

**SREENIVASA INSTITUTE OF TECHNOLOGY AND MANAGEMENT
STUDIES, CHITTOOR
(AUTONOMOUS)**

DEPARTMENT OF MECHANICAL ENGINEERING

LAB MANUAL



**23MEC367L – HEAT TRANSFER LABORATORY
(2025-2026)**

NAME :

ROLL NO. :

CLASS :

BRANCH :

by
Department of Mechanical Engineering

DEPARTMENT VISION AND MISSION

➤ VISION

- To become a center of excellence in mechanical engineering studies and research.

➤ MISSION

M1: Provide congenial academic ambience with necessary infrastructure and learning resources.

M2: Inculcate confidence to face and experience new challenges from industry and society.

M3: Ignite the students to acquire self-reliance in the latest technologies.

M4: Foster enterprising spirit among students.

PROGRAMME EDUCATIONAL OBJECTIVES (PEO's)

Graduates of Mechanical Engineering shall

PEO1: Have professional competency through the application of knowledge gained from subjects like mathematics, physics, chemistry, inter-disciplinary and core subjects like manufacturing engineering, thermal sciences, CAD/CAM and design and development. (**Professional Competency**).

PEO2: Excel in one's career by critical thinking towards successful services and growth of the organization or as an entrepreneur or through higher studies. (**Successful Career Goals**).

PEO3: Enhance knowledge by updating advanced technological concepts for facing the rapidly changing world and contribute to society through innovation and creativity. (**Continuing Education and Contribution to Society**).

PROGRAM SPECIFIC OUTCOMES (PSO's)

PSO1: Apply the knowledge obtained in core areas for the design, analysis and manufacturing of mechanical systems and processes.

PSO2: Exhibit novel concepts on product development with the help of modern CAD/CAM integration, while ensuring best manufacturing practices.

PROGRAM OUTCOMES (PO's)

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems.

PO2. Problem analysis: Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.

PO3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety and the cultural, societal and environmental considerations.

PO4. 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.

PO5. Modern tool usage: Create, select and apply appropriate techniques, resources and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6. 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 practice.

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts and demonstrate the knowledge of and need for sustainable development.

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Individual and team work: Function effectively as an individual and as a member or leader in diverse teams and in multidisciplinary settings.

PO10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations and give and receive clear instructions.

PO11. 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.

PO12. Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.



SREENIVASA INSTITUTE of TECHNOLOGY and MANAGEMENT
STUDIES (Autonomous)

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

- PEO1: Have Professional competency through the application of knowledge gained from subjects like Mathematics, Physics, Chemistry, Inter-Disciplinary and core subjects like Manufacturing Engineering, Thermal Sciences, CAD/CAM and Design & Development. (Professional Competency).
- PEO2: Excel in one's career by critical thinking towards successful services and growth of the organization or as an entrepreneur or through higher studies. (Successful Career Goals).
- PEO3: Enhance knowledge by updating advanced technological concepts for facing the rapidly changing world and contribute to society through innovation and creativity. (Continuing Education and Contribution to Society).

PROGRAM SPECIFIC OUTCOMES (PSO's)

- PSO1:** Apply the knowledge obtained in core areas for the design, analysis and manufacturing of mechanical systems and processes.
- PSO2:** Exhibit novel concepts on product development with the help of modern CAD/CAM integration, while ensuring best manufacturing practices.

23MEC367L – Heat Transfer Laboratory

INDEX

S.No	Experiment Name	Knowledge Gained	Analysis, Design and Use of Modern Tool / Technique	Ability of do experiment and following of ethical principles	Result & Conclusion	VIVA VOCE (Communication, Life Long learning)	TOTAL	Signature of the Faculty
		5	5	5	5	10	30M	
1	Thermal conductivity of insulating powder							
2	Lagged pipe apparatus							
3	Heat transfer through composite wall							
4	Thermal conductivity of metal rod							
5	Heat transfer pin-fin apparatus							
6	Heat transfer co-efficient in forced convection							
7	Heat transfer co-efficient in natural convection							
8	Parallel flow heat exchanger							
9	Counter flow heat exchanger							
10	Stefan Boltzmann apparatus							

23MEEC367L – Heat Transfer Laboratory

CO ATTAINMENT

S.No	Experiment Name	C01	C02	C03	C04	C05	C06	C07	C08	C09
		Knowledge	Analysis	Design	Complex Analysis & Conclusion	Use of modern tools	Communication ability in Lab	safety	Individual / Team work	Life Long Learning
1	Thermal conductivity of insulating powder									
2	Lagged pipe apparatus									
3	Heat transfer through composite wall									
4	Thermal conductivity of metal rod									
5	Heat transfer pin-fin apparatus									
6	Heat transfer co-efficient in forced convection									
7	Heat transfer co-efficient in natural convection									
8	Parallel flow heat exchanger									
9	Counter flow heat exchanger									
10	Stefan Boltzmann apparatus									
Average										

Ex. No.

Date:

THERMAL CONDUCTIVITY OF INSULATING POWDER

OBJECTIVE:

To determine the thermal conductivity of insulating powder for various heat inputs.

THEORY:

- i) Materials having lower thermal conductivity are called insulators. Magnesia, asbestos, glass wool, etc. are some of the thermal insulators. Examples for good thermal conductors are metals like copper, steel, aluminium, etc.
- ii) The radial heat conduction for two concentric hollow spheres transferring heat from inside to outside is given by Fourier's law for spherical shells as given below:

$$q = 4\pi K R_i R_o (T_i - T_o) / (R_o - R_i)$$

Where,

q = rate of heat transfer in watts

R_i = radius of inner sphere in meters

R_o = radius of outer sphere in meters

T_i = Temperature of the inner sphere

T_o = Temperature of the outer sphere

iii) **THERMAL CONDUCTIVITY 'K'**

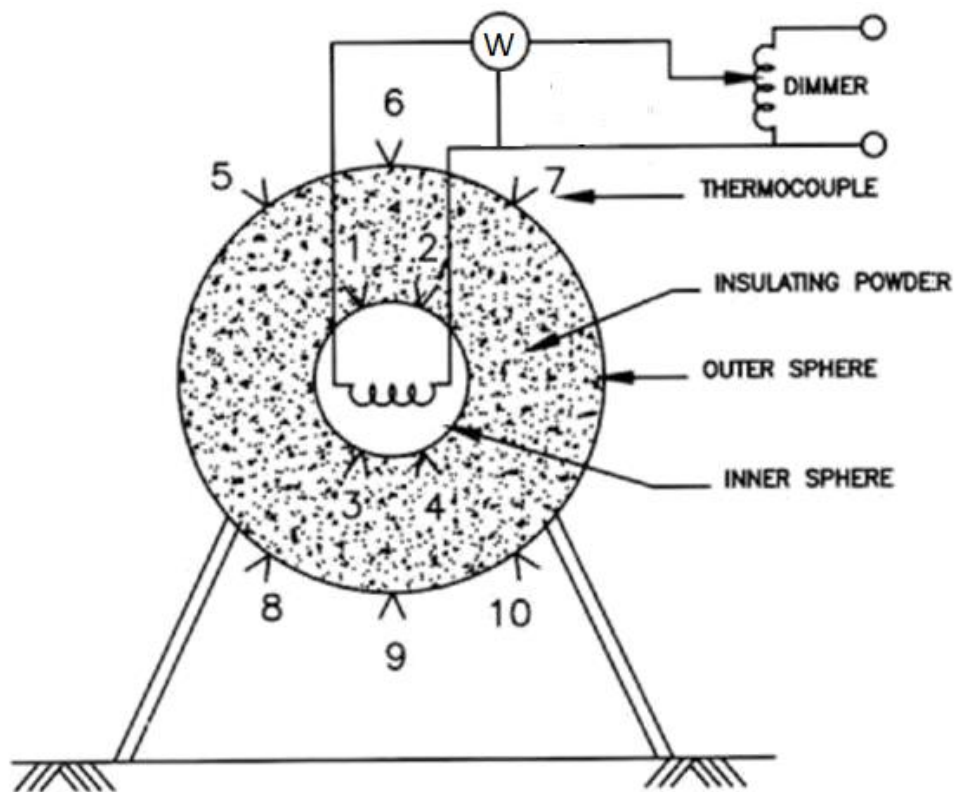
Thermal conductivity is defined as the amount of heat that can flow per unit time across a unit cross sectional area when the temperature gradient is unity. The units of thermal conductivity is W/m-K.

SPECIFICATIONS:

1. Radius of inner sphere R_i = 50mm = 0.05m
2. Radius of outer sphere R_o = 100 mm = 0.10 m
3. Wattmeter maximum 500W
4. Digital temperature indicator range 0 - 400°C
5. Thermocouple types - Chrome Alumel
6. Heating coil (Mica Type) 400W
7. Insulating powder - Asbestos

DESCRIPTION OF APPARATUS:

The apparatus consists of two thin walled concentric copper spheres. Heating coil is provided in the inner sphere. The space between the inner and outer spheres are filled by asbestos insulating powder whose thermal conductivity is to be determined. An electric heater is placed at the center of the inner sphere. The power supply to the heating coil is adjusted by using dimmerstat. Chrome-Alumel thermocouples are used to record the temperatures. Thermocouples 1 to 4 are embedded on the surface of inner sphere and 5 to 10 are embedded on the outer shell surface to measure the temperature of inner and outer surface.



