flow?
7. What is turbulent flow?
8. What is transition flow?
9. What is boundary layer?
10. What is shear resistance?

SPECIAL NOTE:

1. The experiment should be carried out in the absence of wind flow through the window as well as in the absence of fan for better results.

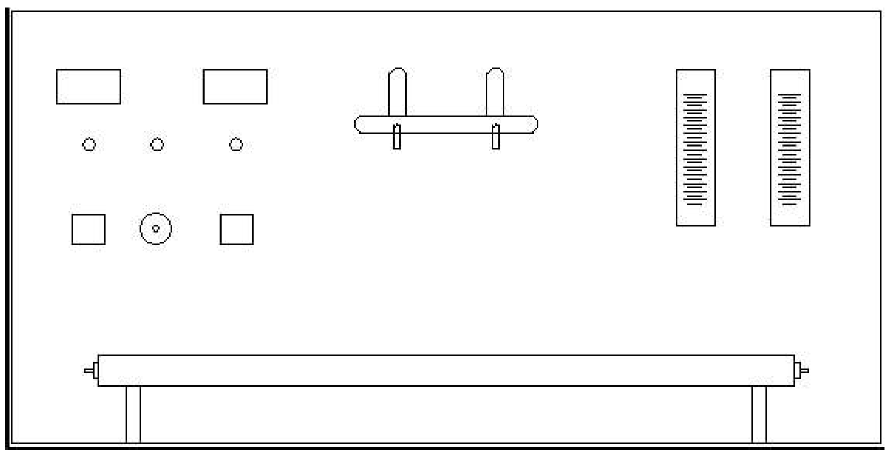
2. For better result, the horizontal and vertical experiments should be conducted after the tube is cooled down to almost room temperature.
3. For comparison of results in horizontal and vertical position the temperatures should be considered for equal interval of time, in both cases.

<u>**Reference:**</u>

1. Heat and Mass transfer by Arora & Domkundwar
2. Chemical Engineers' Handbook, by

Robert H. Perry / Cecil H. Chilton

Publication: McGraw – Hill Book Company (6th edition)



EXPERIMENT NO. 8

PARALLEL & COUNTER FLOW 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 fluid's changes 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 have logarithmic variations. LMTD is less than 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.

AIM:

To determine **LMTD & Effectiveness** of the **heat exchanger** under parallel and counter Flow arrangement.

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.

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
5. Switch ON the heater of the geyser.
6. Set the flow rate of the hot water (say 1.5 to 4 lpm) using
    a. the rotameter of the hot water.
7. Set the flow rate of the cold water (say 3 to 8 lpm) using the
    a. rotameter of the cold water.
8. Wait for sufficient time to allow temperature to reach steady
    a. 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
    a. 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
5. Once the software is opened, the main screen will be displaced
6. Now, press **"START"** button, and the small screen will open
7. Enter the parameters listed for particular test under study.
8. Start the flow on the hot water side.
9. Start the flow through annulus also.
10. Set the exchanger for parallel or counter flow using the
    a. change over mechanism.
11. Switch ON the heater of the geyser.
12. Set the flow rate of the hot water (say 1.5 to 4 Lpm) using

a. the rotameter of the hot water.

13. Set the flow rate of the cold water (say 3 to 8 Lpm) using the

    a. rotameter of the cold water.

14. Wait for sufficient time to allow temperature to reach steady

    a. values.

13. The software starts displaying the calculated values which can be cross verified based on the formulae give after.
14. Click the **"store"** button to store the value can be viewed anytime later.
15. After completion of the Experiment to press the stop button
16. Finally switch of the geyser.

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 TEMERATURE.

CALCULATIONS:

1. **HEAT TRANSFER RATE ,Q**

$$Q = \frac{Q_{H+}Q_C}{2}\ Watts$$

Where,

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

= m_H x C_{PH} x (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 x C_{PC} x (T_4 – T_3) W (for parallel flow)

= m_c x C_{PC} x (T_3 – T_4) 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:**

$$\Delta T_M = \frac{\Delta T_1 - \Delta T_0}{ln(\frac{\Delta T_1}{\Delta T_0})}$$

Where,

ΔT_I = (T_1 - T_3) for parallel flow

ΔT_I = (T_1 - T_4) for counter flow

ΔT_O = (T_2 - T_4) for parallel flow

ΔT_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:**

$$U = \frac{Q}{A \; X \; \Delta T_M} \quad W/m\,^{\circ}K$$

Where,

Q = heat transfer rate

A = π x D_O x L m^2 where, D_O = 0.02m & L = 1m.

ΔT_M = LMTD.

4. **EFFECTIVENESS OF HEAT EXCHANGER, E**

EXPERIMENTAL:

$$\textbf{Eexp}=\frac{T_{CO}-T_{CI}}{T_{HI}-T_{CI}} \quad \text{if } C_{max} > C_{min}$$

$$Eexp = \frac{(T_{HI}-T_{HO})}{T_{HI}-T_{CI}} \quad \text{if } C_{max} < C_{min}$$

THEORETICAL:

THEORETICAL:

$$Eth = \frac{1-e^{-NTU(1+R)}}{(1+R)}$$ For PARALLEL FLOW

$$Eth = \frac{1-e^{-NTU(1-R)}}{1-R^{-NTU(1-R)}}$$ 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

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

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

Other notations have their usual meaning.

