MARRI LAXMAN REDDY
INSTITUTE OF TECHNOLOGY AND MANAGEMENT
(AN AUTONOMOUS INSTITUTION)
(Approved by AICTE, New Delhi & Affiliated to JNTUH, Hyderabad)
Accredited by NBA and NAAC with 'A' Grade & Recognized Under Section2(f) & 12(B)of the UGC act,1956

DEPARTMENT MECHANICAL ENGINEERING

HEAT TRANSFER
LAB MANUAL

SUBJECT NAME	**Heat Transfer Lab**
SUBJECT CODE	**2050381**
COURSE-BRANCH	**B. Tech - Mechanical Engineering**
YEAR-SEMESTER	**III - II**
ACADEMIC YEAR	**2022-2023**
REGULATION	**MLRS-R20**

MARRI LAXAMAN REDDY
INSTITUTE OF TECHNOLOGY AND MANAGEMENT

MISSION AND VISION OF THE INSTITUTE:

Our Vision:

To establish as an ideal academic institution in the service of the nation the world and the humanity by graduating talented engineers to be ethically strong globally competent by conducting high quality research, developing breakthrough technologies and disseminating and preserving technical knowledge.

Our Mission:

To fulfill the promised vision through the following strategic characteristics and aspirations:

- Contemporary and rigorous educational experiences that develop the engineers and managers;
- An atmosphere that facilitates personal commitment to the educational success of students in an environment that values diversity and community;
- Prudent and accountable resource management;
- Undergraduate programs that integrate global awareness, communication skills and team building across the curriculum;
- Leadership and service to meet society's needs;
- Education and research partnerships with colleges, universities, and industries to graduate education and training that prepares students for interdisciplinary engineering research and advanced problem solving;
- Highly successful alumni who contribute to the profession in the global society.

Vision and Mission statements of the Department of Mechanical Engineering:

Vision Statement:

"The Mechanical Engineering Department strives immense success in the field of education, research and development by nurturing the budding minds of young engineers inventing sets of new designs and new products which may be envisaged as the modalities to bring about a green future for humanity"

Mission Statement:

1. Equipping the students with manifold technical knowledge to make them efficient and independent thinkers and designers in national and international arena.
2. Encouraging students and faculties to be creative and to develop analytical abilities and efficiency in applying theories into practice, to develop and disseminate new knowledge.

3. Pursuing collaborative work in research and development organizations, industrial enterprises, Research and academic institutions of national and international, to introduce new knowledge and methods in engineering teaching and research in order to orient young minds towards industrial development.

PROGRAM EDUCATIONAL OBJECTIVE

PEO 1: Graduates shall have knowledge and skills to succeed as Mechanical engineers for their career development.

PEO 2: Graduates will explore in research.

PEO 3: Mechanical Graduates shall have the ability to design products with various interdisciplinary skills

PEO 4: Graduates will serve the society with their professional skills

PROGRAM OUTCOMES

- **A.** Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals and an engineering specialization for the solution of complex engineering problems.
- **B.** Problem Analysis: Identify, formulate, research, review the available literature and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural science and engineering sciences.
- **C.** Design and development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specific needs with appropriate considerations for public health safety and cultural, societal and environmental considerations.
- **D.** Conduct investigations of complex problems: Use research based knowledge and research methods including design of experiments, analysis and interpretation of data and synthesis of the information to provide valid conclusions.
- **E.** Modern tool usage: Create, select and apply appropriate techniques, resources and modern engineering and IT tools including predictions and modeling to complex engineering activities with an understanding of the limitations.
- **F.** The Engineer and society: Apply reasoning, informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practices.
- **G.** Environment and sustainability: Understand the impact of the professional engineering solutions in society and environmental context and demonstrate the knowledge of and need for sustainable development.
- **H.** Ethics: Apply ethical principles and commitment to professional ethics, responsibilities and norms of the engineering practice.
- **I.** Individual and team work: Function effectively as an individual and as a member or leader in diverse teams and in multi-disciplinary settings.
- **J.** Communication: Communicate effectively on complex engineering activities with the engineering community and with the society at large, such as being able to comprehend, write effective reports, design documentation, make effective presentations, give and receive clear instructions.
- **K.** Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
- **L.** Life – long learning: Recognize the need and have the preparation, ability to engage in independent and life – long learning in the broadest context of technological change.

PROGRAMME SPECIFIC OUTCOMES:

PS01: Students acquire necessary technical skills in mechanical engineering that make them employable graduate.

PSO2: An ability to impart technological inputs towards development of society by becoming an entrepreneur.

COURSE OBJECTIVES:

1. To demonstrate the concepts discussed in the Heat Transfer course
2. To experimentally determine thermal conductivity and heat transfer coefficient through various materials.
3. To experimentally measure effectiveness of heat exchangers.
4. To experimentally measure Stefan Boltzmann constant.

COURSE OUTCOMES:

ME 381.1	Applications of concepts of Conduction, Convection & Radiation Principles.
ME 381.2	Calculation of thermal conductivity Heat transfer coefficient of various experiments.
ME 381.3	Calculation of heat transfer coefficient of various experiments.
ME 381.4	Analyzing the performance parameters of HeatExchanger.
ME 381.5	Evaluation of emissivity of real surfaces
ME 381.6	Assessment of Stefan boltz’s mann constant.

INSTRUCTIONS TO THE STUDENTS

1. Every student should obtain a copy of the laboratory manual
2. It is important that all students arrive at each session on time.
3. Dress code: Students must come to the laboratory wearing:
   - Trousers.
   - half-sleeve tops.
   - Leather shoes.
   - Half pants, loosely hanging garments and slippers are not allowed.
4. Students should come with thorough preparation for the experiment to be conducted.
5. Students will not be permitted to attend the laboratory unless they bring the practical record fully completed in all respects pertaining to the experiment conducted in the previous class.
6. Experiment should be started only after the staff-in-charge has checked the experimental setup.
7. All the calculations should be made in the observation book. Specimen calculations for one set of readings have to be shown in the practical record.
8. Wherever graphs are to be drawn, A-4 size graphs only should be used and the same should be firmly attached to the practical record.
9. Practical record and observation should be neatly maintained.
10. They should obtain the signature of the staff-in-charge in the observation book after completing each experiment.
11. Theory regarding each experiment should be written in the practical record before procedure in your own words.

LABORATORY SAFETY PRECAUTIONS

1. Laboratory uniform, shoes & safety glasses are compulsory in the lab.
2. Do not touch anything with which you are not completely familiar. Carelessness may not only break the valuable equipment in the lab but may also cause serious injury to you and others in the lab.
3. Please follow instructions precisely as instructed by your supervisor. Do not start the experiment unless your setup is verified & approved by your supervisor.
4. Do not leave the experiments unattended while in progress.
5. Do not crowd around the equipment's & run inside the laboratory.
6. During experiments material may fail and disperse, please wear safety glasses and maintain a safe distance from the experiment.
7. If any part of the equipment fails while being used, report it immediately to your supervisor. Never try to fix the problem yourself because you could further damage the equipment and harm yourself and others in the lab.
8. Keep the work area clear of all materials except those needed for your work and cleanup after your work.