THERMAL CONDUCTIVITY OF INSULATING POWDER

1 – 4 INNER SPHERE THERMOCOUPLES

5 – 10 OUTER SPHERE THERMOCOUPLES

OBSERVATION TABLE:

Heat Input		Inner Surface temp C					Outer Surface temp C						
Sl. No.	Watt q	T1	T2	T3	T4	average	T5	T6	T7	T8	T9	T10	average

CALCULATIONS:

1. Mean temperature of outer sphere $T_o = (T_5+T_6+T_7+T_8+T_9+T_{10}) / 6 = \underline{\hspace{2cm}} ^\circ\text{C}$

2. Mean temperature of inner sphere $T_i = (T_1+T_2+T_3+T_4) / 4 = \underline{\hspace{2cm}} ^\circ\text{C}$

3. Thermal conductivity of insulating powder

$$K = q \times (R_o - R_i) / 4\pi R_i R_o (T_i - T_o)$$

Where, q = rate of heat transfer = wattmeter reading

The control panel consists of a dimmerstat to control the voltage supplied to the heating element. A wattmeter and a digital temperature indicator are also provided. A channel indicator with selector switch is used to measure different temperatures.

PROCEDURE:

1. Connect the unit to an AC source 240 V - 5amps and switch on the MCB.
2. Operate the dimmerstat slowly to increase the heat input to the heater and adjust the power input (do not exceed 150W) starting from '0' position.
3. Maintain the same heat input throughout the experiment until the temperatures reaches a steady state.
4. Note down the temperature readings by operating selector switch and record them in the observation table.
5. Repeat the experiment for other heat inputs.
6. Assuming one dimensional radial heat conduction across the powdered layer, thermal conductivity of the insulating powder can be determined under steady state condition.

RESULT:

The Thermal Conductivity of the Insulating Powder is found to be _____

Ex. No.

Date:

LAGGED PIPE APPARATUS

OBJECTIVE:

To determine the thermal conductivity of insulating materials using lagged pipe apparatus.

THEORY:

Heat transfer is defined as transmission of heat energy from one region to another region as a result of temperature gradient. Heat transfer takes place by three distinct modes. They are conduction, convection & radiation.

The amount of heat transfer per unit area per unit time known as heat flux. It is denoted by q and expressed in terms of W/m^2-K .

Conduction heat transfer:

Conduction Heat transfer can take place by two mechanisms.

1. By molecular interaction where the heat exchange takes place by kinetic motion.
2. Direct impact of molecules at a relatively high temperature imparting energy to adjacent molecules at lower temperature. This type of energy transfer always exists so long as there is a temperature gradient in molecules of a solid, liquid or gas. By the vibration and rotation of electrons heat transfer takes place.

The free electrons concentration of non metals is very low hence these materials are bad conductors. Pure metals like copper, silver, etc. are good conductors of heat due to availability of free electrons.

Fourier's heat conduction:

A physical law for heat transfer by conduction was given by Fourier (1895) according to which the rate of heat conduction is proportional to area (A), measured normal to the direction of heat flow and the temperature gradient in the direction.

Mathematically,

q is proportional to A and (dT/dx) and thus

$$q = -KA(dT/dx) \quad [- \text{ sign is required since } dT/dx \text{ is negative.}]$$

where, K is a physical property of the substance known as thermal conductivity and is defined as the ability to conduct heat energy through it.

Thermal conductivity of common substance at 20°C:

<u>Substance</u>	<u>Thermal conductivity (W/mK)</u>
Silver pure	407
Copper pure	386
Aluminium pure	175
Mild steel	37
Lead	29
Stainless steel	19
Wood	0.15
Asbestos, Fiber	0.09
Water	0.51
Air	0.02

The radial heat conduction for two concentric cylinders transferring heat from inside to outside is given by Fourier's law in cylindrical co-ordinates as given below:

$$q = 2\pi K L (T_i - T_o) / \ln(R_o/R_i)$$

Where,

q = rate of heat transfer in watts

R_i = radius of inner cylinder in meters

R_o = radius of outer cylinder in meters

T_i = Temperature of the inner cylinder outer radius

T_o = Temperature of the outer cylinder at outer surface

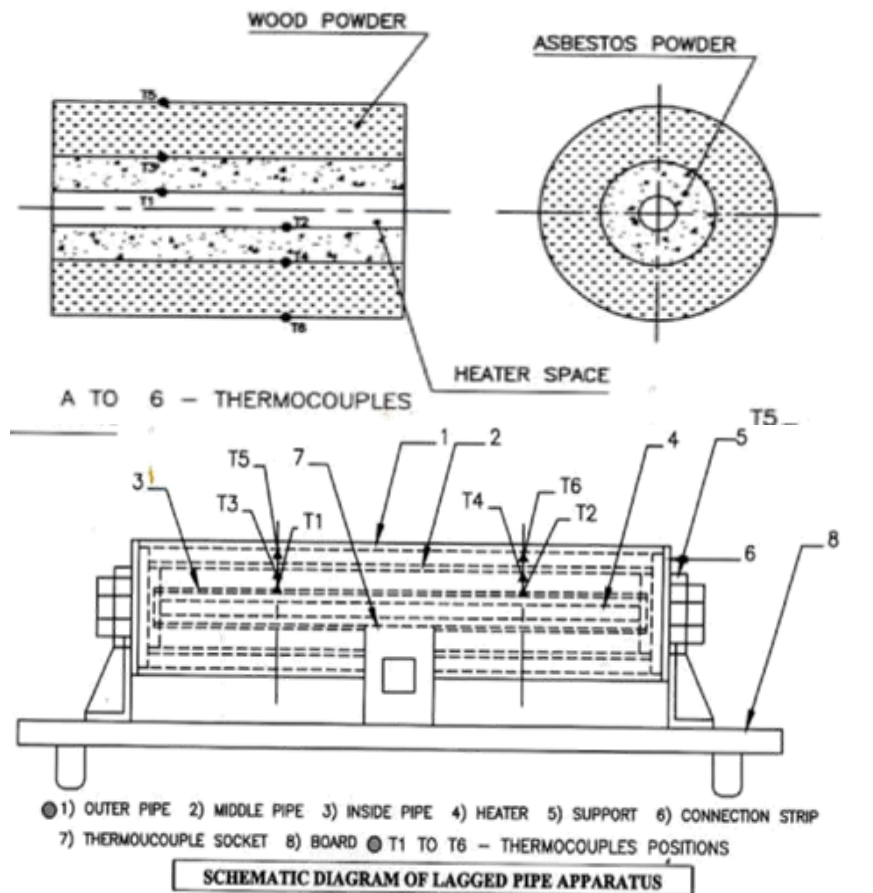
DESCRIPTION OF APPARATUS:

The apparatus consists of two thin walled concentric copper spheres. Heating coil is provided in the inner sphere. The space between the inner and outer spheres are filled by asbestos insulating powder whose thermal conductivity is to be determined. An electric heater is placed at the center of the inner sphere. The power supply to the heating coil is adjusted by using dimmer stat. Chrome-Alumel thermocouples are used to record the temperatures. Thermocouples 1 to 4 are embedded on the surface of inner sphere and 5 to 10 are embedded on the outer shell surface to measure the temperature of inner and outer surface.

The control panel consists of a dimmer stat to control the voltage supplied to the heating element. A wattmeter and a digital temperature indicator are also provided. A channel indicator with selector switch is used to measure different temperatures.

SPECIFICATIONS:

- | | |
|--|----------------------|
| 1. Radius of heater | R1 = 16 mm = 0.016 m |
| 2. Radius of outer pipe containing wood powder | R2 = 35 mm = 0.035 m |
| 3. Radius of outermost pipe containing asbestos | R2 = 47 mm = 0.047 m |
| 4. Heater type - Nichrome wire - centrally placed | |
| 5. Wattmeter capacity maximum 500W | |
| 6. Digital temperature indicator range 0 - 400°C | |
| 7. Thermocouple types - Chrome Alumel | |
| 8. Insulation surrounding heating coil - wood powder | |
| 9. Insulating powder - Asbestos | |



OBSERVATION TABLE:

S NO.	WATTMETER READING (Q)	TEMPERATURE READINGS IN °C					
		T ₁	T ₂	T ₃	T ₄	T ₅	T ₆

CALCULATIONS:

1. Readings

a. Mean Temperature of inside pipe-T_i(inside)

$$T_i(\text{inside}) = (T_1 + T_2) / 2 = \underline{\hspace{2cm}}$$

b. Mean Temperature of middle pipe-T_m(middle)

$$T_m(\text{middle}) = (T_3 + T_4) / 2 = \underline{\hspace{2cm}}$$

c. Mean Temperature of outside pipe-T_o(outside)

$$T_o(\text{outside}) = (T_5 + T_6) / 2 = \underline{\hspace{2cm}}$$

2. Thermal Conductivity of lagged pipe(k)

$$K = q \times \ln(r_o/r_i) / 2\pi L (T_i - T_o) = \underline{\hspace{2cm}} \text{ Watts/m}^0\text{K}$$

PROCEDURE:

1. Connect the unit to an AC source 240 V 5amps and switch on the MC.
2. Operate the dimmerstat slowly to increase the heat input to the heater and adjust the voltage to any desired power starting from '0' position.
3. Maintain the same heat input throughout the experiment until the temperatures reaches a steady state.
4. Note down the following readings provided in the observation table.
5. Repeat the experiment for different heat inputs.
6. With the help of the selector switches record the temperature readings T_1 - T_6 .
7. Tabulate the readings and calculate the thermal conductivity.

RESULT:

The Thermal Conductivity of the Insulating material is found to be _____.

Ex. No.

