QMP 7.1 D/F

Channabasaveshwara Institute of Technology

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(NAAC Accredited & An ISO 9001:2015 Certified Institution)
NH 206, (B.H. Road), Gubbi, Tumkur – 572 216. Karnataka

Department of Mechanical Engineering

Heat Transfer Laboratory

21ME62

B.E - VI Semester

Lab Manual 2023-24

Name : ______________________________________

USN : ______________________________________

Batch : _________________ Section : _____________

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Department of Mechanical Engineering

Heat Transfer Lab Manual

Academic Year 2023-24

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DEPARTMENT OF MECHANICAL ENGG.

Heat Transfer Lab Syllabus

Course	Code	Credits	L-T-P	Assessment		Exam Duration
				SEE	CIA	
Heat Transfer Lab	21ME62	04	0-0-2	20	---	3Hrs

Course Objectives: The primary objective of this course is to provide the fundamental knowledge necessary to understand the behavior of thermal systems.

- This course provides a detailed experimental analysis, including the application and heat transfer through solids, fluids, and vacuum.
- Convection, conduction, and radiation heat transfer in one and two dimensional steady and unsteady systems are examined.

Sl.No.	Experiments
1	Determination of Thermal Conductivity of a Metal Rod.
2	Determination of Overall Heat Transfer Coefficient of a Composite wall.
3	Determination of Effectiveness on a Metallic fin.
4	Determination of Heat Transfer Coefficient in free Convection
5	Determination of Heat Transfer Coefficient in a Forced Convention
6	Determination of Emissivity of a Surface and Determination of Stefan Boltzmann Constant.
7	Determination of LMDT and Effectiveness in a Parallel Flow and Counter Flow Heat Exchangers.
8	Experiments on Boiling of Liquid and Condensation of Vapour.
9	Experiment on Transient Conduction Heat Transfer.
10 11	Use of CFD for demonstrating heat transfer mechanism considering practical applications , Minimum two exercises
12	Using one dimensional transient conduction, experimentally demonstrate estimation of thermal conductivity and thermal diffusivity

Course Outcomes: At the end of the course, the student will be able to:

CO1: Determine the thermal conductivity of a metal rod and overall heat transfer coefficient of composite slabs.

CO2: Determine convective heat transfer coefficient for free and forced convection and correlate with theoretical values.

CO3: Evaluate temperature distribution characteristics of steady and transient heat conduction through solid cylinder experimentally.

CO4: Determine surface emissivity of a test plate and Stefan Boltzmann constant

Reading:

1. M. Necati Ozisik, Heat Transfer – A Basic Approach, McGraw Hill, New York, 2005.
2. Incropera, F. P. and De Witt, D. P., Fundamentals of Heat and Mass Transfer, 5th Edition, John Wiley and Sons, New York, 2006.
3. Holman, J. P., Heat Transfer, 9th Edition, Tata McGraw Hill, New York, 2008.

Scheme of Examination:

ONE question from part -A: 40 Marks
ONE question from part -B: 40 Marks
Viva –Voice : 20 Marks
Total: 100 Marks

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Institutes' Vision

To create centres of excellence in education and to serve the society by enhancing the quality of life through value based professional leadership.

Institutes' Mission

- To provide high quality technical and professionally relevant education in a diverse learning environment.
- To provide the values that prepare students to lead their lives with personal integrity, professional ethics and civic responsibility in a global society.
- To prepare the next generation of skilled professionals to successfully compete in the diverse global market.
- To promote a campus environment that welcomes and honors women and men of all races, creeds and cultures, values and intellectual curiosity, pursuit of knowledge and academic integrity and freedom.
- To offer a wide variety of off-campus education and training programmes to individuals and groups.
- To stimulate collaborative efforts with industry, universities, government and professional societies.
- To facilitate public understanding of technical issues and achieve excellence in the operations of the institute.

Department Vision

- To create state of the art learning environment to nurture the learning.
- Blending human values, academic professionalism and research process in the field of mechanical engineering.
- Blending human values, academic professionalism and research process in the field of mechanical engineering for the betterment of society.