LIST OF EXPERIMENTS

1. Determination of overall heat transfer co-efficient of a composite slab.
2. Determination of heat transfer rate through a lagged pipe.
3. Determination of heat transfer rate through a concentric sphere.
4. Determination of thermal conductivity of a metal rod.
5. Determination of efficiency of a pin-fin.
6. Determination of heat transfer coefficient in forced convection.
7. Determination of heat transfer coefficient in natural convection.
8. Determination of effectiveness of parallel and counter flow heat exchangers.
9. Determination of emissivity of a given surface.
10. Determination of Stefan Boltzmann constant.
11. Determination of heat transfer rate in drop and film wise condensation.
12. Determination of critical heat flux.
13. Demonstration of heat pipe.
14. Determination of Heat transfer coefficient and instantaneous heat transfer for transient heat conduction.

1.THERMAL CONDUCTIVITY OF METAL ROD

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.

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 **digital temperature indicator** on the control panel, which also consists of **heater regulator** and other accessories instrumentation having good aesthetic looks and safe design.

EXPERIMENTATION:

AIM:

To determine the THERMAL CONDUCTIVITY of given metal rod.

PROCEDURE:

- Give necessary electrical and water connections to the instrument.
- Switch on the MCB and console ON to activate the control panel.
- Give input to the heater by slowly rotating the heater regulator.
- Start the cooling water supply through the water jacket (make sure not to exceed 3 lpm).
- Note the temperature at different points, when steady state is reached.
- Repeat the experiment for different heater input.

- 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.

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:*

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

Where,

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

π = constant

2. *MASS FLOWRATE OF WATER, m_W*

$$m_W = \frac{R}{60} \quad kg/\ sec.$$

Where,

R = Rotameter reading in lpm.

3. *HEAT INPUT TO THE SYSTEM, Q_I*

Heat input to the system = Heat carried away by water

$$Q_I = Q_W$$

$$Q_W = m_W \times Cp_W \times \Delta T_W \quad \text{Watts.}$$

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.

= (T5 – T6) °K

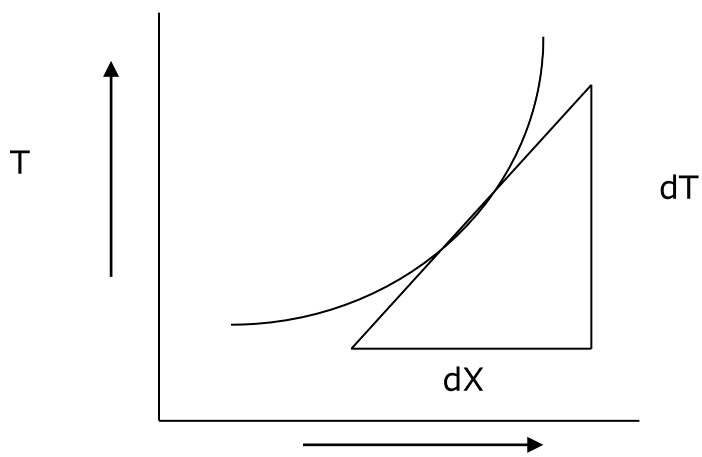
4. ***THERMAL CONDUCTIVITY OF THE METAL ROD, K***

$$K = \frac{Q_I}{A \times (dT/dX)_A} \quad \text{W/m - °K}$$

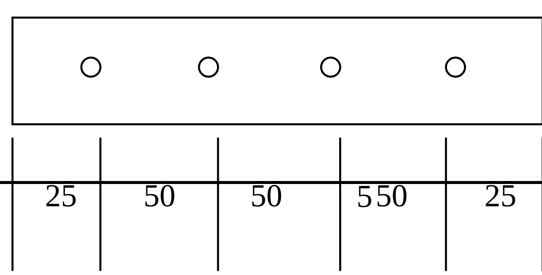
Where,

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:

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

VIVA QUESTIONS :

1. Define thermal conductivity.
2. For which material thermal conductivity is highest?
3. Why negative sign in Fourier's Law?
4. What are the units of thermal conductivity?
5. What is the first law of thermodynamics?
6. What is the second law of thermodynamics?
7. How is thermal conductivity measured practically?
8. Why are diamonds sinks used in cooling electronic components?
9. What is the physical mechanism of conduction in solids, liquids and gases?
10. What do you mean by "ρcp"?
11. What is the physical significance of thermal diffusivity?
12. Is heat transfer a scalar or vector quantity?
13. What do you mean by steady heat transfer and how does it differ from transient heat transfer?
14. What is lumped system? How does heat

transfer in a lumped system differ from steady heat transfer?

15. From heat transfer point of view, what is the difference between isotopic and un isotopic materials?
16. What is heat generation in a solid?
17. How are ordinary and partial differential equations used in heat transfer analysis?
18. What is a boundary condition? Explain.
19. What is the material for which thermal conductivity is to be found in thermal conductivity of solids experiment?
20. What are the units of specific heat?

2.COMPOSITE WALL

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.

DESCRIPTION OF THE APPARATUS:

The apparatus consists of three slabs of Bakelite, CI 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 round to ensure unidirectional heat flow.

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

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

EXPERIMENTATION:

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.

PROCEDURE:

1. Symmetrically arrange the plates and ensure perfect contact between the plates.
2. Switch ON mains and the CONSOLE.
3. Set the heater regulator to the known value.
4. Wait for sufficient time to allow temperature to reach steady values.
5. Note down the Temperatures 1 to 8 using the channel selector and digital temperature indicator.
6. Note down the ammeter and voltmeter readings.
7. Calculate the overall conductance using the procedure given below.
8. Repeat the experiment for different heat input.

OBSERVATIONS:

Sl. No.	Temperatures °C								Heater Input	
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	V	I
1										
2										
3										

CALCULATIONS:

1. **HEAT FLUX ,Q**

$$Q = \frac{V \times I}{A} \text{ Watts}$$

Where,

V = voltmeter reading, volts

I = ammeter reading, amps

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

2. **AVERAGE TEMPERATURES:**

$T_A = (T1 + T2)/2$

$T_B = (T3 + T4)/2$

$T_C = (T5 + T6)/2$

$T_D = (T7 + T8)/2$

Where,

T_A = Average inlet temperature to CI.

T_B = Average outlet temperature to CI.

Average inlet temperature of Bakelite

T_C = Average outlet temperature to Bakelite.

Average inlet temperature to Aluminium.

T_D = Average outlet temperature to Aluminium.