Date:

COMPOSITE WALL APPARATUS

OBJECTIVE:

To calculate thermal conductivity of composite wall

SPECIFICATION:

1. Slab assembly arranged symmetrically on both sides of the slab.
2. Nichrome heater wound on mica heater of 500-Watt capacity.
3. Dimmer stat open type, 230V, 0-2 amp, single phase.
4. Digital temperature indicator
5. Enclosure size : 350x350x350 mm
6. Slab diameter : 300 mm = 0.3m
7. Thickness of mild steel : 20 mm = 0.020m
8. Thickness of Bakelite : 18 mm = 0.018m
9. Thickness of wood : 18 mm = 0.018m
10. Total thickness of slab : 117mm = 0.117m

DESCRIPTION:

The apparatus consists of central heater sandwiched between two sheets. Three types of slabs are provided on both sides of heater, which forms a composite structure. A small hand press is provided to ensure perfect contact between the slabs.

A dimmerstat is provided to vary heat input of heaters and it is measured by a wattmeter. Thermocouples are embedded between interfaces of slabs. A digital temperature indicator is provided to measure temperature at various points by using selector switch.

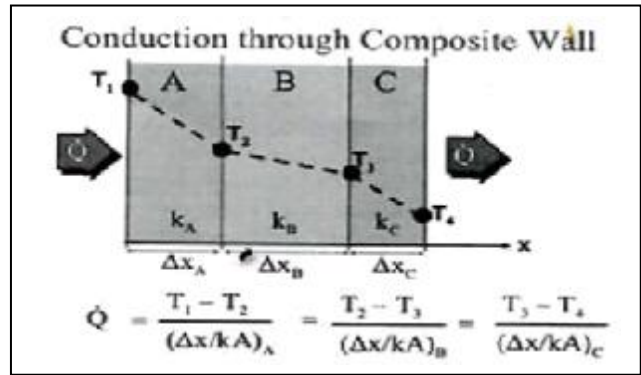
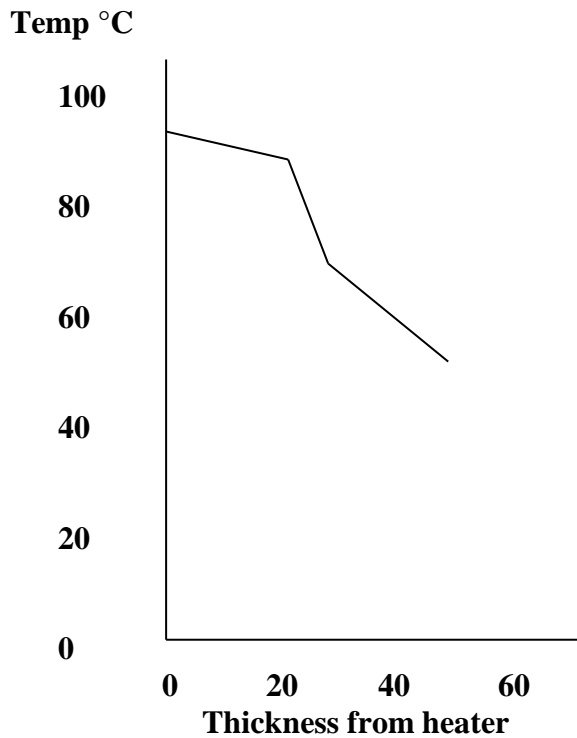
PROCEDURE:

1. Connect the unit to an AC source 240 V - 5amps and switch on the MCB.
2. Close the glass door to achieve proper environmental condition.
3. Arrange the plates in proper fashion on both sides of heater plates using hand press to ensure perfect contact between plates.
4. Operate the dimmerstat slowly to increase the heat input to the heater and adjust the voltage to any desired power starting from '0' position.
5. Maintain the same heat input throughout the experiment until the temperatures reaches a steady state.
6. Note down the readings provided in the observation table.
7. Repeat the experiment for different heat inputs.
8. With the help of the selector switches record the temperature readings T_1 - T_8 .
9. Tabulate the readings and calculate the thermal conductivity using the formula.

RESULT:

The composite wall thermal conductivity is found to be

W/m-K



Observation Table:-

Sl. No.	WATTMETER READING (Q)ts	T1 °C	T2 °C	T3 °C	T4 °C	T5 °C	T6 °C	T7 °C	T8 °C

Formulae:-

- Heat input $Q = \dots\dots$ Watts
- Mean temperature before first wall $T_A \text{ avg} = (T_1 + T_2)/2 = \dots\dots \text{°C}$
 Mean temperature after first wall $T_B \text{ avg} = (T_3 + T_4)/2 = \dots\dots \text{°C}$
 Mean temperature after second wall $T_C \text{ avg} = (T_5 + T_6)/2 = \dots\dots \text{°C}$
 Mean temperature after third wall $T_D \text{ avg} = (T_7 + T_8)/2 = \dots\dots \text{°C}$
- Heat transfer area of the slab = $A = \pi d^2/4$, where "d" is diameter of slab 0.3m
 $= 3.14 \times 0.3^2/4 = \dots\dots \text{m}^2$
- Thermal Resistance of Slab (R)
 $R = \frac{T_A \text{ avg} + T_D \text{ avg}}{Q} = \dots\dots \text{°C/W}$
- Thermal Conductivity of composite slab (K)
 $K = \frac{Q \times \text{thickness}}{A (T_A \text{ avg} - T_D \text{ avg})} = \dots\dots = \dots\dots \text{W/mK}$

Where thickness of slab is $0.2+0.018+0.018 = 0.056\text{m}$

Ex. No.

Date:

THERMAL CONDUCTIVITY OF METAL ROD

OBJECTIVE:

To determine the thermal conductivity of given metal rod.

THEORY:

From Fourier's law of heat conduction

$$Q = -k A (dT/dx)$$

where, Q = Rate of heat conducted, W
 A = Area of heat transfer, m^2
 k = Thermal conductivity of the material, W/m-K
 dT/dx = Temperature gradient

Thermal conductivity is a property of the material and may be defined as the amount of heat conducted per unit time through unit area, when a temperature difference of unit degree is maintained across unit thickness. Conductivity depends upon composition, phase and homogeneity as well as bonding.

DESCRIPTION :

The apparatus consists of a metal rod, one end of which is heated by an electric heating coil while the other end projects into the cooling water jacket. The rod is insulated with glass wool to minimize the radiation and convection loss from the surface of the rod and thus ensure nearly constant temperature gradient throughout the length of the rod. The temperature of the rod is measured at five different locations. The heater is provided with a dimmerstat for controlling the heat input. Water is circulated through the jacket and its flow rate and temperature rise can be measured.

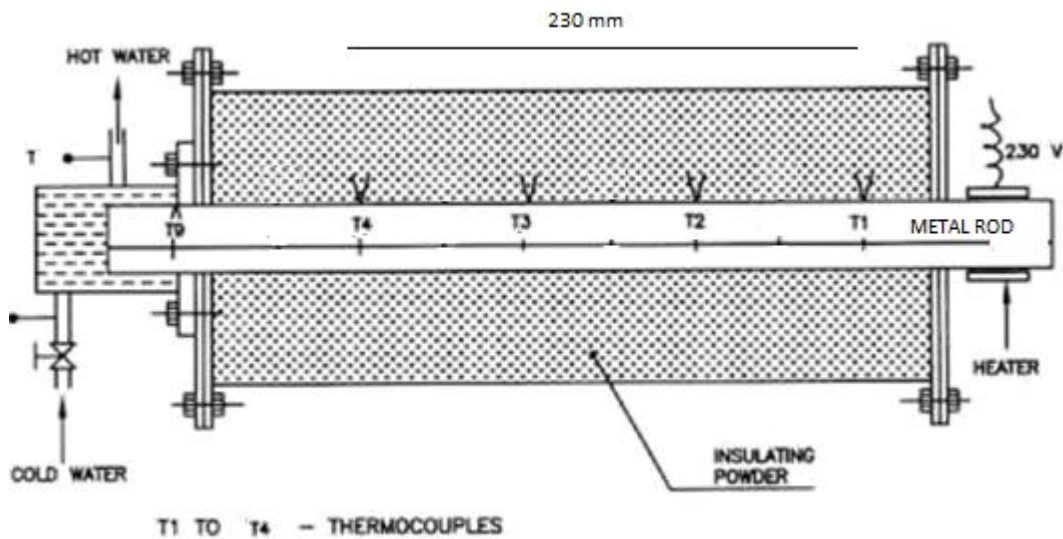
SPECIFICATIONS:

Specimen material	:	Metal rod
Size of the Specimen	:	$\phi 25$ mm, 230mm long thermocoupled
Cylindrical shell	:	400mm long
Wattmeter	:	Digital type, 0-500 W
Heater	:	Band type - Nichrome heater, 500 W
Thermocouple used	:	6 nos. - Digital type, 0-400 , Cr-Al

PRODEDURE:

1. Power supply is given to the apparatus.
2. Give heat input to the heater by slowly rotating the dimmerstat and adjust the voltage to say 25 V, 50 V, etc. Thus corresponding power input varies for heater.
3. Start the cooling water supply through the jacket and adjust its flow rate so that the heat is taken away from the specimen constantly or wait till steady state is obtained at the opposite end through air convection.
4. Allow sufficient time for the apparatus to reach steady state.
5. Note down the readings of wattmeter.
6. Note the temperatures along the length of the specimen rod at 4 different locations.
7. Note down the inlet & outlet temperatures of cooling water and measure the flow rate of water. Repeat the experiment for different heat inputs.