Department Mission

The mission of the department is to

- Provide requisite foundation to our students in Mechanical Engineering.
- Provide cutting edge laboratory resources to bridge the gap between theoretical and practical concepts.
- Provide exposure to various mechanical industries through periodic industrial visits.
- Enhance our students skill set and to make them industry ready by systematic skill development program.

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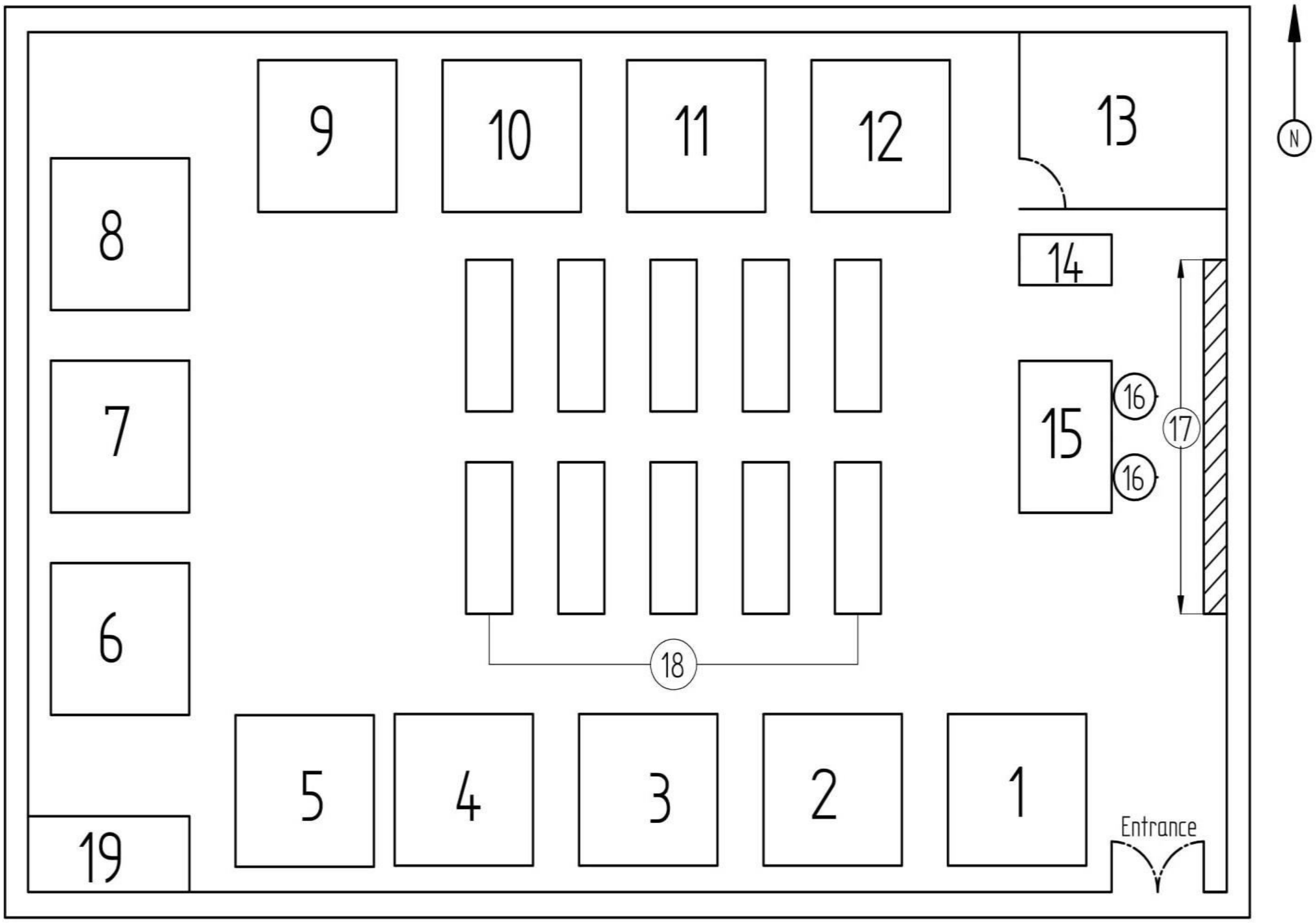