3. **THERMAL CONDUCTANCE:**

PRACTICAL:

$$C = \frac{Q}{(T_A - T_D)} \qquad \text{W/m °K}$$

Where,

Q = heat input in watts

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

THEORETICAL:

$$C = \frac{1}{1/A\,(L_1/K_1 + L_2/K_2 + L_3/K_3)} \quad W/m\ °K$$

K_1 = 25 W/m °K

K_2 = 0.08 W/m °K

K_3 = 204 W/m °K

L_1 = 25 mm L_2 = 20 mm L_3 = 12 mm

4. **OVERALL THERMAL CONDUCTIVITY OF THE SLAB, K**

$$K = \frac{Q \times B}{(T_A - T_D)} \quad W/m\ °K$$

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

5. **PLOT TEMPERATURE DISTRIBUTION CURVE**

PRECAUTIONS:

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

VIVA QUESTIONS

1. Define thermal conductivity?
2. For which material thermal conductivity is highest?
3. Why negative sign in Fourier's Law?
4. What are the units of thermal conductivity?
5. What is the first law of thermodynamics?
6. What is the second law of thermodynamics?
7. How is thermal conductivity measured practically?
8. Why are diamonds sinks used in cooling electronic components?
9. What is the physical mechanism of conduction in solids, liquids and gases?
10. What do you mean by "ρcp"?
11. What is the physical significance of thermal diffusivity?
12. Is heat transfer a scalar or vector quantity?
13. What do you mean by steady heat transfer and how does it differ from transient heat transfer?
14. What is lumped system? How does heat transfer in a lumped system differ from steady heat transfer?
15. How are ordinary and partial differential equations used in heat transfer analysis?
16. What is a boundary condition? Explain. 1. What is convection?
17. Classify convection.
18. What is forced convection & natural convection?
19. Explain difference between forced convection and natural convection?
20. Force convection in a liquid bath is caused by----

3.HEAT TRANSFER THROUGH LAGGED PIPE

HEAT TRANSFER THROUGH LAGGED PIPE

INTRODUCTION:

The costs involved in insulting either heated or refrigerated equipment, air-conditioned rooms, pipes, ducts, tanks, and vessels are of a magnitude to warrant careful consideration of the type and quantity of insulation to be used. Economic thickness is defined as *the minimum annual value* of the sum of the cost of heat loss plus the cost of insulation, or, in more general terms, as the thickness, of a given insulation that will save the greatest cost of energy while paying for itself within an assigned period of time. At low values of thickness, the amortized annual cost of insulation is low, but the annual cost of heat energy is 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.

The calculation of economic thickness for an industrial installation is not easy, owing to the large number of variables and separate calculations involved. This has all been reduced to manual form in "How to determine economic thickness of insulation", published by National Insulation Manufacturers Association, New York.

CRITICAL THICKNESS OF INSULATION:

It must not be taken for granted that insulation only retards the rate of heat flow. The addition of small amount of insulation to small diameter wires or tubes frequently increases the rate of heat flow through the tube to the ambient air. It was shown elsewhere in the standard books with experiment that the rate of heat loss was increased by the addition of the asbestos sheet.

CRITICAL THICKNESS OF INSULATION FOR CYLINDER:

When a solid cylinder of radius R1 is insulated with an insulation of thickness(R2-R1), then the heat flow from the surface of the solid cylinder to the surrounding is given by

$$Q = \frac{2\,\pi L\,(T_{input} - T_{outlet})}{\frac{1}{K_2} \log_e \frac{R_{outer}}{R_{inner}} + \frac{1}{R_{outer} h_o}} \quad W$$

Where, L is the length of the cylinder,

K_2 is the conductivity of the insulation, and

h_O is the combined(convection and radiation) heat transfer co-efficient on the outer surface of the insulation.

DESCRIPTION:

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 dia, and that of zone 3 to 90mm dia and zone 4 to 110mm dia. The heater of 500 watts is centred 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 ot 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.

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

EXPERIMENTATION:

AIM:

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

PROCEDURE:

- Switch on the MCB and then console on switch to activate the control panel.
- Switch on the heater and set the voltage (say 40V) using the heater regulator and digital voltmeter.
- Wait for reasonable time to allow temperatures to reach steady state.
- Measure the voltage, current and temperatures from T_1 to T_7 at known time interval.
- Calculate the heat transfer co-efficient using the procedure given.
- 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:

$$Q = \frac{2\,\pi L\,(T_{input} - T_{outlet})}{\frac{1}{K_2}\,log_e \frac{R_{outer}}{R_{inner}} + \frac{1}{R_{outer} h_o}} \quad W$$

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

$R_{outer/inner}$ indicates respective radius of the zones.

$T_{input/outlet}$ indicates respective temp. of the zones.

L = 0.150m

K_2 = Thermal conductivity of insulation.

RESULT:

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

PRECAUTIONS:

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

VIVA QUESTIONS

1.What is conduction?

2.State Fourier’s law of conduction

3.Define Thermal conductivity

4.Write down the equation for conduction of heat through a slab or plane wall.

5.Write down the equation for conduction of heat through a hollow cylinder.

6.What are the factors affecting the thermal conductivity?

7.What id meant by lagged ?

8.Write the equation for calculating heat transfer in cylindrical components

9. Write the equation for calculating heat transfer in Spherical components

10.What are various materials used for insulating?

11.What are the various factors effecting on heat transfer coefficient?

12.What is meant by Zone

13.What is meant by critical thickness?

14. Explain Reynolds number?
15. What is critical Reynolds number?
16. Explain Prandtl number.
17. Fluid properties are evaluated at what temperature?
18. For forced convection, Nussult number is a function of---------
19. The Prandtl number will be lowest for------
20. What is significance of Nussult’s number in convection?

4.NATURAL CONVECTION

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 with in the fluid and a body force. Grashoffs number a dimensionless quantity plays a very important role in natural convection.

ESCRIPTION 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.

Contol panel instrumentation consists of:

d. **Digital Temperature Indicator** with channel selector.
e. **Digital Voltmeter** & **Ammeter** for power measurement.
f. **Heater regulator** to regulate the input power.

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

EXPERIMENTATION:

AIM:

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

PROCEDURE:

9. Keep the tube in the vertical position.
10. Switch on MCB and then CONSOLE ON switch.
11. Switch on the heater and set the voltage (say 40V) using heater regulator and the digital voltmeter.
12. Wait for sufficient time to allow temperature to reach steady values.
13. Note down the Temperatures 1 to 4 using the channel selector and digital temperature indicator.
14. Note down the ammeter and voltmeter readings.

15. Calculate the convection heat transfer co-efficient using the procedure given below.
16. Repeat the experiment for different heat inputs and also for horizontal position with different heat inputs.

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.

OBSERVATIONS:

Sl. No.	Position	Temperatures °C				Heater Input	
		T_1	T_2	T_3	T_4	V	I
1							
2							
3							
4							
5							

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

CALCULATIONS:

PRACTICAL

$$\frac{Q}{A\,(Tm - Ta)}$$

1. h = ________

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

A = Area of the tube surface = π d L

d = 0.038m 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,

$$Pr = \frac{\mu\ Cp}{k} \qquad Gr = \frac{L^3 \rho^2 \beta\ (Tm - Ta)}{\mu^2}$$

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

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.