Sl No	Power (W)	Metal rod thermocouple reading (°C)							Water temp (°C)		Volume flow rate of water, V cc/min
		T1	T2	T3	T4	T5	T6	T7	Inlet	Outlet	
									T8	T9	



CALCULATION:

Plot the variation of temperature along the length of the rod. From the graph, obtain dT/dx , which is the slope of the straight line passing through/near to the points in the graph. Assuming no heat loss because of insulation, heat conducted through the rod = heat dissipated at the open end.

$$\text{Watt meter reading } Q = -k A (dT/dx)$$

where, 'k' = thermal conductivity of metal rod, (W/m-K) to be determined

$$'A' = \text{Cross sectional area of metal rod} = \pi d^2/4 = 3.14 \times 0.025^2/4 = \text{m}^2$$

$$dT = T7 - T1 \quad \text{and} \quad dx = 0.23\text{m} \quad \text{distance between T7 \& T1 thermocouples}$$

Thermal conductivity of the metal rod is given by

$$k = \text{Watt meter reading} / A (dT/dx)$$

RESULT:

The thermal conductivity of given metal rod is found to be _____ W/m°C

Ex. No.

Date:

HEAT TRANSFER FROM PIN-FIN APPARATUS

AIM: To calculate the efficiency of fin

THEORY: A brass fin of circular cross section is fitted across a long rectangular duct. The other end of heater is connected to the suction side of blower and the air flows fast through the fin perpendicular to its axis. One end of the fin projects out side the duct & is heated by the heater. Temperature at various locations are measured by thermocouples.

SPECIFICATIONS:

Length of the fin, 'L' = 145mm
Diameter of the fin, 'd_f' = 12mm
Thermal conductivity of fin material (brass) = 110.7 W/m²-K
Diameter of the orifice, 'd_o' = 42 mm
Coefficient of discharge of the orifice, 'Cd' = 0.62
Density of manometric fluid = 1.28 kg/m³

PROCEDURE:

1. Connect the equipment to electric power supply.
2. Keep the thermocouple selector switch to zero position.
3. Turn the Variac (dimmerstat) clockwise and adjust the power input to the heater to the desired value and switch on the blower.
4. Set the air-flow rate to any desired value by adjusting the difference in mercury levels in the manometer and allow the unit to stabilize.
5. Note down the temperatures, T1 to T6 from the thermocouple selector switch.
6. Note down the difference in level of the manometer and repeat the experiment for different power inputs to the heater.

Sl. No.	Heat Input		Pressure drop, 'h' mm of mercury,	Temperatures, 0C					
	V	A		T1	T2	T3	T4	T5	T6

CALCULATIONS:

$$\beta = \frac{d_0}{d_p} \quad \begin{array}{l} d_0 = \text{Diameter of the Orifice} \\ d_p = \text{Diameter of the pipe} \end{array}$$

Velocity of Orifice

$$V_o = C_d \sqrt{\frac{2gh(\rho_m - \rho_a)}{\rho_a} \frac{1}{(1-\beta^2)}}$$

ρ_m = density of manometric fluid = $13.6 \times 10^3 \text{ kg/m}^3$

ρ_a = density of air = 1.17 kg/m^3

$$V_a = \text{Velocity of air in the duct} = \frac{\text{Velocity at orifice} \times \text{cross sectional area of orifice}}{\text{Cross sectional area of duct}}$$

$$V_a = \frac{V_o \times (\pi d_0^2)/4}{W \times B}$$

where, d_p = diameter of pipe

d_0 = diameter of orifice

W = Width of the duct

B = Breadth of duct

Average surface temperature of fin is given by

$$T_s = \frac{T_1 + T_2 + T_3 + T_4 + T_5}{5} + 273.15 \text{ K}$$

$$T_\infty = T_6 = \text{Ambient temperature} = \quad + 273.15 \text{ K}$$

$$T_m = \text{Mean temperature} = \frac{T_s + T_\infty}{2}$$

Properties of air at _____0C

$$v = \quad , Pr = \quad , K = \quad$$

$V_a df$

$$Re = \frac{V_a df}{\nu} =$$

Re = Reynolds number

Pr = Prandtl number

Nu = Nusselt number

The relationship for Nu is

$$Nu = C Re^n Pr^{1/3}$$

$$Nu = C Re^n Pr^{1/3}$$

For	Re = 0.4 to 4.0	C = 0.989 and n = 0.33
	Re = 4 to 40	C = 0.911 and n = 0.385
	Re = 40 to 4000	C = 0.683 and n = 0.466
	Re = 4000 to 40,000	C = 0.293 and n = 0.618
	Re = 40,000 to 400,000	C = 0.27 and n = 0.805

$$h = \frac{Nu k}{df}$$

thermal conductivity of fin material, 'K' = 110.7 W/m-K

$$m = \sqrt{\frac{h P}{K A}}$$

Temperature distribution is given by

$$\frac{T - T_\infty}{T_o - T_\infty} = \frac{\cosh m(L-x)}{\cosh mL}$$

Therefore, $T = T_\infty + (T_o - T_\infty) \frac{\cosh m(L-x)}{\cosh mL}$

Distance x, m	Temperature from Experiment °C	Temperature °C from calculation

- x1 = 0.045 T1 =
- x2 = 0.075 T2 =
- x3 = 0.105 T3 =
- x4 = 0.135 T4 =

$$\text{Effectiveness of fin} = \frac{\sqrt{PK} \tanh mL}{h A}$$

$$\text{Efficiency of fin} = \frac{\tanh mL}{mL}$$

Ex. No.

Date:

HEAT TRANSFER BY FORCED CONVECTION

AIM: To determine the convective heat transfer coefficient and the rate of heat transfer by forced convection for flow of air inside a horizontal pipe.

THEORY:

Convective heat transfer between a fluid and a solid surface takes place by the movement of fluid particles relative to the surface. If the movement of fluid particles is caused by means of external agency such as pump or blower that forces fluid over the surface, then the process of heat transfer is called forced convection.

In convective heat transfer, there are two flow regions namely laminar & turbulent. The non-dimensional number called Reynolds number is used as the criterion to determine change from laminar to turbulent flow. For smaller value of Reynolds number viscous forces are dominant and the flow is laminar and for larger value of Reynolds numbers the inertia forces become dominant and the flow is turbulent. Dittus–Boelter correlation for fully developed turbulent flow in circular pipes is,

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

Where, $n = 0.4$ for heating of fluid

$n = 0.3$ for cooling of fluid

$$N_u = \text{Nusselt number} = \frac{hd}{K}$$

$$Re = \text{Reynolds Number} = \frac{Vd}{\nu}$$

$$Pr = \text{Prandtl Number} = \frac{\mu c_p}{k}$$

DESCRIPTION OF THE APPARATUS:

The apparatus consists of a blower to supply air. The air from the blower passes through a flow passage, heater and then to the test section. Air flow is measured by an orifice meter placed near the test section. A heater placed around the tube heats the air, heat input is controlled by a dimmerstat. Temperature of the air at inlet and at outlet is measured using thermocouples. The surface temperature of the tube wall is measured at different sections using thermocouples embedded in the walls. Test section is enclosed in a asbestos rope where the circulation of rope is avoid the heat loss to out side.

PROCEDURE:

1. Start the blower after keeping the valve open, at desired rate.
2. Put on the heater and adjust the voltage to a desired value and maintain it as constant
3. Allow the system to stabilize and reach a steady state.
4. Note down all the temperatures T_1 to T_7 , voltmeter and ammeter readings, and manometer readings.
5. Repeat the experiment for different heat input and flow rates.

SPECIFICATIONS :

Specimen	: Copper Tube
Size of the Specimen	: I.D. 25mm x 400mm long
Heater	: Externally heated, Nichrome wire Band Heater
Ammeter	: Digital type, 0-20amps, AC
Voltmeter	: Digital type, 0-300volts, AC
Dimmerstat for heating Coil	: 0-230v, 2amps
Thermocouple Used	: 7 nos.
Centrifugal Blower	: Single Phase 230v, 50 hz, 13000rpm
Manometer	: U-tube with mercury as working fluid
Orifice diameter, 'd _o '	: 20 mm
G. I pipe diameter, 'd _p '	: 40 mm

OBSERVATION TABLE:

Room Temperature $T_R = \dots\dots\dots + 273.15 \text{ K}$

Sl. No	Heater input			Diff. in Manometer reading h_m mm	Air temp. °C		Tube surface Temperature °C						
	Voltmeter reading V volts	Ammeter reading I amps	VI watts		Inlet T_1	Outlet T_7	T_2	T_3	T_4	T_5	T_6		

SPECIMEN CALCULATIONS:

1. Mass density of air $\rho_a = \frac{P}{RT_R} \text{ kg/m}^3$

Where, $P = \text{Atmospheric Pressure} = 101325 \text{ N/m}^2$
 $R = \text{Gas constant for air} = 287 \text{ J/kg K}$
 $T_R = \text{Room temperature in K}$

2. Pressure drop across orifice meter in 'm of air

$$h_a = \frac{\rho_m h_m}{\rho_a}$$

where, $\rho_m = \text{Mass density of mercury} = 13600 \text{ kg /m}^3$
 $h_m = \text{Differential manometer reading of mercury}$

3) Velocity of air at the orifice

$$V_o = C_d \sqrt{\frac{2gh_a}{1 - (d_o/d_p)^4}} \text{ m/s}$$

4) Velocity of air in the tube

$$V_a = \frac{V_o (\pi d_o^2/4)}{(\pi d_s^2/4)} = \frac{V_o d_o^2}{d_s^2} \text{ m/s}$$

(Note: Change in density of air with temperature is neglected i.e., $\rho_a = \text{constant}$)

5. Average surface temperature of the tube

$$T_s = \frac{T_2 + T_3 + T_4 + T_5 + T_6}{5} + 273.15 \text{ } ^\circ\text{K}$$

6. Mean temperature of air

$$T_{\infty} = \frac{T_1 + T_7}{2} + 273.15 \quad ^{\circ}\text{K}$$

Properties of air are taken at $T_m = \frac{T_s + T_{\infty}}{2}$ $^{\circ}\text{K}$

At temperature T_m , kinematic viscosity ' ν ', Prandtl number ' Pr ' and thermal conductivity ' k ' are taken from properties of air table

6. Reynolds Number $Re = \frac{V_a \times d_s}{\nu}$

8. Nusselt number $Nu = 0.023 Re^{0.8} Pr^{0.3}$

9. $Nu = \frac{h \times d_s}{k}$

Forced convective heat transfer $h = \frac{Nu \cdot k}{d_s} \quad \text{W/m}^2\text{-K}$

10. Rate of heat transfer

$$Q = h A (T_{\infty} - T_s)$$

$$Q = h \pi d_s l_s (T_{\infty} - T_s) \dots \text{ watt}$$

Result:

The convective heat transfer coefficient and the rate of heat transfer by forced convection for flow of air inside a horizontal pipe is found to be _____

Ex. No.