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

$$\%Error = \frac{Eth - Eexp}{Eth} * 100$$

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.

RESULT:

Effectiveness of the **heat exchanger** under parallel is

Effectiveness of the **heat exchanger** under counter Flow arrangement is

APPLICATIONS:

1. Intercoolers and air pre heaters.
2. Condensers and boilers in steam plant.
3. Condensers and evaporators in refrigeration units.

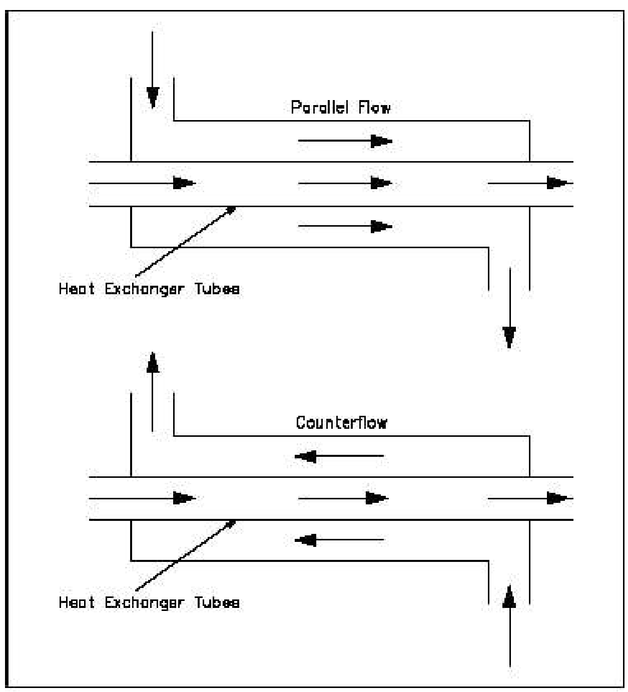


Figure 9 Fluid Flow Direction

VIVA-VOCE QUESTIONS:

1. What is heat exchanger?
2. Classificatins of heat transfer?

3. What is evaporation?

4. What is mean by fouling factor in heat exchanger?

5. Define heat exchanger effectiveness?

6. What is mean of parallel flow heat exchanger?

7. What is mean of counter flow heat exchanger?

8. What is difference between parallel flow and counter flow heat exchanger?

9. What is mean of cross flow heat exchanger?

10. What is LMTD?

Reference:

1. Heat and Mass transfer by Arora & Domkundwar
2. Chemical Engineers' Handbook, by

   Robert H. Perry / Cecil H. Chilton

   Publication: McGraw – Hill Book Company (6th edition)

EXPERIMENT NO. 9

PIN-FIN APPARATUS

INTRODUCTION:

A spine or pin-fin is an extended surface of cylindrical or conical shape used for increasing the heat transfer rates from the surfaces, whenever it is not possible to increase the rate of heat transfer either by increasing heat transfer co-efficient or by increasing the temperature difference between the surface and surrounding fluids. The fins are commonly used on engine heads of scooter, motorcycles, as well as small capacity compressors. The pin type fins are also used on the condenser of a domestic refrigerator.

AIM:

1. To find out the temperature distribution along the given fin for constant base temperature under natural and force flow conditions.
2. To find out effectiveness of the fin under both conditions.

DESCRIPTION OF THE APPARATUS:

The apparatus consists of

Pin type fin of dia 12mm and 150 mm long made of **copper** with suitable temperature points.

Heater of 250 watts capacity.

Heater regulator to supply the regulated power input to the heater.

Digital Data logger is used to measure power input to the heater.

Thermocouples at suitable position to measure the surface temperatures of the fin.

Blower unit to blow air through the duct with orifice meter and **acrylic manometer** to measure the air flow rate from the blower. A control valve is provided to regulate the air flow.

Control panel to house all the instrumentation.

With this the whole arrangement is mounted on an aesthetically

Designed self-sustained MS powder coated frame with a separate control panel.

PROCEDURE:

1. Switch on the MCB and then console on switch to activate the control panel.
2. Switch on the heater and regulate the power input using the heater regulator.
3. Switch on the blower unit and adjust the flow of air using gate valve of blower to a desired difference in manometer (**for forced flow only otherwise skip to step 4)**.
4. Wait for reasonable time to allow temperatures to reach steady state.
5. Measure the voltage, current and temperatures from T_1 to T_6 at known time interval.
6. Calculate the effectiveness & efficiency of the fin using the procedure given.
7. Repeat the experiment for different values of power input to the heater and blower air flow rates.

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
5. Once the software is opened, the main screen will be displaced
6. Now, press **"START"** button, and the small screen will opened
7. Enter the parameters listed for particular test under study.
8. The software starts displaying the calculated values which can be cross verified based on the formulae give after.
9. Select the Process Natural or Forced If you selected forced Switch on the Blower. U selected Natural Air Flow is not required. Switch of the Blower.
10. Switch on Blower and adjust the air Flow rate by using the Valve See the Air flow rate in Indicator.
11. Switch on the heater and set the voltage (say 40V) using heater regulator.
12. Wait for sufficient time to allow temperature to reach steady values.
13. Repeat the experiment for different heat inputs and also for horizontal position with different heat inputs.
14. Wait to attain the steady state.
15. Click the **"store"** button to store the value can be viewed anytime later.