RESULT:

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

PRECAUTIONS:

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

VIVA QUESTIONS

1. What is convection?
2. Classify convection.
3. What is forced convection & natural convection?
4. Explain difference between forced convection and natural convection?
5. On which properties does convection heat transfer strongly depend?
6. Define convection heat transfer coefficient with dimensions.
7. Define Nussult number.
8. Develop velocity boundary layer for flow over a flat plate?
9. The Prandtl number will be lowest for------
10. What is significance of Nussult's number in convection?
11. The hydro dynamic and thermal boundary layers are identical at Prandtl number equal to-----
12. The temperature gradient in the fluid flow over a heated plate will be------
13. The ratio of heat transfer by convection to that by conduction is called-----
14. Define buoyancy force and discuss significance of the buoyancy force in Natural convection?
15. Define volume expansion coefficient and discuss significance in Natural convection?

16. Define Grashoff number and discuss significance of Grashoff number?
17. The free convection heat transfer is significantly affected by----
18. The dimension less parameter ( ) 3 3 3 g l t μ β ρ Δ is called as----
19. The convective heat transfer coefficient from a hot cylindrical surface exposed to still air varies in accordance with------
20. For Laminar conditions, the thickness of thermal boundary layer increases with the distance from the leading edge in proportion to-----

5.FORCED CONVECTION

HEAT TRANSFER THROUGH FORCED CONVECTION

INTRODUCTION:

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.

Out of these types of heat transfer the convective heat transfer which of our present concern, divides into two catagories, Viz.,

NATURAL CONVECTION : If the motion of fluid is caused only due to difference in density resulting from temperature gradients without the use of pump or fan, then the mechanism of heat transfer is known as "*Natural or Free Convection*".

FORCED CONVECTION : If the motion of fluid is induced by some external means such as a pump or blower, then the heat transfer process is known as "*Forced Convection*".

The newtons law of cooling in convective heat transfer is given by,

$$q = h \, A \, \Delta T$$

Where, **q** = Heat transfer rate, in watts

A = Surface area of heat flow, in m^2

ΔT = Overall temperature difference between the wall and fluid, in ^{o}C

h = Convection heat transfer co-efficient, in watts/m^2 ^{o}C

This setup has been designed to study heat transfer by forced convection.

DESCRIPTION OF THE 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 500watts capacity.

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

Digital Voltmeter and Ammeter to measure poser input ot 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.

Blower unit to blow air through the heat exchanger with orifice meter and 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 NOVAPAN Board control panel.

EXPERIMENTATION:

AIM:

To determine convective heat transfer coefficient in forced convection.

PROCEDURE:

- Switch on the MCB and then console on switch to activate the control panel.
- Switch on the blower unit first and adjust the flow of air using wheel valve of blower to a desired difference in manometer.
- Switch on the heater and set the voltage (say 80V) using the heater regulator and digital voltmeter.
- Wait for reasonable time to allow temperatures to reach steady state.
- Measure the voltage, current and temperatures from T_1 to T_6 at known time interval.

- Calculate the convective heat transfer co-efficient using the procedure given.
- Repeat the experiment for different values of power input to the heater and blower air flow rates.

OBSERVATIONS:

SL No.	Manometer Reading, m of water		HEAT INPUT		Air temperature, °C		TEMPERATURE, °C SURFACE			
	H1	H2	V	I	T4	T5	T1	T2	T3	T4
1.										
2.										
3.										
4.										

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

CALCULATIONS:

PRACTICAL

1. $h = \dfrac{Q}{A\,(Ti - To)}$

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)/3

THEORETICAL

$$h = (0.023 \times Pr^{0.4} \times Re^{0.8} \times k) / D$$

Where,

$$Re = \frac{\rho VD}{\mu} \qquad Pr = \frac{\mu\, Cp}{K}$$

where ,

D = inner diameter of the tube = 0.036

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

<u>Mass flow rate of air is calculated as follows</u>:

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

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

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

<u>Flow area is calculated as follows</u>:

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

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

RESULT:

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

PRECAUTIONS:

- Check all the electrical connections.
- Do not run the equipment if the voltage is below 180V.
- Do not obstruct flow of air while experiment is going on.

- Make sure that heater regulator is at the minimum position before switching on the console.
- Do not attempt to alter the equipment as this may cause damage to the whole system.

VIVA QUESTIONS

1. What is convection?
2. Classify convection.
3. What is forced convection & natural convection?
4. Explain difference between forced convection and natural convection?
5. Force convection in a liquid bath is caused by----
6. Explain Newton's law of cooling?
7. Give the relation between 'Fluid velocity' and 'Heat transfer'?
8. On which properties does convection heat transfer strongly depend?
9. Define convection heat transfer coefficient with dimensions.
10. Define Nussult number.
11. Develop velocity boundary layer for flow over a flat plate?
12. What is drag force?
13. Define friction coefficient (or) drag coefficient?
14. Explain Reynolds number?
15. What is critical Reynolds number?
16. Explain Prandtl number.
17. Fluid properties are evaluated at what temperature?
18. For forced convection, Nussult number is a function of---------
19. The Prandtl number will be lowest for------
20. What is significance of Nussult's number in convection?

6.STEFAN BOLTZMAN’S APPARATUS

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 hat 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.

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.

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

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

Digital Temperature Indicator with channel selector to measure the temperatures.

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.

EXPERIMENTATION:

AIM:

- To determine the Stefan Boltman's constant.

PROCEDURE:

- Fill water slowly into the overhead water heater.
- Switch on the supply mains and console.
- Switch on the heater and regulate the power input using the heater regulator. (say 60 – 85 °C)
- After water attains the maximum temperature, open the valve of the heater and dump to the enclosure jacket.
- Wait for about few seconds to allow hemispherical enclosure to attain uniform temperature – the chamber will soon reach the equilibrium. Note the enclosure temperature.
- Insert the Test specimen with the sleeve into its position and record the temperature at different instants of time using the stop watch.
- Plot the variation of specimen temperature with time and get the slope of temperature versus time variation at the time t = 0 sec

- Calculate the Stefan Boltzman's constant using the equations provided.
- Repeat the experiment 3 to 4 times and calculate the average value to obtain the better results.