HEAT TRANSFER LAB LAYOUT

1. Emissivity Measurement Apparatus.
2. Composite Wall Apparatus.
3. Natural Convection Apparatus.
4. Forced Convection Apparatus.
5. Heat Transfer Through Pin-Fin Apparatus.
6. Vapour Compression & Air Conditioning Test Rig Apparatus.
7. Vapour Compression Refrigeration Test Rig Apparatus.
8. Drop & Film Wise Apparatus.
9. Thermal Conductivity Of Metal Rod Apparatus.
10. Transient Heat Conduction Apparatus.
11. Parallel & Counter Flow Apparatus.
12. Stefan Boltzmann Apparatus.
13. Staff Room.
14. Instructor Table.
15. Staff Table.
16. Staff Chairs.
17. White & Green Board.
18. Students Desks.
19. Almerah.

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HEAT TRANSFER LAB

List Of Experiments

1. Determination of Thermal Conductivity of a Metal Rod.
2. Determination of Overall Heat Transfer Coefficient of a Composite wall.
3. Determination of Effectiveness on a Metallic fin.
4. Determination of Heat Transfer Coefficient in a free Convection on a vertical tube.
5. Determination of Heat Transfer Coefficient in a Forced Convention Flow through a Pipe.
6. Determination of Emissivity of a Surface.
7. Determination of Steffan Boltzman Constant.
8. Determination of LMDT and Effectiveness in a Parallel Flow and Counter Flow Heat Exchangers
9. Experiments on Boiling of Liquid and Condensation of Vapour
10. Experiment on Transient Conduction Heat Transfer

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DEPARTMENT OF MECHANICAL ENGINEERING

LECTURE PLAN

Faculty Name:

Sem. & Sec.: **VI 'A'** Sub: **HT LAB** Sub. Code: **21ME62**

Sl. No.	Date	Lesson Plan No.	Name of the Experiment	Remarks
Batch				
1		LP.1	Determination of thermal conductivity of metal rod	
2		LP.2	Determination of overall heat transfer coefficient of a composite wall	
3		LP.3	Determination of heat transfer coefficient in a free or natural convection	
4		LP.4	Determination of heat transfer coefficient in a forced convection	
5		LP.5	Determination of effectiveness on a metallic Pin - fin	
6		LP.6	Determination of Emissivity of a surface	
7		LP.7	Determination of Stefan Boltzmann constant	
8		LP.8	Determination of LMTD and effectiveness in a parallel & counter flow heat exchanger	

9.		LP.9	Determination of heat transfer coefficient & overall heat transfer in film wise & drop wise condensation	
10.		LP.10	Determination of transient heat conduction	
11.		LP.11	Revision	
12.		LP.12	Lab I A	

EXTRA LABS

Month	DATE
May	
June	
July	
August	

Signature of staff **HOD**

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Safety Precautions to the Students.

- ✓ Laboratory uniform, shoes & safety glasses are compulsory in the lab.
- ✓ 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.
- ✓ Please follow instructions precisely as instructed by your supervisor. Do not start the experiment unless your setup is verified & approved by your supervisor.
- ✓ Do not leave the experiments unattended while in progress.
- ✓ Do not crowd around the equipment's & run inside the laboratory.
- ✓ During experiments material may fail and disperse, please wear safety glasses and maintain a safe distance from the experiment.
- ✓ 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.
- ✓ Keep the work area clear of all materials except those needed for your work and cleanup after your work.

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Course Objectives & Outcomes.

Course Objectives:

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

Course Outcomes:

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

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DEPARTMENT OF MECHANICAL ENGINEERING.