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

OBSERVATIONS:

SL No.	Manometer Reading, m of water		HEAT INPUT		Air temperature, °C	TEMPERATURE, °C		
						SURFACE		
	H1	H2	V	I	T4	T1	T2	T3
1.								
2.								
3.								
4.								

CALCULATIONS:

NATURAL CONVECTION

N_U = = 1.1 $(Gr.Pr)^{1/6}$ when 10^{-1} Gr Pr 10^{4}

= 0.53 $(Gr.Pr)^{0.25}$ when 10^{4} Gr Pr 10^{9}

= 0.13 $(Gr.Pr)^{0.33}$ when 10^{9} Gr Pr 10^{12}

Where,

$$Pr = \frac{\mu C_p}{K} \qquad Gr = \frac{L^3 \rho^2 \beta (T_m - T_a)}{\mu^2}$$

$\beta = 1/(273+T_m)$

where ,

Tm = mean effective temperature of the fin.

Ta = ambient temperature of the chamber.

All the properties of air should be taken at (Tm + Ta)/2 from the data hand book.

FORCED CONVECTION

N_U = $0.615(R_e)^{0.466}$ when 40< Re > 4000

N_U = $0.174(Re)^{0.168}$ when 40 00 < Re > 40 x 10^3

$$Re = \frac{\rho V D}{\mu}$$

where ,

D = inner diameter of the tube =

$$V \quad \frac{mass\ flow\ rate\ of\ air}{Flow\ area} \text{ m/s}$$

Mass flow rate of air is calculated as follows:

= 0.62 x a x $\sqrt{2gH}$

where, a = $\frac{\pi d^2}{4}$, d= 0.020

$$H = \frac{(H1 \sim H2) \times 1000}{1.293} \text{ m of air column}$$

Flow area is calculated as follows:

$$= \frac{\pi D^2}{4}, \quad D = 0.050m$$

All the properties of air should be taken at (Tm + Ta)/2 from the data hand book.

Now after doing the above steps find the following:

TEMPERATURE DISTRIBUTION ALONG THE FIN

The temperature distribution along the fin is given by,

$$\frac{T_X - T_1}{T_1 - T_6} = \frac{Coshm(L - X)}{Cosh(mL)}$$

Where

T_x= is the temperature along the fin at a distance 'x'

Measured from the base,

T_1 = is the fin base temperature,

T_6 = is surrounding air temperature

x = is the distance of the unknown temperature point and

L = is the length of the fin = 0.11m

$$m = \sqrt{\frac{hp}{K_{f A_c}}}$$

Where

Ac = is the Cross-section area of the fin

$= \frac{\pi Dc^2}{4}, D_c = 0.012$

P = is perimeter of the fin = πDc,

K_f= is conductivity of fin material = 380 W/m - °K

h = is the heat transfer co-efficient of fin

$$h = \frac{Nu\ X\ Kair}{Dc}$$

where,

Nu = Nusselt Number calculated

K_{air} = from the property tables

Dc = diameter of the fin = 0.012

After calculating the value of 'h' find the value of 'm' and then find out T_x at distances from the base of the fin and compare with the obtained reading