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

RESULT:

Stefan Boltzman's constant is ____________

PRECAUTIONS:

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

VIVA QUESTIONS

1. Explain Radiation.
2. Heat energy transfers in radiation in which form?
3. What is a Block body?
4. Explain Stefan – Boltzman's law? What is value of the Stefan – Boltzman contant?
5. Explain spectral blackbody emissive power?
6. Discuss Planck's distribution law.
7. Define emissivity.
8. Explain obsorptivity, reflectivity and transmissivity.
9. Define irradiation.
10. Explain Kirchoff's law.
11. Radiation between two surfaces mainly depends on-----
12. Define Shape factor (or) view factor (or) configure factor (or) angle factor

13. Explain Radiosity?
14. Explain Radiation Heat transfer between two surfaces?
15. What is network representation and what is its algebra?
16. Define Radiation shields?
17. Thermal radiation occur in the portion of electro magnetic spectrum between the wavelengths ---
18. For infinite parallel plates with emissivities $\varepsilon 1$ and $\varepsilon 2$ shape factor for radiation from surface 1 to surface 2 is ----
19. Why water is heated before starting the experiment?
20. What is the function of glass tube?

7.PARALLEL & COUNTER FLOW HEAT EXCHANGER

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 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 **Digital Temperature indicator** with **channel selector** is provided to measure the temperature.

The whole arrangement is mounted on an **Aesthetically designed self sustained sturdy frame** made of **MS tubes** with **NOVAPAN board control**

panel. The control panel houses all the indicators, accessories and necessary instrumentations.

EXPERIMENTATION:

AIM:

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

PROCEDURE:

17. Switch ON mains and the CONSOLE.
18. Start the flow on the hot water side.
19. Start the flow through annulus also.
20. Set the exchanger for parallel or counter flow using the change over mechanism.
21. Switch ON the heater of the geyser.
22. Set the flow rate of the hot water (say 1.5 to 4 Lpm) using the rotameter of the hot water.
23. Set the flow rate of the cold water (say 3 to 8 Lpm) using the rotameter of the cold water.
24. Wait for sufficient time to allow temperature to reach steady values.
25. Note down the Temperatures 1 to 4 using the channel selector and digital temperature indicator.
26. Note down the flow rates of the water and tabulate.
27. Now, change the direction of flow for the same flow rates and repeat the steps 9 to 11.
28. Repeat the experiment for different flow rates of water.

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:

T1 = COLD WATER INLET TEMPERATURE (in case of parallel flow)
COLD WATER OUTLET TEMPERATURE (in case of counter flow)
T2 = COLD WATER OUTLET TEMPERATURE (in case of parallel flow)
COLD WATER INLET TEMPERATURE (in case of counter flow)
T3 = HOT WATER INLET TEMPERATURE.
T4 = HOT WATER OUTLET TEMERATURE.

CALCULATIONS:

6. HEAT TRANSFER RATE ,Q

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

WHERE,

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

= $m_H \times C_{PH} \times (T4 - T3)$ 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. (T3+T4)/2

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

= $m_C \times C_{PC} \times (T2 - T1)$ W (for parallel flow)

= $m_C \times C_{PC} \times (T1 - T2)$ 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. (T1+T2)/2

7. LMTD – Logarithmic mean temperature difference:

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

Where,

ΔT_I = $(T_{HI} - T_{CI})$ for parallel flow

ΔT_I = $(T_{HI} - T_{CO})$ for counter flow

ΔT_O = $(T_{HO} - T_{CO})$ for parallel flow

ΔT_O = $(T_{HO} - T_{CI})$ for counter flow

NOTE: The suffix H = HOT WATER

C = COLD WATER

I = INLET

O = OUTLET

8. OVERALL HEAT TRANSFER CO-EFFICIENT:

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

Where,

Q = heat transfer rate

$A = \pi \times D_O \times L$ m² where, D_O = 0.02m & L = 1m.

ΔT_M = LMTD.

9. EFFECTIVENESS OF HEAT EXCHANGER, Ɛ

EXPERIMENTAL:

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

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

THEORETICAL:

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

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

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.

10. PERCENTAGE OF ERROR, %ERROR

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

PRECAUTIONS:

- Check all the electrical connections.
- Do not run the equipment if the voltage is below 180V.

Do not attempt to alter the equipment as this may cause damage to the whole system.

VIVA QUESTIONS:

1. Force convection in a liquid bath is caused by----
2. Explain Newton's law of cooling?
3. Give the relation between 'Fluid velocity' and 'Heat transfer'?
4. On which properties does convection heat transfer strongly depend?
5. Define convection heat transfer coefficient with dimensions.
6. Define Nussult number.
7. Develop velocity boundary layer for flow over a flat plate?
8. What is drag force?
9. Define friction coefficient (or) drag coefficient?
10. Explain Reynolds number?
11. What is critical Reynolds number?
12. Explain Prandtl number.
13. Fluid properties are evaluated at what temperature?
14. For forced convection, Nussult number is a function of---------
15. The Prandtl number will be lowest for------
16. What is significance of Nussult's number in convection?
17. The temperature gradient in the fluid flow over a heated plate will be------
18. The ratio of heat transfer by convection to that by conduction is called-----
19. Define buoyancy force and discuss significance of the buoyancy force in Natural convection?
20. Define Grashoff number and discuss significance of Grashoff number?

8.CONDENSATION APPARATUS

CONDENSATION APPARATUS

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.

Centrifugal Monoblock Pump with control valves and bypass to regulate the flow of water through the condenser tube.

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.

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

EXPERIMENTATION:

AIM:

- To determine overall heat transfer coefficient (U_O)
- To determine steam side film coefficient (h_S)
- To determine cold fluid heat transfer coefficient (h_I)
- To draw Wilson's plot and hence calculate the value of h_I theoretical from graph.(optional)

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 $0.2 kg/cm^2$) 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/cm²).

- **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/cm²	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

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

where,

W = Cold fluid flow rate, lpm

2. HEAT CARRIED AWAY BY COLD FLUID

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

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

$$M_C = \frac{Vc}{T} \quad Kg/s$$

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

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

Where,

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

5. <u>OVERALL HEAT TRANSFER CO – EFFICIENT</u>

$$U_O = \frac{Q_C}{A \times \Delta t_{LMTD}} \quad W/m^2 - {}^\circ K.$$

Where,

Q_C = heat carried away by water, Watt.

A = Area occupied by the inner tubes, m².

= $\pi D_O \times L \times N$ 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. <u>COLD FLUID HEAT TRANSFER CO - EFFICIENT</u>:

$$h_I = 0.023 \times (Re)^{0.8} \times (Pr)^{0.3} \times (K/D_I) \quad W/m^2 - {}^\circ K.$$

Where,

Re = Reynolds number.

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

V = Velocity of the cold fluid,

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

$$A_T = \frac{\pi \times D_I^2}{4} \quad m^2.$$

ρ = density of the fluid, kg/m³.

μ = viscosity of fluid, Cp.

Pr = Prandlt Number.

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

11. STEAM SIDE HEAT TRANSFER CO - EFFICIENT

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

Where,

$\Delta T = (T_S - T_W) \quad {}^\circ K.$

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

L = Length of the condenser = 0.18 m.