TABULAR COLUMN:

Sl No.	**Flow Rate of water**		**Water Temp.**		**Temp. of Metal Rod**					**Temp. in Insulating shall**			
	LPM	**Kg/sec**	**T_{10}**	**T_{11}**	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_8**	**T_9**

RESULTS (STANDARD):

Metal	**Thermal Conductivity W/m ^{0}k**	**State**
Pure Copper	330 – 385	at 20^0C
Brass	95 – 107	at 20^0C
Steel	20 – 45	at 20^0C
Stainless Steel	55 – 65	at 20^0C

FORMULAS:

Heat carried away by water

$Q_w = m_w \, Cp_w \, \triangle T$

m_w = Mass of flow rate of water in kg/sec

Cp_w = Specific heat of water = 4.178 KJ / Kg ^{0}K

$\triangle T = T_{wo} - T_{wi}$

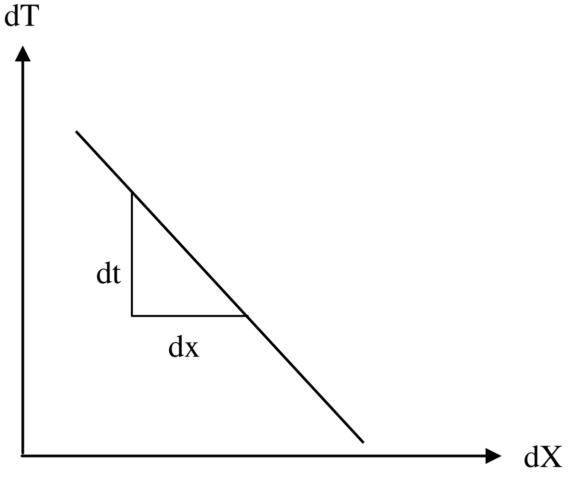
$$q = Q_w + \frac{[(2\pi l \times k\,(T_5 - T_1))}{[\ln(r_o / r_i))]}$$

k = Thermal conductivity of insulating powder

q = Heat flux

Plot the graph of temp. V/s distance [dT V/s dx]

And find out the temp. Gradient [dT / dx]



Experiment No.1 **Date: _ / _ /_**

THERMAL CONDUCTIVITY OF METAL ROD APPARATUS

AIM:

To determine the thermal conductivity of the given metal rod

INTRODUCTION:

Thermal conductivity is the physical property of the material. Based on the value of thermal conductivity of material its heat transfer capacity can be determined. Thermal conductivity (often denoted k, λ, or κ) is the property of a material to conduct heat.

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

DESCRIPTION:

The experimental setup consists of a metal bar, one end of which is heated by an electrical heater while the other end projects inside a cooling water jacket. The middle portion is surrounded by a cylindrical shell filled with insulating powder and five thermocouple are placed on the bar for temperature measurement. For radial measurement of temperature 4 thermocouples are placed at a sections/radius of 42.5 mm& 55mm in the insulating shell.

The heater is provided with a dimmerstat for controlling the heat input, water under a constant head is circulated through the jacket and its flow rate and temperature rise are measured using measuring jar and temperature sensors.

PROCEDURE:

(1) Adjust the flow of water to 0.1-0.2 liters / min on Rotameter
(2) Put on the Power supply and adjust the variac to obtain the required Heat input
(3) Wait till the steady state is reached.
(4) Take the readings of thermocouples $T_1 – T_{11}$
(5) Repeat experiment for different heat input and water flow rate

SPECIFICATION:

Metal rod: Copper
Total length of the metal bar : 400 mm
Effective length : 320 mm
Diameter of the Metal rod : 35 mm
Insulation: Chalk powder
Distance between two consecutive thermocouple: 60 mm (T_1 to T_5)
Radial distance of the thermocouple in the insulating Shell:
Inner radians r_i = 42.5 mm + (35/2)
Outer radians r_o = 55 mm+ (35/2)

CALCULATIONS:

Heat carried away by water

$Q_w = m_w \, Cp_w \, \triangle T$

m_w = Mass of flow rate of water in kg/sec

Cp_w = Specific heat of water = 4.178 KJ / Kg ^{0}K

$\triangle T = T_{wo} - T_{wi}$

$$Q = Q_w + Q_{\text{conduction}} = Q_w + \frac{2\pi K.\, l(T_6 - T_7)}{[\ln (r_o / r_i)]}$$

k = 0.012w/mº k for insulating powder

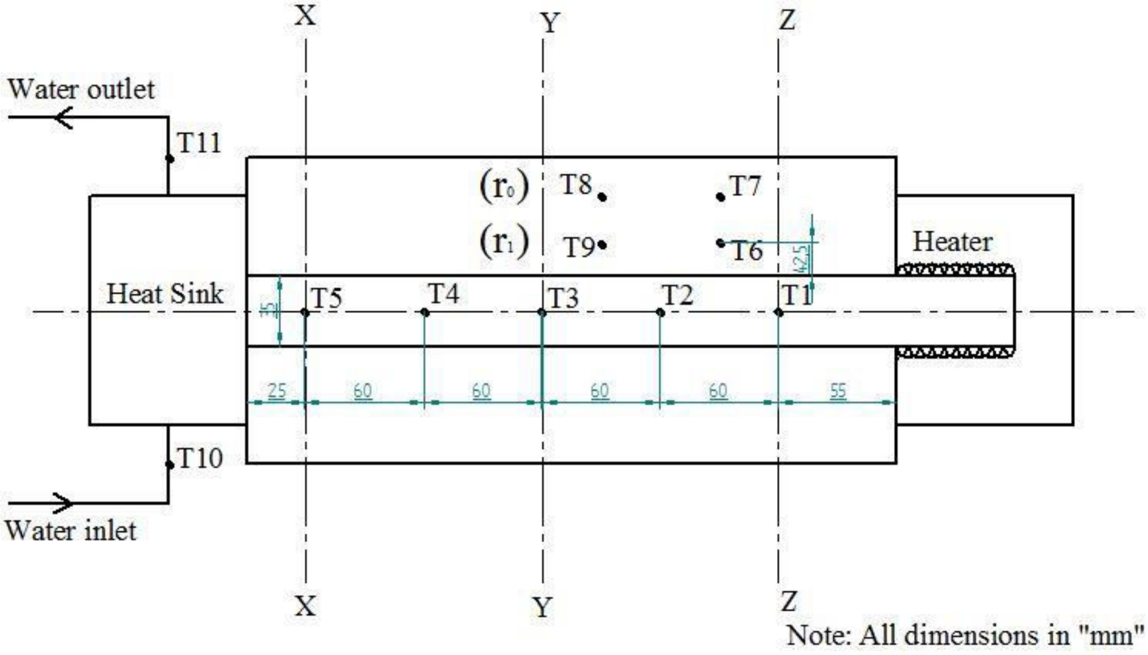
Also

$$\therefore \quad Q = -KA \frac{dT}{dx}$$

$$\therefore \quad K = \frac{-Q}{A.\dfrac{dT}{dx}}$$

where A = c/s area of metal rod [$\Pi d^2/4$]

where K is the thermal conductivity of metal rod in (W/ mºk)



Note: All dimensions in "mm"

Work Sheet

Date: Faculty signature

SPECIFICATION:

1. Mild Steel 25 mm thick of 300 mm dia. 1 No. K1 = 25 w/m ^{0}K
2. Hylam 19mm thick of 300 mm dia 1 No K_2 = 0.05 w/m ^{0}K
3. Wooden 12mm thick of 300 mm dia 1 No K_3 = 0.08 w /m ^{0}K
4. Mica Heater 300 watts of 300 mm dia 1No
5. Digital temperature indicator 12 channel 1No
6. Digital volt meter 1 No
7. Digital Ammeter 1No
8. Temperature Sensors PT 100 12 Nos

Tabulation:

MILD STEEL		**HYLAM**		**WOOD**	
L_1 = 25 mm K_1		L_2 = 19 mm K_2		L_3 = 12 mm K_3	
T_1T_2	T_3T_4	T_3 T_4	T_5T_6	T_5T_6	T_7T_8

TABULER COLUMN:

T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	V	I	Remarks

Experiment No.2 **Date: _ / _ /_**

COMPOSITE WALL APPARATUS

AIM:

To determine the overall heat transfer coefficient of a composite wall

APPARATUS:

The apparatus consists of three slabs of different materials of different thickness 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.