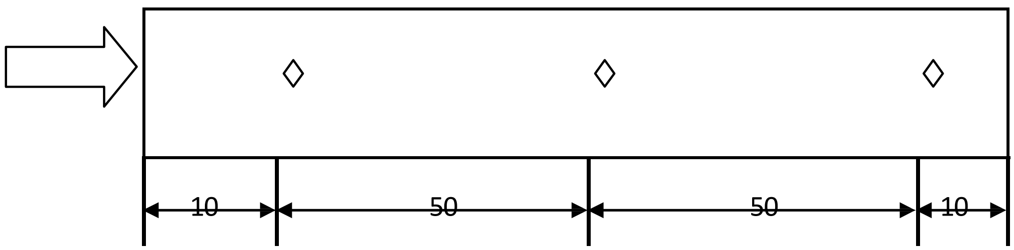
RATE OF HEAT TRANSFER FROM THE FIN

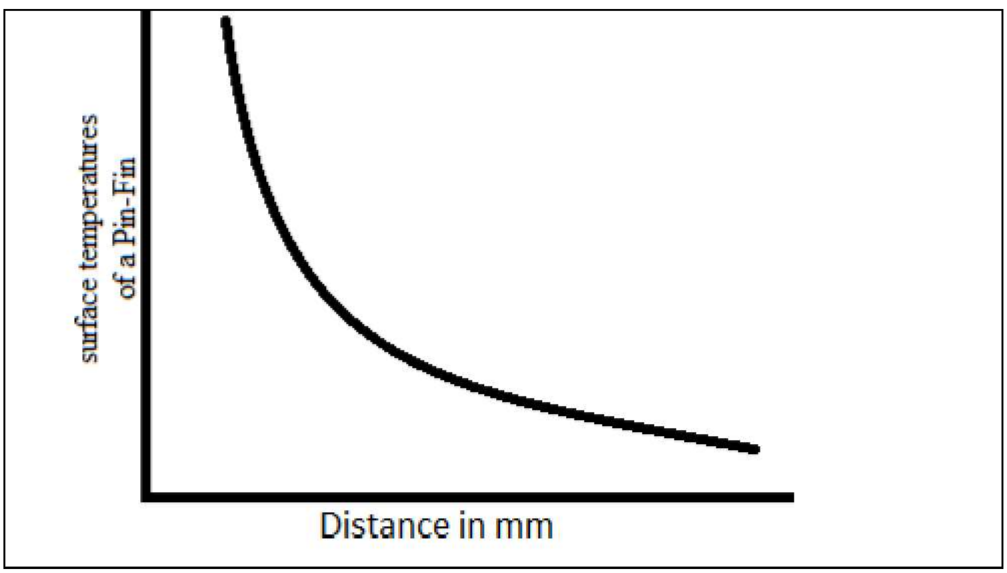
$$Q = \sqrt{hPK_fA} \text{ x (Tm – Ta) x tanh (mL)}$$

Where the units have their usual meaning

EFFICIENCY OF THE FIN

$$H_{mech} = \frac{\tan h\ (ml)}{ml}$$





RESULT:

1. The temperature distribution along the given fin for constant base temperature under natural and force flow conditions are
2. Effectiveness of the fin under both conditions are.

APPLICATIONS:

1. Economizers for steam power plants.
2. Convectors for steam and hot water heating systems.

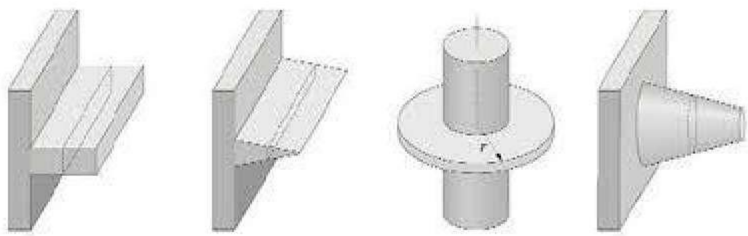
3. Radiator in automobiles.

4. Air-cooled engine cylinder heads.

5. Small capacity compressors.

6. Electric motor bodies.

7. Transformers and electronic equipments.



VIVA-VOCE QUESTIONS:

1. What is use fin?
2. Define efficiency of the fin?
3. Define effectiveness of the fin?
4. What are the assumptions are made for the analysis of heat flow through the fin?
5. What are the types of fins?
6. Define heat transfer coefficient?
7. Define thermal conductivity?
8. What do you meat homogeneous material?
9. What is thermal resistance?
10. What is steady state?

EXPERIMENT NO. 10

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 °K⁴

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, for 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 follows temperature proportionality.

AIM:

To determine the Stefan Boltman's constant.

DESCRIPTION OF THE APPARATUS:

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.

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

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

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

6. Now, press **"START"** button, and the small screen will be opened
7. Enter the parameters listed for particular test under study.
8. Now, set the temp by using thermostat regulator to known valve.
9. Now press "START BUTTON" on the screen so the software automatically starts recording the temperatures and other values.
10. Switch on the heater and regulate the power input using the heater regulator. (say 60 – 85 °C)
11. After water attains the maximum temperature, open the valve of the heater and dump to the enclosure jacket.
12. Wait for about few seconds to allow hemispherical enclosure to attain uniform temperature – the chamber will soon reach the equilibrium. Note the enclosure temperature.
13. Also, the software starts displaying the calculated values which can be cross verified based on the formulae give thereafter.
14. Enter the **STORE BUTTON** to store the values.
15. Press report button to see the stored values
16. finally, thermostat you kept at 0 *C

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:

$$\sigma = \frac{m\,Cp\,(dTs/dt)=0}{A_D\,(T_e^4 - T_s^4)}$$

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

PRECAUTIONS:

1. Check all the electrical connections.
2. Do not run the equipment if the voltage is below 180V.
3. Do not switch on the heater without water in the overhead tank.
4. Do not turn the heater regulator to the maximum as soon as the equipment is started.
5. Do not attempt to alter the equipment as this may cause damage to the whole system.

RESULT:

Stefan Boltzman’s constant is ________________

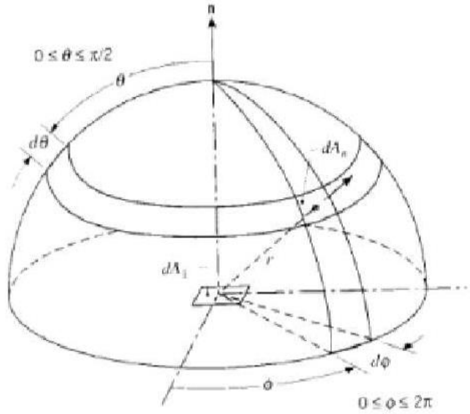


FIGURE 12.8
Emission from a differential element of area dA_1 into a hypothetical hemisphere centered at a point on dA_1.