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

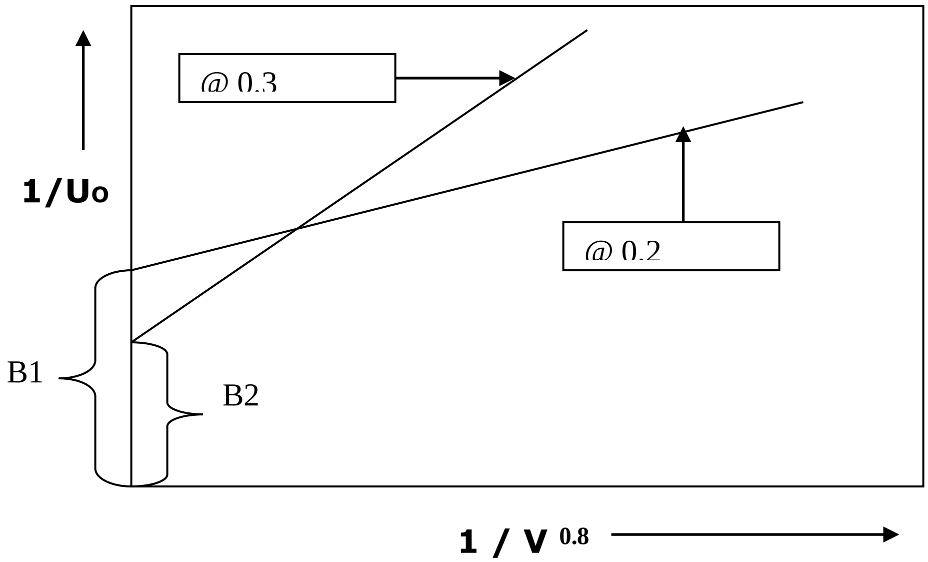
TABULATE THE READING

Sl. No	Heat carried away by cold fluid, 'Qc' watt	Heat lost by steam 'Qs' watt	Logarithm temp. mean difference 'Δt_{LMTD}' °K.	Overall heat transfer co-efficient 'UO' W/m² - °K.	$\frac{1}{U_O}$	Velocity of the cold fluid, 'V'	$\frac{1}{V^{0.8}}$	RENOLDS NUMBER, Re	PRANDLT NUMBER, Pr	Cold fluid side heat transfer co-efficient, 'hI'	Steam side heat transfer co – efficient, 'hS' W/m²

12. GRAPH* (WILSON'S GRAPH) :

- Draw the graph of **1 / V $^{0.8}$** Vs **1/Uo**

* draw for different steam pressures.



13. CALCULATION OF THEORETICAL COLD FLUID HEAT TRANSFER CO-EFFICIENT :

➢ Find R_D using the WILSON'S Graph, i.e.,

$$R_D = \frac{1}{U} - \frac{1}{hi_{Exp}} \quad ....1$$

Where , 1/U = intercept at higher pressure, say B1.
hi_{Exp} = heat transfer co-efficient at cold fluid side.

➢ Now, to find the Theoretical cold fluid heat transfer Co-efficient at other pressures, use the same above Formula ,

$$R_D = \frac{1}{U} - \frac{1}{hi_{Theo}}$$

Where, 1/U = intercept at the given pressure.
R_D = from equation 1.

PRECAUTIONS:

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

VIVA QUESTIONS

1.Explain briefly about Wilson method?
2.Write the formula for calculating heat lost by steam?
3.What is the use of rotameter?
4.What is the use of thermocouples?
5.what is meant by LMTD?
6. The normal automobile radiator is a heat exchanger of which type?
7. The Condenser in a thermal power plant is an exchanger of which type?
8. What is correction factor?
9. What is effectiveness?
10. What is the relation between fouling and overall heat transfer coefficient?
11. Define heat capacity ratio?
12. Explain different methods to design heat exchangers?
13.Which type of heat transfer takes place in heat exchangers?

14. What is fouling?

15.What is significance of Stanton number?

16. The convective heat transfer coefficient from a hot cylindrical surface exposed to still air varies in accordance with------

17. For Laminar conditions, the thickness of thermal boundary layer increases with the distance from the leading edge in proportion to------

18. Which dimensionless number has a significant role in forced convection?

19. Explain about a heat exchanger.

20. Classify heat exchangers

9.PIN – FIN APPARATUS

HEAT TRANSFER THROUGH PIN – FIN

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 fo 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.

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 250watts capacity.

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

Digital Voltmeter and Ammeter to measure power input to the heater.

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

Digital Temperature Indicator with channel selector to measure the temperatures.

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.

EXPERIMENTATION:

AIM:

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

PROCEDURE:

- Switch on the MCB and then console on switch to activate the control panel.
- Switch on the heater and regulate the power input using the heater regulator.
- 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)**.
- Wait for reasonable time to allow temperatures to reach steady state.
- Measure the voltage, current and temperatures from T_1 to T_6 at known time interval.

- Calculate the effectiveness & efficiency of the fin using the procedure given.
- Repeat the experiment for different values of power input to the heater and blower air flow rates.

OBSERVATIONS:

SL No.	Manometer Reading, m of water		HEAT INPUT		Air temperature, °C	TEMPERATURE, °C				
						SURFACE				
	H1	H2	V	I	T6	T1	T2	T3	T4	T5
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,

$$Pr = \frac{\mu\, Cp}{k} \qquad Gr = \frac{L^3 \rho^2 \beta\ (Tm - Ta)}{\mu^2}$$

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

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

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

$$N_U = 0.174(R_e)^{0.168} \text{ when } 40\,00 < Re > 40 \times 10^3$$

$$Re = \frac{\rho VD}{\mu}$$

where ,

D = inner diameter of the tube = 0.050

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

Mass flow rate of air is calculated as follows:

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

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

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

Flow area is calculated as follows:

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

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,

$$\frac{T_X - T_1}{T_1 - T_6} = \frac{\text{Cosh } m(L - x)}{\text{Cosh }(mL)}$$

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

$$m = \frac{h\,p}{K_f\,Ac}$$

Where

Ac = is the Cross-section area of the fin

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

P = is perimeter of the fin = π Dc,

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

h = is the heat transfer co-efficient of fin

Nu x Kair

Dc.