Date:

HEAT TRANSFER BY NATURAL CONVECTION

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

THEORY:

Natural convection heat transfer takes place by movement of fluid particles within to solid surface caused by density difference between the fluid particles on account of difference in temperature. Hence there is no external agency facing fluid over the surface. It has been observed that the fluid adjacent to the surface gets heated, resulting in thermal expansion of the fluid and reduction in its density. Subsequently a buoyancy force acts on the fluid causing it to flow up the surface. Here the flow velocity is developed due to difference in temperature between fluid particles.

The following empirical correlations may be used to find out the heat transfer coefficient for vertical cylinder in natural convection.

$$\frac{1}{4} \quad 5$$

$$Nu = 0.53 (Gr \cdot Pr)^{1/4} \text{ for } Gr \cdot Pr < 10$$

$$\frac{1}{4} \quad 5 \quad 8$$

$$Nu = 0.56 (Gr \cdot Pr)^{1/4} \text{ for } 10 < Gr \cdot Pr < 10^8$$

$$\frac{1}{3} \quad 8 \quad 12$$

$$Nu = 0.13 (Gr \cdot Pr)^{1/3} \text{ for } 10 < Gr \cdot Pr < 10^{12}$$

Where, $Nu = \text{Nusselt number} = \frac{hL}{k}$

$$Gr = \text{Grashof number} = \frac{L^3 \beta g (T_s - T_a)}{\nu^2}$$

$$Pr = \text{Prandtl number} = \frac{\mu c_p}{k}$$

$\beta = \text{Volumetric coefficient of thermal expansion}$

$$\text{For ideal gases } \beta = \frac{1}{T_f}$$

Where ' T_f ' is the absolute film temperature at which the properties are taken.

SPECIFICATIONS:

Specimen	: Stainless Steel tube,
Size of the Specimen	: I.D 38mm / O.D 44mm, 500mm length
Heater	: Nichrome wire type heater along its length
Thermocouples used	: 8nos.
Ammeter	: Digital type, 0-2amps, AC
Voltmeter	: Digital type, 0-300volts, AC
Dimmerstat for heating coil	: 0-230 V, 2 amps, AC power
Enclosure with acrylic door	: For visual display of test section (fixed)

APPARATUS:

The apparatus consists of a stainless steel tube fitted in a rectangular duct in a vertical position. The duct is open at the top and bottom and forms an enclosure and serves the purpose of undisturbed surroundings. One side of the duct is made of acrylic sheet for visualization. A heating element is kept in the vertical tube, which heats the tube surface. The heat is lost from the tube to the surrounding air by natural convection. Digital temperature indicator measures the temperature at different points with the help of seven temperature sensors, including one for measuring surrounding temperature. The heat input to the heater is measured by Digital Ammeter and Digital Voltmeter and can be varied by a dimmerstat.

PROCEDURE:

1. Ensure that all ON/OFF switches given on the panel are at OFF position.
2. Ensure that variac knob is at zero position, provided on the panel.
3. Now switch on the main power supply (220 V AC, 50 Hz).
4. Switch on the panel with the help of mains ON/OFF switch given on the panel.
5. Fix the power input to the heater with the help of variac, voltmeter and ammeter provided.
6. Take thermocouple, voltmeter & ammeter readings when steady state is reached.
7. When experiment is over, switch off heater first.
8. Adjust variac to zero position.
9. Switch off the panel with the help of Mains On/Off switch given on the panel.
10. Switch off power supply to panel.

PRECAUTIONS:

1. Never switch on main power supply before ensuring that all on/off switches given on the panel are at off position
2. Never run the apparatus if power supply is less than 180 or above 200 volts.

TABULAR COLUMN:

Sl. No.	V Volts	I Amps	VI watts	Thermocouple readings °C								
				T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈ chamber	

CALCULATIONS:

$$1. T_s = \frac{T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7}{7} + 273.15 \quad ^\circ\text{K}$$

$$T_a = \text{Surrounding ambient temperature} = T_8 = \quad + 273.15 \quad ^\circ\text{K}$$

2. Obtain the properties of air at a mean temperature of

$$T_m = \frac{(T_s + T_a)}{2} \quad ^\circ\text{K}$$

3. Volumetric coefficient of thermal expansion

$$\beta = \frac{1}{T_m}$$

$$4. \text{ Grashof Number, } Gr = \frac{L^3 \beta g (T_s - T_a)}{\nu^2}$$

where, ν = kinematic viscosity

$$6. \text{ Rayleigh Number } Ra = Gr.Pr$$

$$7. \text{ Nusselt Number } Nu = \frac{hL}{k}$$

The following correlations are used to find Nusselt Number

$$Nu = 0.53 (Ra)^{1/4} \text{ for } Ra < 10^5$$

$$Nu = 0.56 (Ra)^{1/4} \text{ for } 10^5 < Ra < 10^8$$

$$Nu = 0.13 (Ra)^{1/3} \text{ for } 10^8 < Ra < 10^{12}$$

8. Free convective heat transfer coefficient

$$h = \frac{Nu \ k}{L} \quad \text{W/m}^2\text{-K}$$

9. Heat transfer rate by convection

$$Q_c = h A (T_s - T_a)$$

$$Q_c = h \pi d L (T_s - T_a) \quad \text{watt}$$

10. Heat Input to the coil

$$Q_i = V \times I \quad \text{watt}$$

RESULT:

The heat transfer coefficient for heat transfer by convection from vertical cylinder through natural convection is found to be _____ W/m²K.

Ex. No.

Date:

PARALLEL FLOW HEAT EXCHANGER

OBJECTIVE:

To determine LMTD and overall heat transfer coefficient for parallel flow heat exchanger

HEAT EXCHANGER:

Heat exchanger is a device in which heat is transferred from one fluid to another. Common examples of heat exchangers are:

- Condensers and boilers in steam plant
- Inter coolers and pre-heaters
- Refrigeration and Air Conditioners
- Chemical, Fertilizer and Refineries
- Food and meat processing plant
- Automobile radiators
- Regenerators

CLASSIFICATION OF HEAT EXCHANGERS:

Based on the nature of heat exchange process:

Direct contact type – Here the heat transfer takes place by direct mixing of hot and cold fluids

Indirect contact heat exchangers – Here the two fluids are separated through metallic wall.
ex. Regenerators, Recuperators etc.

Based on the relative direction of fluid flow:

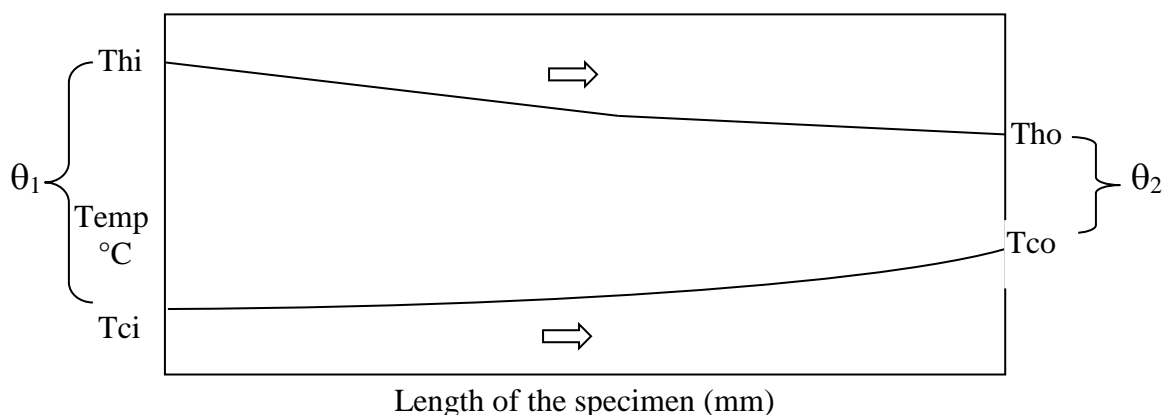
Parallel flow heat exchanger – Here both hot and cold fluids flow in the same direction

Counter flow heat exchanger – Here hot and cold fluids flow in opposite direction