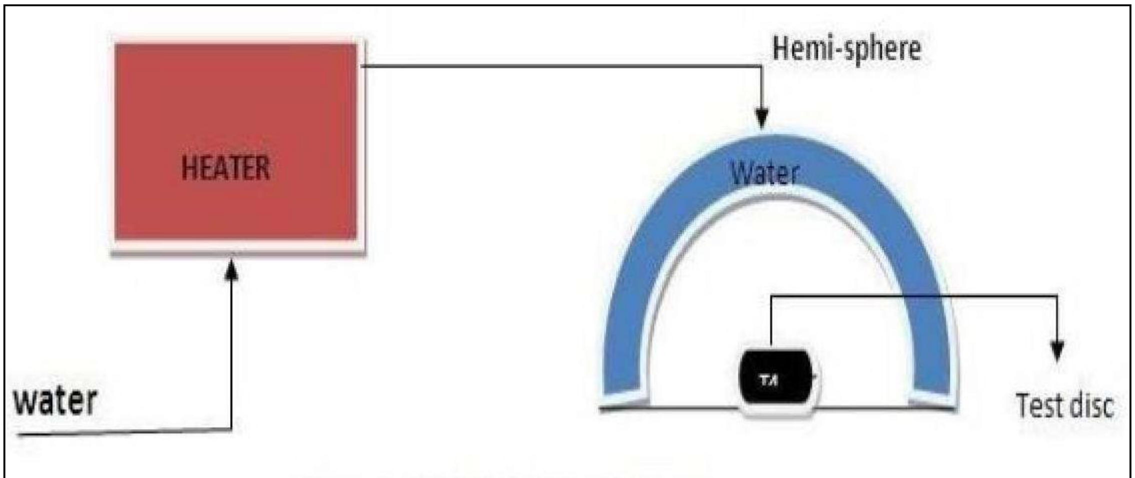


FIG: STEFAN BOLTZMANN APPARATUS

VIVA-QUESTIONS:

1. Define radiation heat transfer?
2. Define total emissive power?
3. Define monochromatic emissive power?
4. Define emissivity?
5. Define intensity of radiation?
6. Define absorptivity?
7. Define reflectivity?
8. Define transmitivity?
9. State Kirchhoff law?
10. State plank's law?

Reference:

1. Heat and Mass transfer by Arora & Domkundwar
2. Chemical Engineers' Handbook, by
   Robert H. Perry / Cecil H. Chilton

Publication: McGraw – Hill Book Company (6th edition)

EXPERIMENT NO. 11

THERMAL CONDUCTIVITY OF 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 vibration 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.

AIM:

To determine the THERMAL CONDUCTIVITY of given concentric sphere.

DESCRIPTION OF THE APPARATUS:

The apparatus consists of the **COPPER sphere of 150 mm diameter and 250 mm diameter 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.

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

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
5. Once the software is opened, the main screen will be displaced
6. Now, press **"START"** button, and the small screen will opened
7. Enter the parameters listed for particular test under study.
8. the software starts displaying the calculated values which can be cross verified based on the formulae give after.
9. Before switch on the Heater Please check the Oil.
10. Switch on the heater and set the voltage (say 40V) using heater regulator.
11. Wait for sufficient time to allow temperature to reach steady values.
12. Repeat the experiment for different heat inputs and different heat inputs.
13. Wait to attain the steady state.
14. Click the **"store"** button to store the value can be viewed anytime later.
15. 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 x I Watts

Where,

V = Voltage

I = Current

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

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

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:

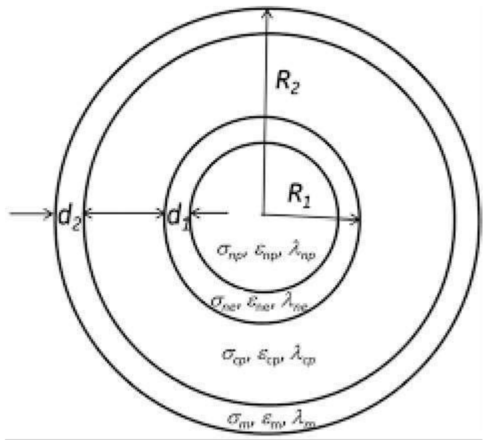
1. Input should be given very slowly.
2. Do not run the equipment if the voltage is below 180V.
3. Check all the electrical connections before running.
4. Before starting and after finishing the experiment the heater controller should be in off position.
5. Do not attempt to alter the equipment as this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

RESULT:

THERMAL CONDUCTIVITY of given concentric sphere is

APPLICATIONS:

1. Storage of chemicals.
2. Storage of fluids.



VIVA-VOCE QUESTIONS:

1. Define heat?
2. Define heat transfer?
3. Enumerate the basic laws which govern the heat transfer?
4. What is conduction heat transfer?
5. What is the significance of heat transfer?
6. Aplicationsof heat transfer?
7. What is fourier's law of heat conduction?
8. State some essential features of fourier's law?
9. Define thermal conductivity of material?
10. What is thermal resistance?
11. What is newton's law of cooling?
12. Define insulation?
13. What are the applications of insulations?
14. Define critical thickness of insulation?