Temperature sensors are fitted at the interface of the plates at different points as to obtain average temperature for each surface. Heat conducted through the composite wall is taken away by atmospheric air.

EXPERIMENTAL PROCEDURE:

1. The heat input to the heater is fixed for any desired temperature (assume $T_1 = T_i$) of the plates.
2. After a steady state condition is reached, average temperature of the slabs at the interface is noted.
3. By varying the heat input to the system through variac different sets of readings can be obtained.

CALCULATIONS:

(a) Heat flow through composite wall

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

$$Q = \frac{K_1 A1 (T_1' - T_2')}{L_1} = \frac{K_2 A2 (T_2' - T_3')}{L_2} = \frac{K_3 A3 (T_3' - T_4')}{L_3}$$

$$K_1 = \frac{QL_1}{A_1 (T_1' - T_2')}, \text{ where } A = \frac{\pi D^2}{4} \text{ where } D = 300 \text{ mm.}$$

$$K_2 = \frac{QL_2}{A_2 (T_2' - T_3')}$$

$$K_3 = \frac{QL_3}{A_3 (T_3' - T_4')}$$

Where $\mathbf{A_1 = A_2 = A_3 = A}$.

Note: $T_1' = (T_1+T_2)/2$.

$T_2' = (T_3+T_4)/2$.

$T_3' = (T_5+T_6)/2$.

$T_4' = (T_7+T_8)/2$.

(b) Overall heat transfer coefficient (U_0) in (W/m^2K)

$$U_0 = \frac{1}{A\left(\frac{L_1}{K_1A} + \frac{L_2}{K_2A} + \frac{L_3}{K_3A}\right)}$$

Work Sheet

Date: Faculty signature

TABULAR COLUMN:

Free Convection

SI.No.	Voltage	Current In amps	Position of the thermocouple from the pin base in mm & Temp. along the pin – fin in ^oC					Amb. Temp In ^oC
			0	20	40	60	80	
	V	I	T_1	T_2	T_3	T_4	T_5	T_6
1								
2								
3								
4								

DATA:

Length of the pin – fin (L) = 120mm
Diameter of the pin fin (D) = 13mm
Diameter of the orifice (D_0) = 30mm
Diameter of the pipe (Dp) = 50mm
Coefficient of discharge C_d = 0.64
Thermal conductivity of fin material (K) = 110 W/mK
Duct size = 150 mm x 100mm
Distance between each thermocouple on pin fin = 20 mm

Forced Convection

SI.No.	Voltage	Current In amps	Position of the thermocouple from the pin base in mm & Temp. along the pin – fin in ^oC					Amb. Temp In ^oC
			0	20	40	60	80	
	V	I	T_1	T_2	T_3	T_4	T_5	T_6
1								
2								
3								
4								

Experiment No.3 **Date: _ / _ /_**

HEAT TRANSFER THROUGH PIN - FIN

AIM:

To determine the following in natural convection and forced convection:

- Theoretical and Experimental temperature along the length of the pin – fin
- Effectiveness of the pin – fin
- Efficiency of the pin – fin

Fins are deliberately provided protrusions on metallic surfaces to increase the heat transfer area. Fins could be of uniform cross sectional area or the area may be varying along the length of the fin. Under same conditions, a surface with a fin transfer heat faster than a surface without a fin. A common example is the fin provided in the cylinder of an air cooled internal combustion engine. Heat is transferred by the heated surface to the fin by conduction and in turn the pin transfer heat to then surrounding fluid either by natural or forced convection.

‘Effectiveness of a Fin’ (E) is defined as the ratio of the heat transfer from a surface with a fin and without the fin.
‘Fin Efficiency’ (η) is defined as the ratio of actual heat transfer from a surface to the heat that would have been transferred had the entire fin area were to be at the base temperature

APPARATUS:

The apparatus, mainly, consists of a fin in the form of a horizontal metallic pin. The pin is heated at one end.(i.e., the base of the fin) by an electric heater. The pin is located in the middle of a long duct which can be supplied by air from a blower. When the blower is on and air is being forced against the fin, the fin is subjected to forced convection heat transfer. When the blower is off the pin is subjected to natural convection heat transfer. There are five Temp sensors (t1 to t5) fixed on the surface of the fin. Each is separated from the next one by 20 mm. The first sensor is at the fin. One more sensors (t6) measure the room air temperature. The air flow rate through the duct is measured using an orifice meter. The power supplied to heater is evaluated by measuring the voltage and the current.