Cross flow heat exchangers – Here the two fluids cross one another

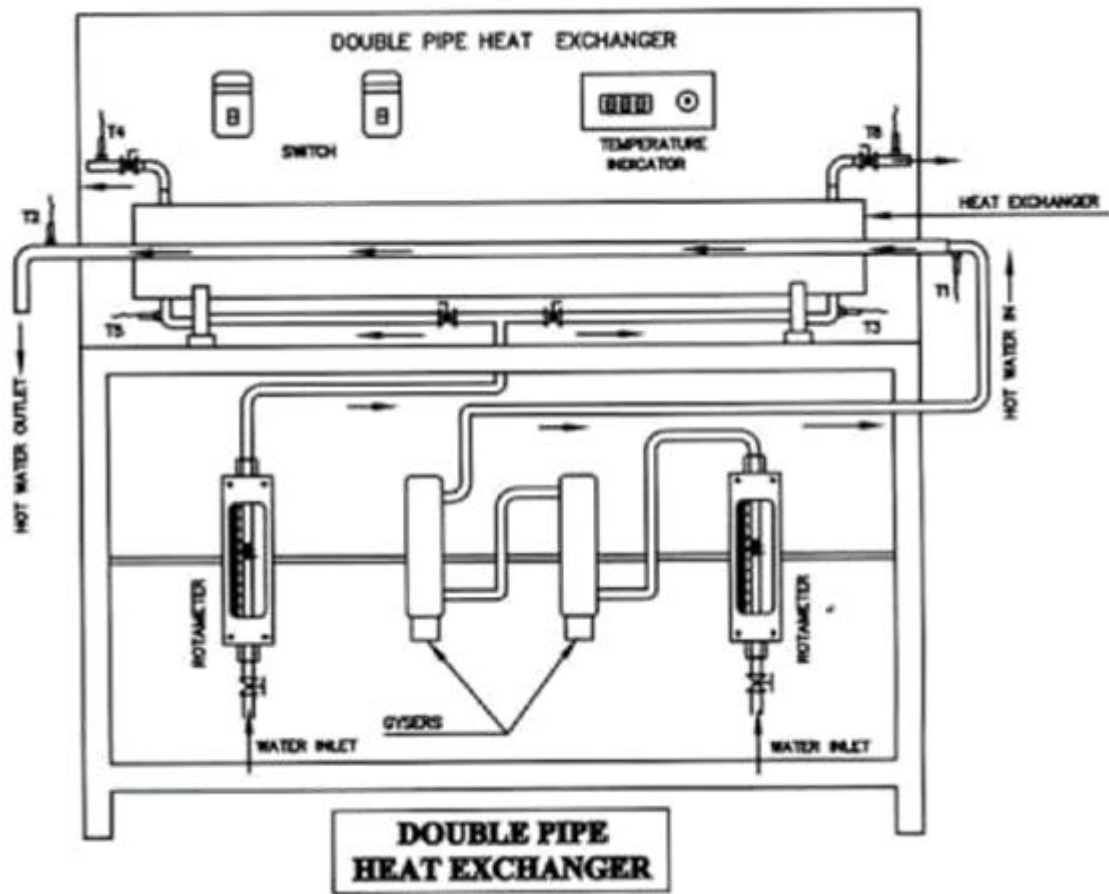
LOGARITHMIC MEAN TEMPERATURE DIFFERENCE (LMTD):

LMTD is defined as that temperature difference which, if constant, would give the same rate of heat transfer as usually occurs under variable conditions of temperature difference.

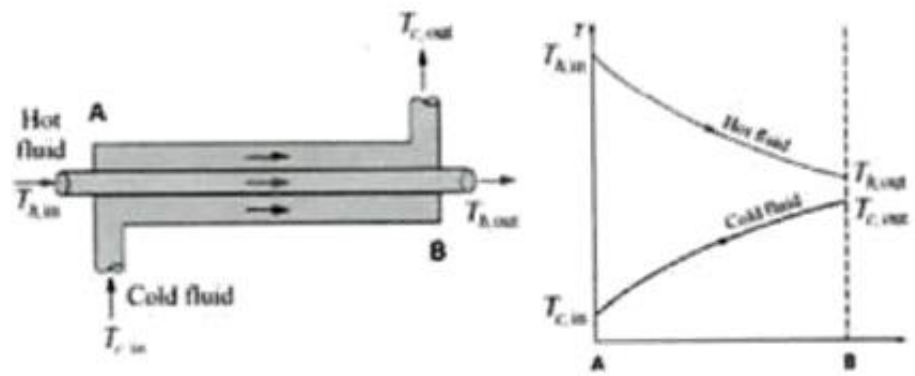


For Parallel flow:

$$\text{LMTD} = \frac{(T_{ho} - T_{co}) - (T_{hi} - T_{ci})}{\ln [(T_{ho} - T_{co}) / (T_{hi} - T_{ci})]} = \frac{\theta_2 - \theta_1}{\ln (\theta_2 / \theta_1)} \quad \text{OR} \quad \frac{(\text{HTD} - \text{LTD})}{\ln (\text{HTD} / \text{LTD})}$$



PARALLEL FLOW ARRANGEMENT



Where, HTD = higher temperature difference i.e. θ_2 and LTD = lower temp. difference i.e. θ_1
 T_{ho} = Outlet temperature of hot fluid
 T_{co} = Outlet temperature of cold fluid
 T_{hi} = Inlet temperature of hot fluid
 T_{ci} = Inlet temperature of cold fluid

OVERALL HEAT TRANSFER COEFFICIENT:

The rate of heat transfer between hot and cold fluid is given by

$$Q = U_o A_o / \text{LMTD}$$

Where,

U_o is overall heat transfer coefficient based on outer surface area of tubes, $\text{W/m}^2\text{-K}$
 A_o is the total outer surface area of tubes, m^2

EFFECTIVENESS:

Effectiveness of a heat exchanger is defined as the ratio of actual heat transfer rate to the theoretical maximum possible heat transfer rate.

$$\text{Effectiveness: } \varepsilon = \frac{Q_{\text{actual}}}{Q_{\text{max}}}$$

It can be shown that

$$\varepsilon = \frac{T_{hi} - T_{ho}}{T_{hi} - T_{ci}} \quad \text{if } m_h C_h < m_c C_c$$

$$\text{And } \varepsilon = \frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}} \quad \text{if } m_c C_c < m_h C_h$$

Where,

m_h and m_c are the mass flow rate of hot and cold fluids respectively in kg/s ;
 C_h and C_c are the specific heat of hot and cold fluids respectively in J/kg-K .

DESCRIPTION OF THE APPRATUS:

The apparatus consists of a concentric tube heat exchanger. The hot fluid namely hot water is obtained from the Geyser of capacity 1 kW through temperature controller. It flows through the inner tube while cold water flows through the annulus. The cold fluid i.e. cold water can be admitted at any one of the ends enabling the heat exchanger to run as a parallel flow or as a counter flow exchanger. This can be adjusted by operating different valves sets.

Measuring jar / Rotameter is used to measure flow rate of cold and hot water. Temperature of the fluid can be measured using thermocouples with digital display indicator. The outer tube is provided with insulation to minimize the heat loss to the surroundings.

SPECIFICATIONS:

Specimen material	: G.I. tube
Size of the inner tube	: ϕ 28 mm x 1500 mm long
Outer Shell material	: G.I
Size of the Outer Shell	: ϕ 50 mm
Geyser capacity	: 1 litre, heating power 1 kW

OBSERVATION TABLE:

Sl. No.	Hot water flow rate m_h , kg/s	Cold water flow rate m_c , kg/s	Temperature of cold water in °C		Temp. of hot water in °C	
			Inlet T_{ci}	Outlet T_{co}	Inlet T_{hi}	Outlet T_{ho}

EQUATIONS USED:

Heat transfer from hot water must be equal to heat gained by cold fluid

$$Q_h = m_h C_{ph} (T_{hi} - T_{ho}) \text{ watts} =$$

m_h = mass flow rate of hot water kg/sec

C_{ph} = Specific heat of hot water = 4186 J/ kgK

Heat gain by the cold fluid

$$Q_c = m_c C_{pc} (T_{co} - T_{ci}) \text{ watts}$$

m_c = Mass flow of cold fluid, kg/s

C_{pc} = Specific heat of cold fluid = 4186 J/kgK

$$\text{Average heat flow } Q = \frac{Q_h + Q_c}{2} \text{ watts}$$

$$\text{LMTD} = \frac{\theta_2 - \theta_1}{\ln (\theta_2/\theta_1)} \text{ } ^\circ\text{C}$$

$\theta_1 = T_{hi} - T_{ci}$ and $\theta_2 = T_{ho} - T_{co}$ for parallel flow heat exchanger

Overall heat transfer coefficient based on outside surface area of inner tube

$$U_o = \frac{Q}{\text{Contact area } A_o \times \text{LMTD}} = \quad / \quad \text{W/m}^2 \text{ K}$$

Where,

$$A_o = \pi d_o \times l \text{ m}^2 =$$

d_o = Outer diameter of the tube = 0.028 m

l = length of the tube = 1.5 m

PROCEDURE:

1. First switch on the MCB in the panel
2. Start the flow of cold water through the annulus and run the exchanger as parallel flow.
3. Switch ON the geyser provided on the panel
4. Allow the hot water to flow through the inner tube by regulating the valve.
5. Adjust the flow rate of hot water and cold water by using rotameters & valves.
6. Keep the flow rate same till steady state conditions are reached.
7. Note down the temperatures on hot and cold water sides. Also note the flow rate.
8. Record the readings in the tabular column.
9. Repeat the experiment for different flow rates and for different temperatures.
10. Calculate LMTD, U as per the formulae.

The same method is followed for counter flow also.

RESULT:

The LMTD for parallel flow heat exchanger is found to _____

Overall heat transfer coefficient parallel flow heat exchanger is found to _____

Ex. No.