Reference:

1. PROCESS HEAT TRANSFER, by
2. Wareh L. McCabe
3. Julian C. Smith
4. Peter Harioth
5. Publication: McGraw Hill (6^{th} edition)
6. Heat and Mass transfer by Arora & Domkundwar

EXPERIMENT NO. 12

THERMAL CONDUCTIVITY OF METAL ROD

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.

AIM:

To determine the THERMAL CONDUCTIVITY of given metal rod.

DESCRIPTION OF THE APPARATUS:

The apparatus consists of the **COPPER rod of 200mm test section**. Heat is provided by means of **band heater** at one end and released through **water jacket** arrangement. **Thermocouples** are provided at the suitable points to measure the surface and water 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.

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. Start the cooling water supply through the water jacket (make sure not to exceed 3 lpm).
5. Note the temperature at different points, when steady state is reached.
6. Repeat the experiment for different heater input.
7. After the experiment is over, switch off the electrical connections, allow the water to flow for some time in the water jacket and then stop it.

PROCEDURE : COMPUTERIZED

TAKING READINGS – COMPUTERIZED

1. Turn on the computer 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
5. Once the software is opened, the main screen will be displaced
6. Now, press **"START"** button, and the small screen will be opened
7. Enter the parameters listed for particular test under study.
8. the software starts displaying the calculated values which can be cross verified based on the formulae give after.
9. Give input to the heater by slowly rotating the heater regulator.
10. Start the cooling water supply through the water jacket (make sure not to exceed 3 lpm).
11. Click the **"store"** button to store the value can be viewed anytime later.
12. After completion of the Experiment to press the stop button.

TABULAR COLUMN

SL No.	Rotameter Reading, R lpm	Water temperature, °C		TEMPERATURE, °C SURFACE			
		T5	T6	T1	T2	T3	T4
1.							
2.							
3.							
4.							

CALCULATIONS:

1. **CROSS – SECTIONAL AREA OF METAL ROD:**

$$A = \frac{\pi d^2}{4} \; m^2$$

Where,

d = diameter of the of the metal rod = 0.05 m.

π = constant

2. **MASS FLOWRATE OF WATER, m_W**

$$m_w = \frac{R}{60} \; kg/sec$$

Where,

R = Rotameter reading in lpm.

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

Heat input to the system = Heat carried away by water

$Q_I = Q_W$

$Q_W = m_W \times Cp_W \times \Delta T_W$ Watts.

Where,

m_W = mass flowrate of water, kg/sec.

Cp_W = Specific heat of water = 4180 J/kg °K .

ΔT_W = Temperature difference of water inlet and outlet from

the water jacket.

= (T1 – T2) °K

4. THERMAL CONDUCTIVITY OF THE METAL ROD, K

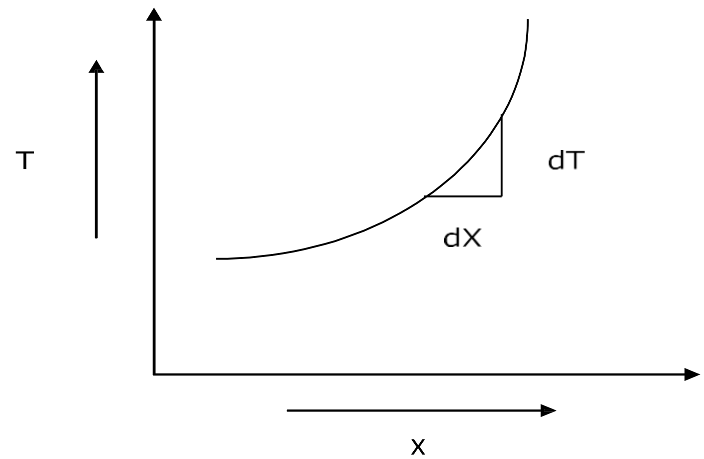
$$K = \frac{Q_I}{A \times (\frac{dt}{dx})} \; w/m^0K$$

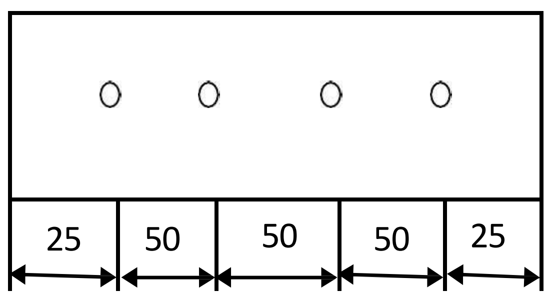
Where,

A = cross – sectional area of the rod

$(dT/dX)_A$ = slope calculated from graph. (shown in the diagram)

Where '**X'** = test length with thermocouple points as shown below





PRECAUTIONS:

1. Do not give heater input without the supply of water.
2. Input should be given very slowly.
3. Run the water in the jacket for about 5 min after the experiment.
4. Do not run the equipment if the voltage is below 180V.
5. Check all the electrical connections before running.
6. Before starting and after finishing the experiment the heater controller should be in off position.
7. Do not attempt to alter the equipment as this may cause damage to the whole system.