CALCULATIONS :

(a). Natural convection

$$Q = VI$$

$$A = \pi DL$$

We have, $T_a = T_6$

$$H = \frac{Q}{A(T_s - T_a)}$$

$$\text{Where } Ts = \frac{T_1+T_2+T_3+T_4+T_5}{5}$$

$$\text{We have } m = \sqrt{(H*P/ K*A)}$$

$$P = \pi D$$

(ii) Effectiveness,

Effectiveness is evaluated from:

$$E = \frac{\text{Tanh}\ (mL)}{\sqrt{HA/ KP}}$$

Fin Effectiveness =	

(iii) Fin Efficiency , η:

$$\eta = \frac{\text{Tanh}\ (mL)}{mL}$$

Fin Efficiency =	

PROCEDURE:

(a) Natural Convection:-

The electric heater is switched on.

The potential drop across the heater coil is adjusted to be around 60 V.

Wait until near steady state conditions are reached.

At this instant the temperatures indicated by any thermocouple does not change substantially in a certain period, say 30 s.

Enter the various experimental observations in the following table:

(b) Forced Convection:

After taking reading for natural convection heat transfer, switch the blower on.

Adjust the flow rate of air through the duct such that the pressure drop across the orifice is 40 – 50 mm H_2O.

Wait for near steady state conditions.

Take the different readings and enter them in the following tabular form:

(b). Forced convection

$$Q = VI$$

$$A = (\pi DL)$$

We have, $T_a = T_6$

$$H = \frac{Q}{A(T_s - T_a)}$$

Where $T_s = \frac{T_1+T_2+T_3+T_4+T_5}{5}$

We have $m = \sqrt{(HP/KA)}$

$$P = \pi D$$

(ii)Effectiveness,

Effectiveness is evaluated from:

$$E = \frac{\tanh(mL)}{\sqrt{HA/KP}}$$

Fin Effectiveness =	

(iii) Fin Efficiency , η:

$$\eta = \frac{\tanh(mL)}{mL}$$

Fin Efficiency =	

Work Sheet

Date: Faculty signature

SPECIFICATION:

Dia of the tube ‘d’ = 38 mm (0.038 m)
Length of the tube ‘L’ = 500 mm (0.5 m)
Duct Size = 250 mm x 250 mm x 900 mm
No. of Temperature sensors = 7 Nos.

TABULAR COLUMN:

Sl. No.	Dimmer stat Reading W	Voltmeter Reading V , Volts	Current I Amps	Surface Temperature ° C						Ambient Temp° C
				T1	T2	T3	T4	T5	T6	T7
1										
2										

CALCULATIONS:

Heat transfer co-efficient, $h = \dfrac{Q}{A\,(Ts - Ta)}$

Q = Rate of heating, = V * I, watts.
A = π . D. L, where D= Dia. of cylinder rod
L = length of cylinder
T_s = Surface temperature

$$T_s = \frac{T_1+T_2+T_3+T_4+T_5+T_6}{6}$$

Ta = Ambient temperature =T_7

Experiment No.4 **Date: _ / _ /_**

NATURAL CONVECTION

AIM:

To determine the natural convection heat transfer co-efficient for the vertical tube exposed to atmospheric air.

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 principle 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 warmer fluid would be replaced by the colder fluid creating convection currents. 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 which is due to the presence of a density gradient with in the fluid and a body force. Grashof number a dimensionless quantity plays a very important role in natural convection.