=

where,

Nu = Nusselt Number calculated
Kair = 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

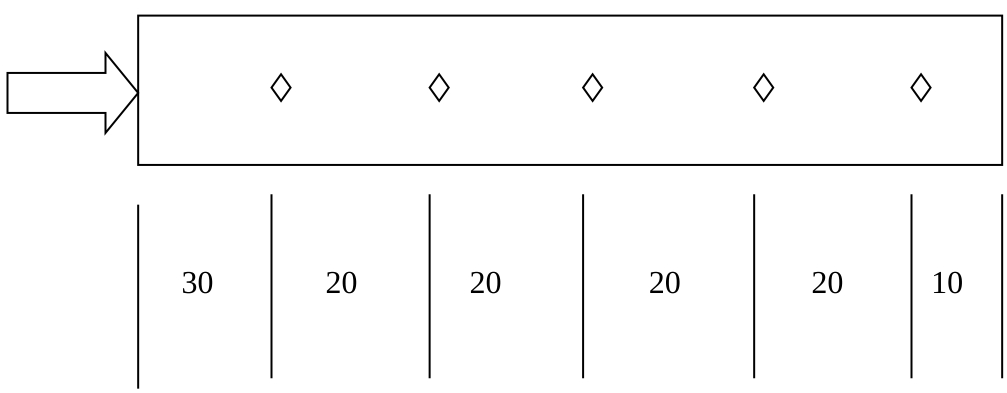
RATE OF HEAT TRANSFER FROM THE FIN

$$Q = \sqrt{hPK_F A} \times (Tm - Ta) \times \tanh mL$$

Where the units have their usual meaning

EFFICIENCY OF THE FIN

$$H_{mech} = \frac{\tan h\ mL}{mL}$$



PRECAUTIONS:

- Check all the electrical connections.
- Do not run the equipment if the voltage is below 180V.
- Do not obstruct flow of air while experiment is going on.
- Do not turn the heater regulator to the maximum as soon as the equipment is started.
- Do not attempt to alter the equipment as this may cause damage to the whole system.

VIVA QUESTIONS

1. What is convection?
2. Classify convection.
3. What is forced convection & natural convection?
4. Explain difference between forced convection and natural convection?
5. Force convection in a liquid bath is caused by----
6. Explain Newton's law of cooling?
7. Give the relation between 'Fluid velocity' and 'Heat transfer'?
8. On which properties does convection heat transfer strongly depend?
9. Define convection heat transfer coefficient with dimensions.
10. Define Nussult number.
11. Develop velocity boundary layer for flow over a flat plate?
12. What is drag force?
13. Define friction coefficient (or) drag coefficient?
14. Explain Reynolds number?
15. What is critical Reynolds number?

16. Explain Prandtl number.

17. Fluid properties are evaluated at what temperature?

18. For forced convection, Nussult number is a function of---------

19. The Prandtl number will be lowest for------

20. What is significance of Nussult's number in convection?

10.EMMISSIVITY

MEASUREMENT OF SURFACE EMMISSIVITY

INTRODUCTION:

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 temperature indicator with channel selector, digital voltmeter and ammeter for measurement of power and other necessary instrumentation. The whole arrangement is on the single bench considering all **safety and aesthetics factors**.

EXPERIMENTATION:

AIM:

The experiment is conducted to determine the emmissivity of the non – black surface and compare with the black 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 and digital voltmeter.
3. Switch On the heater of the Gray body and set the voltage (say 30V) using the heater regulator and digital voltmeter.
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.

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:

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

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

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 , ε_G

The emmissivity of the gray body is ε_G = _________.

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 (6^{th} edition)

PRECAUTIONS:

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

Viva questions

1.What is emissivity?

2.Why we use gray and black body?

3.Why the power is supplied separately through auto-transfer and watt-meter?

4.What is meant by absorbvity and transitivity?

5. What is meant by Reflectivity?

6. Explain Newton's law of cooling?

7. Give the relation between 'Fluid velocity' and 'Heat transfer'?

8. On which properties does convection heat transfer strongly depend?

9. Define convection heat transfer coefficient with dimensions.

10. Define Nusselt number.

11. Develop velocity boundary layer for flow over a flat plate?

12. What is drag force?

13. Define friction coefficient (or) drag coefficient?

14. Explain Reynolds number?

15. What is critical Reynolds number?

16. Explain Prandtl number.

17. Fluid properties are evaluated at what temperature?

18. For forced convection, Nussult number is a function of---------

19. The Prandtl number will be lowest for------

20. What is significance of Nussult's number in convection?

HEAT TRANSFER THROUGH CONCENTRIC SPHERE APPARATUS

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 **ALUMINIUM sphere of 75mm dia and 150mm 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. The temperature is shown by means of the **digital temperature indicator** on the control panel, which also consists of **heater regulator** and other accessories instrumentation having good aesthetic looks and safe design.

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EXPERIMENTATION:

AIM:

To determine the Rate of Heat Transfer in a given concentric sphere with respect to time.

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, at know time slots.
5. Repeat the experiment for different heater input.
6. After the experiment is over, switch off the electrical connections.

TABULAR COLUMN

SL No.	Time	TEMPERATURE, °C				
		Inner	Surface			
		T1	T2	T3	T4	T5
1.						
2.						
3.						
4.						

CALCULATIONS:

1. HEAT TRANSFER RATE in Concentric Sphere, Q

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

Where,

r1 = radius of the inner sphere = 0.0375m

r2 = radius of the outer sphere = 0.075m

K = Thermal conductivity of Aluminium sphere (205)

T1 = Temp. of the inner sphere

Tavg = Temp of the outer sphere = (T2+T3+T4+T5)/4

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.

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)

VIVA QUESTIONS

1.What is meant by concentric?

2.Explain briefly about fouriers law

3.Write the formulae for calaculating heat transfer through concentric sphere

4.Write the units of Q and K

5. Force convection in a liquid bath is caused by----

6. Explain Newton's law of cooling?

7. Give the relation between 'Fluid velocity' and 'Heat transfer'?

8. On which properties does convection heat transfer strongly depend?

9. Define convection heat transfer coefficient with dimensions.

10. Define Nussult number.

11. Develop velocity boundary layer for flow over a flat plate?

12. What is drag force?

13. Define friction coefficient (or) drag coefficient?

14. Explain Reynolds number?

15. What is critical Reynolds number?

16. Explain Prandtl number.

17. Fluid properties are evaluated at what temperature?

18. For forced convection, Nussult number is a function of---------

19. The Prandtl number will be lowest for------

20. What is significance of Nussult's number in convection?

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.

2. DESCRIPTION OF APPARATUS:

- The apparatus consists of a specially designed **Glass Cylinder**.
- An arrangement above the Cylinder in the form of **Bakelite plate** is provided to place the main **Heater** and the Nichrome wire heater arrangement.
- The base is made of MS and is powder coated with Rubber cushion to place the Glass cylinder.
- **Heater regulator** to supply the regulated power input to the heater.

- **Digital Voltmeter and Ammeter** to measure poser input ot 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.
- The whole arrangement is mounted on an Aesthetically designed sturdy frame made of MS tubes and NOVAPAN Board with all the provisions for holding the tanks and accessories.

3. EXPERIMENTATION:

i. AIM:

- To observe the formation of pool boiling and
- To draw the graph of heat flux Vs. Bulk Temperature upto Burnout (Critical) condition.

ii. PROCEDURE:

1. Fill in the Glass Cylinder with **Distilled Water** above the heater level.
2. Connect the **Nichrome 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. (also note the above parameters even at the break point.)