RESULT:

The THERMAL CONDUCTIVITY of given metal rod is

APPLICATIONS:

1. Design of thermal and nuclear power plants.

2. Design of heat engines.

3. Design of steam generators.

4. Design of condensers.

5. Design of space vehicles.

VIVA-VOCE QUESTIONS:

1. Define heat?
2. Define heat transfer?
3. enumerate the basic laws which govern the heat transfer?
4. What is conduction heat transfer?
5. What is the significance of heat transfer?
6. aplicationsof heat transfer?
7. What is fourier's law of heat conduction?
8. state some essential features of fourier's law?
9. define thermal conductivity of material?
10. What is thermal resistance?
11. What is newton's law of cooling?

Reference:

1 PROCESS HEAT TRANSFER, by

Wareh L. McCabe Julian C. Smith Peter Harioth

Publication: McGraw Hill (6th edition)

2 Heat and Mass transfer by Arora & Domkundwar

3 Chemical Engineers' Handbook, by

Robert H. Perry / Cecil H. Chilton

Publication: McGraw – Hill Book Company (6th edition)

EXPERIMENT NO. 13

TRANSIENT HEAT CONDUCTION APPARATUS

INTRODUCTION:

When a body is subjected to heating or cooling, irrespective of the material it requires 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 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:

- **PERIODIC HEAT FLOW** : where the temperature within the system undergoes periodic changes which may be regular or irregular.
- **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.

AIM:

- To determine heat transfer coefficient and instantaneous heat transfer rate for transient heat conduction and draw the graph of temperature variation with time

DESCRIPTION OF APPARATUS:

- The apparatus consists of a specially designed **Stainless-Steel Tank with heater arrangement.**
- An **ALUMINIUM sphere** is provided to study the experiment with the stand to place in the heater tank.
- **Heater regulator with Thermostat** to supply the regulated power input to the heater and to set the temperature.
- **Thermocouples** at suitable position to measure the temperatures.
- **Digital data logger** used to measure the temperatures.

- The whole arrangement is mounted on an aesthetically designed sturdy frame made of NOVAPAN Board with all the provisions for holding the tanks and accessories.

PROCEDURE : MANUAL

1. Take the fluid (water or oil) in the tank.
2. Heat the fluid to the required temperature say 70°C in case of water and more than 100 °C in case of oil.
3. Note down the initial temperature of sphere and hot fluid.
4. Immerse the sphere in hot fluid bath for heating.
5. Note down the surface temperature of the sphere at every 10 seconds till it attains fluid temperature.
6. Take out the sphere from hot fluid and cool it in atmospheric air.
7. Repeat the experiment for different temperatures of fluid.

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
5. Once the software is opened, the main screen will be displaced on the main screen press **"PORT"** button and select the USB port connected,
6. Now, press **"START"** button, and the small screen will be opened
7. Enter the parameters listed for particular test under study.
8. Now, set the temp by using thermostat regulator to known valve.
9. Now press "START BUTTON" on the screen so the software automatically starts recording the temperatures and other values.
10. Also, the software starts displaying the calculated values which can be cross verified based on the formulae give thereafter.
11. Enter the **STORE BUTTON** to store the values.
12. Press report button to see the stored values
13. finally, thermostat you kept at 0 *C

OBSERVATIONS

Initial Temp. of the fluid, T_1 =____°C

Initial Temp. of the sphere, T2=____°C

Sl. No.	Temperatures °C		Time, t sec
	T1	T2	

CALCULATIONS:

Determination of Heat Transfer Co-efficient, h

$$h = \frac{N_u K}{D}\ W/_{m^2 K}$$

Where,

Nu = Nusselt Number and is given by

$N_u = 2 + 0.43\,(G_r P_r)^{0.25}$ for $1<GrPr<10^5$

$N_u = 2 + 0.50\,(G_r P_r)^{0.25}$ for $3x10^5<GrPr<8x10^5$

Pr = Pradantle Number from handbook

G_r = Grashoff's Number & is given by

$$Gr = \frac{D^3 \rho^2 \beta g \Delta T}{\mu^2}$$

D = Diameter of sphere = 0.075 m

K = Thermal conductivity of fluid, W/mK,

water or oil in case of heating,

air in case of cooling

ρ = Density of fluid, kg/m^3

β = Volumetric thermal expansion coefficient, /K

= $1/(T_f+273)$

T_f = Mean film temperature, °C

= $(T_o+T\infty)/2$

Δt = Temp. difference between sphere and fluid, °C

= $(T_o \sim T\infty)$

μ = Absolute viscosity of fluid, $N\text{-}s/m^2$

NOTE:

Properties of fluid such as ρ, μ, K, P_r are obtained from HMT data book at T_f

Determination of Instantaneous Heat Flow, Q

Where,

$$\boldsymbol{Q_i = -hA(T_i - T_\infty)e^{-Bi\,Fo}} \text{ **Watts**}$$

$$Bi = \frac{hr}{K_S}$$

$$Fo = \frac{\alpha t}{r^2}$$

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

A = Surface area of the sphere = $4\pi r^2$.