Date:

COUNTER FLOW HEAT EXCHANGER

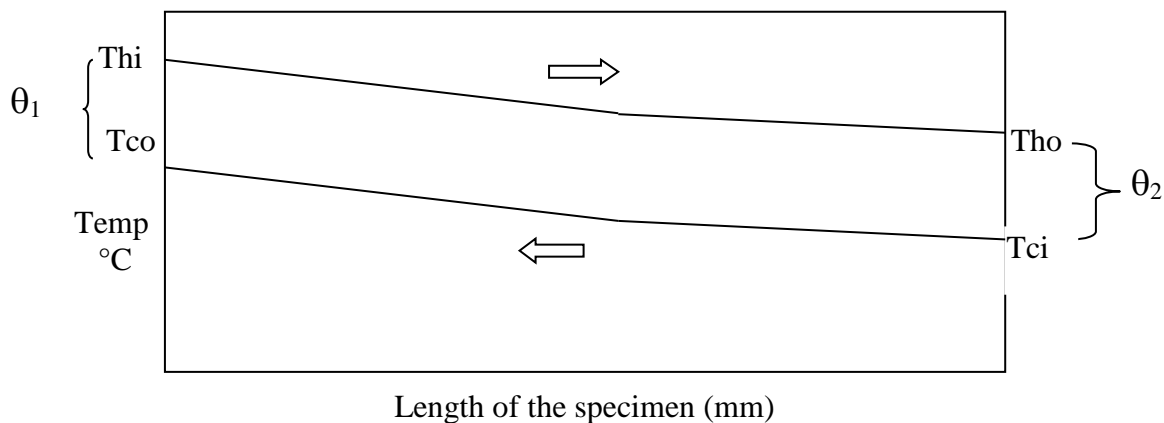
OBJECTIVE:

To determine LMTD and overall heat transfer coefficient for counter flow heat exchanger

HEAT EXCHANGER AND LOGARITHMIC MEAN TEMPERATURE DIFFERENCE (LMTD):

Heat exchanger is a device in which heat is transferred from one fluid to another. Common examples of heat exchangers are:

LMTD is defined as that temperature difference which, if constant, would give the same rate of heat transfer as usually occurs under variable conditions of temperature difference.



For Counter flow:

$$\text{LMTD} = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln [(T_{hi} - T_{co}) / (T_{ho} - T_{ci})]} = \frac{\theta_2 - \theta_1}{\ln (\theta_2 / \theta_1)} \quad \text{OR} \quad \frac{(\text{HTD} - \text{LTD})}{\ln (\text{HTD} / \text{LTD})}$$

Where, HTD = higher temperature difference and LTD = lower temp. difference

T_{ho} = Outlet temperature of hot fluid

T_{co} = Outlet temperature of cold fluid

T_{hi} = Inlet temperature of hot fluid

T_{ci} = Inlet temperature of cold fluid

OVERALL HEAT TRANSFER COEFFICIENT:

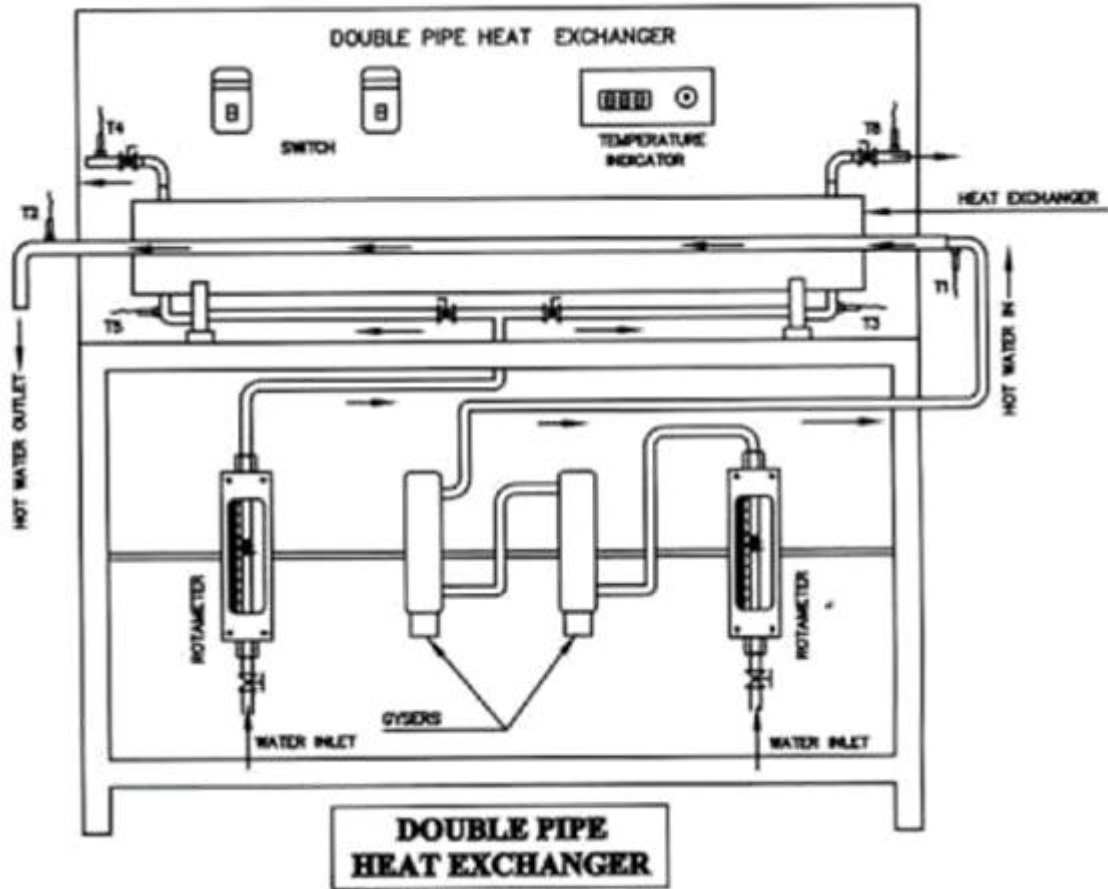
The rate of heat transfer between hot and cold fluid is given by

$$Q = U_o A_o / \text{LMTD}$$

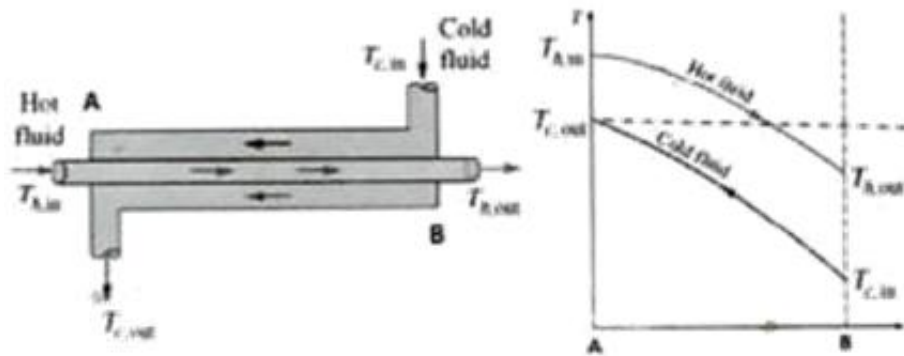
Where,

U_o is overall heat transfer coefficient based on outer surface area of tubes, $\text{W/m}^2\text{-K}$

A_o is the total outer surface area of tubes, m^2



COUNTER FLOW ARRANGEMENT



OBSERVATION TABLE:

Sl. No.	Hot water flow rate m_h , kg/s	Cold water flow rate m_c , kg/s	Temperature of cold water in °C		Temp. of hot water in °C	
			Inlet T_{ci}	Outlet T_{co}	Inlet T_{hi}	Outlet T_{ho}

EQUATIONS USED:

Heat transfer from hot water must be equal to heat gained by cold fluid

$$Q_h = m_h C_{ph} (T_{hi} - T_{ho}) \text{ watts} =$$

m_h = mass flow rate of hot water kg/sec

C_{ph} = Specific heat of hot water = 4186 J/ kgK

Heat gain by the cold fluid

$$Q_c = m_c C_{pc} (T_{co} - T_{ci}) \text{ watts}$$

m_c = Mass flow of cold fluid, kg/s

C_{pc} = Specific heat of cold fluid = 4186 J/kgK

$$\text{Average heat flow } Q = \frac{Q_h + Q_c}{2} \text{ watts}$$

$$\text{LMTD} = \frac{\theta_2 - \theta_1}{\ln(\theta_2/\theta_1)} \text{ } ^\circ\text{C}$$

$\theta_1 = T_{hi} - T_{co}$ and $\theta_2 = T_{ho} - T_{ci}$ for counter flow heat exchanger

Overall heat transfer coefficient based on outside surface area of inner tube

$$U_o = \frac{Q}{\text{Contact area } A_o \times \text{LMTD}} = \quad / \quad \text{W/m}^2 \text{ K}$$

Where,

$$A_o = \pi d_o \times l \text{ m}^2$$

$$d_o = \text{Outer diameter of the tube} = 0.028 \text{ m}$$

$$l = \text{length of the tube} = 1.5 \text{ m}$$

DESCRIPTION OF THE APPRATUS:

The apparatus consists of a concentric tube heat exchanger. The hot fluid namely hot water is obtained from the Geyser of capacity 1 kW through temperature controller. It flows through the inner tube while cold water flows through the annulus. The cold fluid i.e. cold water can be admitted at any one of the ends enabling the heat exchanger to run as a parallel flow or as a counter flow exchanger. This can be adjusted by operating different valves sets.

Measuring jar / Rotameter is used to measure flow rate of cold and hot water. Temperature of the fluid can be measured using thermocouples with digital display indicator. The outer tube is provided with insulation to minimize the heat loss to the surroundings.