9. Repeat the above experiment by replacing the **Test Wire** and for Different Temperatures of Water.

iii. OBSERVATIONS

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

NOTE:
T1 = TEMPERATURE OF BULK HEATER
T2 = TEMERATURE OF NICHROME HEATER
T3 = TEMPERATURE OF THE WATER

iv. CALCULATIONS:

1. Surface Area of the Wire, A

$$A = \Pi DL \quad m^2$$

where d = diameter of Test Wire = 0.122mm
L = Length of Test Wire = to be measured. (50 mm)

2. Heat Input, Q

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

Where,

V = Voltage in Volts.

I = Current in Amps.

3. Heat Flux, q

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

4. Heat Transfer Co - efficient, h

Where,

$$h = 1.54 q^{0.75} \quad W/m^2 K$$

$1.54\, q^{0.75}$

q = Heat Flux

5. Temperature Excess, ΔT

$$\Delta T = \sqrt{\left(\frac{h}{5.58}\right)} \quad K$$

5.58

v. TABULAR COLUMN

Sl No	Heat Flux, q	Temperature Excess, ΔT

vi. 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)

4. 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.

Note: For any further clarifications on how to run the equipment or for up gradation, please write to us at: services@mechtrixindia.com

Viva questions

1. What is meant by heat flux
2. What is drag force?
3. Define friction coefficient (or) drag coefficient?
4. Explain Reynolds number?
5. What is critical Reynolds number?
6. Explain Prandtl number.
7. Fluid properties are evaluated at what temperature?
8. For forced convection, Nussult number is a function of---------
9. The Prandtl number will be lowest for------
10. What is significance of Nussult's number in convection?
11. The hydro dynamic and thermal boundary layers are identical at Prandtl number equal to-----
12. The temperature gradient in the fluid flow over a heated plate will be------
13. The ratio of heat transfer by convection to that by conduction is called-----
14. What is significance of Stanton number?
15. The convective heat transfer coefficient from a hot cylindrical surface exposed to still air varies in accordance with------
16. For Laminar conditions, the thickness of thermal boundary layer increases with the distance from the leading edge in proportion to-----
17. Which dimensionless number has a significant role in forced convection?
18. Why the power is supplied separately through auto-transfer and watt-meter?
19. What is meant by absorbvity and transitivity?
20. . What is meant by Reflectivity

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 qrenching, cooling of IC engine cylinders, and heating of boiler tubes are common examples of unsteady state heat flow.

2. DESCRIPTION OF APPARATUS:

- The apparatus consists of a 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 Temperature Indicator** with channel selector to measure the temperatures.
- The whole arrangement is mounted on an Aesthetically designed sturdy frame made of MS tubes and NOVAPAN Board with all the provisions for holding the tanks and accessories.

3. EXPERIMENTATION:

i. AIM:

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

ii. PROCEDURE:

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 core and outer 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. Note down the temperature at every 10 second till it reaches atmospheric condition.
8. Repeat the experiment for different temperatures of fluid.

iii. OBSERVATIONS

T_1 = water temp
T_2 = surface temp
T_3 = core temp

Intial Temp. of the fluid, T_∞ = _____ °C

*** T2** in case of water or oil – heating
T1 in case of air. – Cooling

Intial Temp. of the sphere, To = T3 =_____ °C

Sl. No.	Temperatures °C		Time, t sec
	Tc = T3 Cooling	To = T2 Heating	
			10
			20
			30

Note:
Take T2 with respect to time for Heating process and
Take T3 with respect to time for Cooling process.

iv. CALCULATIONS:

1. Determination of Heat Transfer Co-efficient, h

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

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 $3\times10^5 < GrPr < 8\times10^5$

Pr = Pradantle Number from handbook

G_r = Grashoff's Number & is given by

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

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, $N\text{-}s/m^2$

$\mu = \rho \nu$

NOTE:

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

2. Determination of Instantaneous Heat Flow, Q

$$Q_i = -hA(T_i - T_\infty)e^{-B_i F_o} \text{ Watts}$$

Where,

$$B_i = Biot\ Number = \frac{h\,r}{K_S}$$

$$F_o = Fourier\ Number = \frac{\alpha\,t}{r^2}$$

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

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

α=Thermal diffusivity of sphere material =84.18×10^{-6} m^2/s

t = Time at the given instant, sec

r= Radius of the sphere, m

T_i= Initial surface temperature of the sphere, °C,

T_∞= Initial temperature of hot fluid or cold fluid

K_S= Thermal conductivity of sphere = 205 W/mK

3. 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

v. RESULTS:

- The heat transfer coefficient for transient heat conduction heat transfer.

vi. GRAPHS:

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

4. 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.

Note: For any further clarifications on how to run the equipment or for

up gradation, please write to us at:

services@mechtrixindia.com

Viva questions

1. What is meant by Transient heat conduction
2.What is the difference between steady state and unsteady state condition
3. What is the difference between Periodic heat flow and Non-Periodic heat flow
4.Define Biot Number
5. Force convection in a liquid bath is caused by----
6. Explain Newton's law of cooling?
7. Give the relation between 'Fluid velocity' and 'Heat transfer'?
8. On which properties does convection heat transfer strongly depend?
9. Define convection heat transfer coefficient with dimensions.
10. Define Nussult number.
11. Develop velocity boundary layer for flow over a flat plate?
12. What is drag force?
13. Define friction coefficient (or) drag coefficient?
14. Explain Reynolds number?
15. What is critical Reynolds number?
16. Explain Prandtl number.
17. Fluid properties are evaluated at what temperature?
18. For forced convection, Nussult number is a function of---------
19. The Prandtl number will be lowest for------
20. What is significance of Nussult's number in convection?

HEAT PIPE DEMONSTRATION

INTRODUCTION:

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.

DESCRIPTION OF THE 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 other 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.

Contol 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.

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

EXPERIMENTATION:

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.

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	
	T_1	T_2	T_3	T_4	T_5	T_6	V	I
1								
2								
3								
4								
5								

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

CALCULATIONS:

1. **Calculation of heat flux, q**

$$q = \frac{Q}{A} = \frac{k \times \partial T}{\partial x} \quad W/m^2$$

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

dt = Temperature difference.

dx = Length b/w thermocouples.

RESULT:

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

VIVAQUESTIONS

1.What is the purpose of heatpipe

2.How do you calculate the heat flux?

3.Write the formulae for calculating heat transfer through concentric Sphere

4.Write the units of Q and K

5. Force convection in a liquid bath is caused by----

6. Explain Newton's law of cooling?

7. Give the relation between 'Fluid velocity' and 'Heat transfer'?

8. On which properties does convection heat transfer strongly depend?

9. Define convection heat transfer coefficient with dimensions.

10. Define Nussult number.

11. Develop velocity boundary layer for flow over a flat plate?

12. What is drag force?

13. Define friction coefficient (or) drag coefficient?

14. Explain Reynolds number?

15. What is critical Reynolds number?

16. Explain Prandtl number.

17. Fluid properties are evaluated at what temperature?

18. For forced convection, Nussult number is a function of---------

19. The Prandtl number will be lowest for------

20. What is significance of Nussult's number in convection?