α=Thermal diffusivity of sphere material =84.18x10^{-6} m^2/s

t = Time at the given instant, sec

r= Radius of the sphere, m

T_i= T1 =Temperature of the sphere at given time instant, °C,

T_∞=T2= Initial temperature of hot fluid or cold fluid

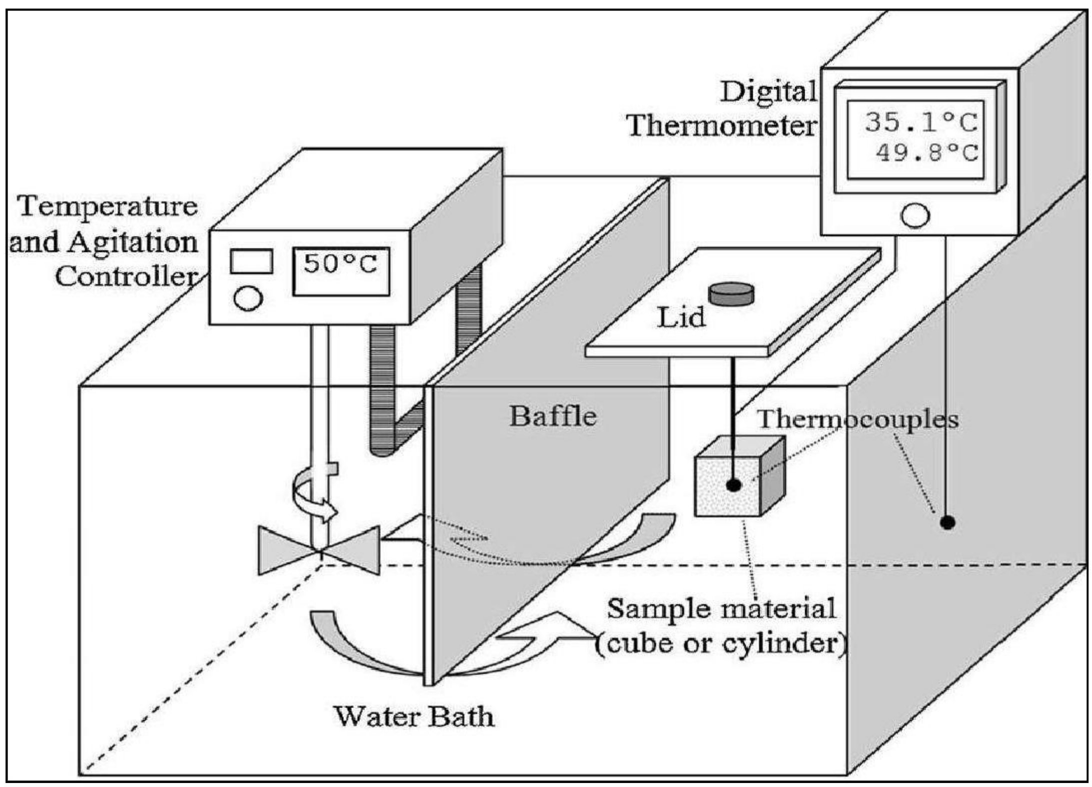
K_s= Thermal conductivity of sphere = 205 W/mK

1. Determination of Theoretical Temperatures, T

$$\frac{(T - T_\infty)}{(T_i - T_\infty)} = e^{-B_i F_o}$$

T= Temperature of the sphere in the given time, °C

Fo is obtained at different time instants



LIMITATIONS & PRECAUTIONS

1. Maximum Load is limited to 70°C.
2. This is general equipment for study in undergraduate level, for consideration of higher level studies you can add any extra parameter required. For adding the parameters call the supplier.

3. Don’t run the equipment if the voltage is less than 180V.
4. 230V, 1ph with neutral and proper earthing to be provided.
5. Don’t alter the equipment without the supervision of the supplier.

RESULTS:

The heat transfer coefficient for transient heat conduction is

GRAPHS:

- Experimental temperature v/s time,
- Theoretical temperature v/s time

APPLICATIONS:

1.Cooling of IC engines.

2.Automobile engines.

3. Heating and cooling of metal billets.

4. Cooling and freezing of food.

5. Heat treatment by quenching.

6. Brick burning.

7. Vulcanizations of rubber.

8. Starting and stopping of various heat exchange units in power installation.

VIVA-VOCE QUESTIONS:

1. What do you meat steady state?
2. What do you meat un-steady state?
3. Applications of un-steady state conduction?
4. What do you mean periodic variation un-steady state conduction?
5. What do you mean non-periodic variation un-steady state conduction?
6. What do you mean netonian heating or cooling?
7. What do you meat thermal time constant?
8. What is thermal diffusivity?
9. Define characteristic length?
10. Define biot number?
11. Define fourier’number?
12. What is lumped capacity?
13. What are the assumptions for lumped capacity analysis?
14. Define a semi-infinite body?
15. What are significance of heslier charts in solving transient conduction problems?

Reference:

1 Heat and Mass transfer by Arora & Domkundwar
2 Chemical Engineers' Handbook, by
Robert H. Perry / Cecil H. Chilton

Publication: McGraw – Hill Book Company (6th edition)