SPECIFICATIONS:

Specimen material	: G.I. tube
Size of the inner tube	: ϕ 28 mm x 1500 mm long
Outer Shell material	: G.I
Size of the Outer Shell	: ϕ 50 mm
Geyser capacity	: 1 litre, heating power 1 kW

PROCEDURE:

- 1.First switch on the MCB in the panel
- 2.Start the flow of cold water through the annulus and run the exchanger as counter flow.
- 3.Switch ON the geyser provided on the panel
- 4.Allow the hot water to flow through the inner tube by regulating the valve.
- 5.Adjust the flow rate of hot water and cold water by using rotameters & valves.
- 6.Keep the flow rate same till steady state conditions are reached.
- 7.Note down the temperatures on hot and cold water sides. Also note the flow rate.
- 8.Record the readings in the tabular column.
- 9.Repeat the experiment for different flow rates and for different temperatures.
- 10.Calculate LMTD, U as per the formulae.

RESULT:

The LMTD for counter flow heat exchanger is found to _____

Overall heat transfer coefficient counter flow heat exchanger is found to _____

Ex. No.

Date:

STEFAN BOLTZMAN APPARATUS

OBJECTIVE:

To determine the value of Stefan Boltzman constant for radiation heat transfer.

THEORY:

The most commonly used thermal radiation law is Stefan Boltzman law which states that the total emissive power of a perfect black body is proportional to fourth power of the absolute temperature of black body surface

$$E_b = \sigma T^4$$

Heat radiated by a gray body $Q = \epsilon A \sigma T^4$ watts

where, $\sigma =$ Stefan Boltzman constant $= 5.67 \times 10^{-8} \text{ W}/(\text{m}^2 \text{ K}^4)$

$\epsilon =$ Emissivity of the surface

$A =$ Radiating surface Area

DESCRIPTION:

The apparatus consists of a flanged copper hemisphere fixed on a flat non-conducting plate. A test disc made of copper is fixed to the plate. Thus the test disc is completely enclosed by the hemisphere. The outer surface of the hemisphere is enclosed in a vertical water jacket used to heat the hemisphere to a suitable constant temperature. Five Cr-Al thermocouples are attached at three strategic places on the surface of the hemisphere to obtain the temperatures.

The disc is mounted on an ebonite rod which is fitted in a hole drilled at the center of the base plate. Another Cr-Al thermocouple (T6) is fixed to the disc to record its temperature. Fill the water in the SS water container with immersion heater kept on top of the panel.

SPECIFICATIONS:

Specimen material	: Copper
Size of the test disc	: ϕ 15mm x 0.5mm thickness
Base Plate	: ϕ 300mm x 12mm thickness (hylam)
Heater	: 1.5 kW capacity, immersion type
Copper Bowl	: ϕ 200mm
Digital temperature indicator	: 0 to 400 °C
Thermocouples used	: 3 nos. on hemisphere

OBSERVATION TABLE:

Let T_d = Temperature of the disc before inserting into the plate in K Temperature – time response of test disc

Thermocouple	Temperature of the copper hemisphere ° C
T ₁	
T ₂	
T ₃	
T ₄	
T ₅	
Average = °C = + 273 = K	

Time t sec	Temperature T ₆ ° C
start	
15	
30	
45	

CALCULATIONS:

Plot the graph of temperature of the disc v/s time to obtain the slope (dT/dt) of the line, which passes through/nearer to all points.

T_d = Temperature of the disc before inserting to test chamber ° K (ambient)

Rate of change of heat capacity of the disc = $m C \frac{dT}{dt}$

$$\text{Net energy radiated on the disc} = \sigma A_d (T_{avg}^4 - T_d^4)$$

where, A_d = area of the disc = $\frac{\pi d^2}{4} \text{ m}^2 = 0.7854 \times 0.015^2 = 0.000177 \text{ m}^2$
 $d = 15 \text{ mm}$

C = specific heat of specimen = 0.18 kJ/kg-K

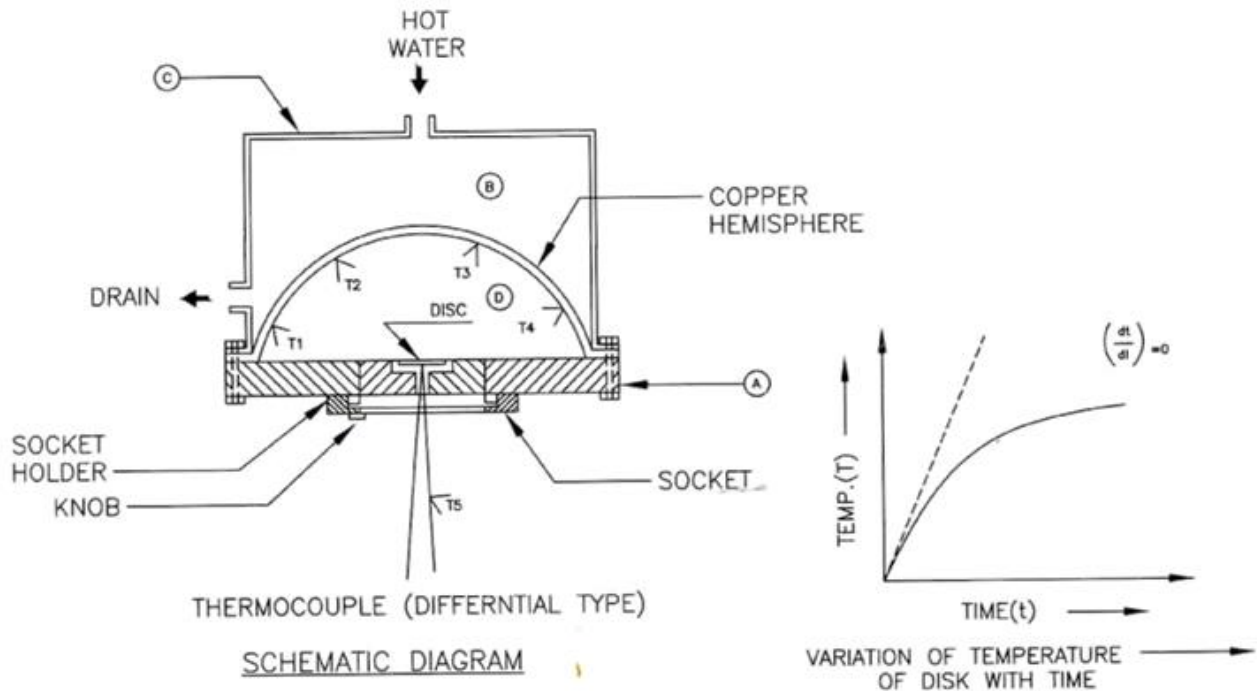
Rate of change of heat capacity of the disc = Net energy radiated on the disc

$$m C_p \frac{dT}{dt} = \sigma A_d (T_{avg}^4 - T_d^4)$$

Thus 'σ' can be evaluated as shown

$$\begin{aligned} \sigma &= \frac{m C_p \frac{Dt}{dt}}{A_d (T_{avg}^4 - T_d^4)} \\ &= \frac{0.007 \text{ kg} \times \frac{\text{J}}{\text{kgK}} \times \dots}{0.000177 \text{ m}^2 \times (\dots - \dots)} \\ &= \dots / (\dots - \dots) \\ &= \dots \times 10^{-8} \text{ W / m}^2 \end{aligned}$$

Stop Watch : Digital type
 Water Jacket : ϕ 300 mm, SS
 Mass of specimen, 'm' : 7 g
 specific heat of disc 'C' : 0.18 kJ/kg-K = 180 J / kgK



STEFAN BOLTZMAN APPARATUS

PROCEDURE:

1. Remove the test disc before starting the experiment.
2. Heat the water in the SS container to its boiling point.
3. Allow the boiling water into the container kept at the bottom containing copper hemisphere until it is full. Allow sufficient time to attain thermal equilibrium which is indicated by the five thermocouples provided on the hemisphere.
4. Insert the test disc fixed on the ebonite rod sleeve completely inside and lock it. Start the stop clock simultaneously.
5. Note down the temperature of the test disc T6 at an interval of about 15 sec for about 15 to 20 minutes.

RESULT:

The experiment value of Stefan Boltzman constant is _____

RUBRICS FOR HEAT TRANSFER LAB

	Excellent(3)	Good(2)	Fair(1)
Conduct Experiments (CO1)	Student successfully completes the experiments and explains the experiment concisely and well.	Student successfully completes the experiments and explains the experiment moderately.	Student successfully completes the experiments and unable to explain the experiment.
Analysis and Synthesis (CO2)	Analyze the experiments in details and thoroughly.	Reasonably analyze the experiments.	Improperly analyze the experiments.
Design (CO3)	Students successfully complete the experimental design and explain the design process in brief and well.	Students successfully complete the design and explain appropriate design process.	Students successfully complete the design and unable to explain design process.
Complex Analysis & Conclusion (CO4)	Thorough comprehension through analysis/ Synthesis.	Reasonable comprehension through analysis/ synthesis.	Improper comprehension through analysis/ Synthesis.
Use modern tools in engineering practice (CO5)	Students used modern instruments and tools to complete the experiments.	Students used few modern instruments and tools to complete the experiments.	Students not capable of using modern instruments and tools to complete the experiments.
Report Writing (CO6)	Generate the report with clear procedure of the experiment using excellent language.	Generate the report with clear procedure of the experiment using understandable language.	Generate the report with improper language.
Ethics and Lab safety (CO7)	Students demonstrate good understanding and follow lab ethics and safety.	Students demonstrate good understanding of lab ethics and safety.	Students demonstrate fair knowledge of lab ethics and safety.
Ability to work as individual (CO8)	Ability to Perform the experiments as an individual with clear proof of tasks and effort.	Ability to Perform the experiments as an individual with moderate proof of tasks and effort.	Inability to Perform the experiments as an individual with clear proof of tasks and effort.
Continuous learning (CO9)	Highly enthusiastic towards continuous learning.	Interested in continuous learning.	Inadequate interest in continuous learning.