DESCRIPTION:

The apparatus consists of a brass tube fitted in a rectangular duct in a vertical fashion. The duct is open at the top and bottom and forms an enclosure and served the purpose of undisturbed surrounding. One side of the duct is made up of Perspex for visualization. An electric heating element is kept in the vertical tube which intern heats the tube surface. The heat is lost from the tube to the surrounding air by natural convection. The temperature of the vertical tube is measured by seven thermocouples. The heat input to the heater is measured by an Ammeter and a Voltmeter and is varied by a dimmer stat. The tube surface is polished to minimize the radiation losses.

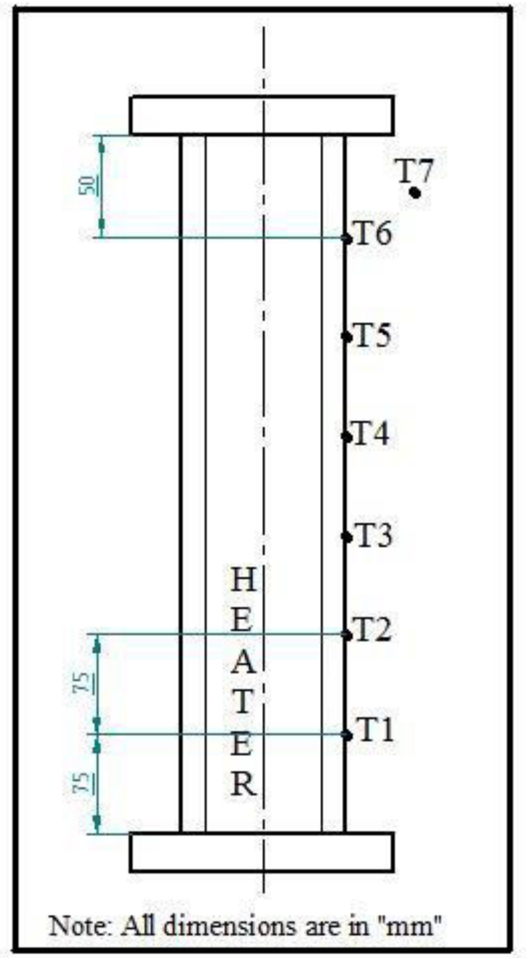
PROCEDURE:

(1) Switch on the supply and adjust the variac to obtain the required heat input
(2) Wait till the steady state is reached.
(3) Take the readings (Note down the readings) of thermocouples $T_1 - T_6$.
(4) Note down the ambient temperature T_7.
(5) The experiment can be repeated for different heat inputs

SPECIFICATION

NATURAL CONVECTION APPARATUS

Tube Material : Brass
Dia of the tube : 38 mm
Length of the tube : 500 mm
Distance between two Consecutive thermocouple 75 mm (T1 to T6)



Work Sheet

Date: Faculty signature

TABULAR COLUMN:

Sl. No.	Voltmeter Reading 'V'	Current 'I'	Surface Temperature ° C					Air inlet Temp	Air Outlet Temp
	Volts	Amps	T_2	T_3	T_4	T_5	T_6	T_1 ° C	T_7 ° C
1									
2									

CALCULATIONS:

To find convective transfer co-efficient

$$Q = h A (T_w - T_a)$$

$$h = \frac{Q}{A (T_w - T_a)} \quad \text{where } A = \Pi D_0 L$$

Where

Q = heat transfer rate = V * I= watts.

Dia of the tube D_0 = 32 mm

Length of test section L = 610 mm

T_w = avg. Surface temperature.

$$T_w = \frac{(T_2 + T_3 + T_4 + T_5 + T_6)}{5}$$

$$T_a = \frac{(T_1 + T_7)}{2}$$

Experiment No.5 **Date: _ / _ /_**

HEAT TRANSFER THROUGH FORCED CONVECTION

AIM:

To determine the surface heat transfer co-efficient ‘h’for a horizontal tube loosing heat by forced convection.

THEORY:

Convection is a process of energy transport by the combined action of heat conduction, energy storage and mixing motion. When the mixing motion is induced by some external agency such as pump or a blower the process is called forced convection. The intensity of the mixing motion is generally high in forced convection and consequently the heat transfer coefficients are higher than free convection. By using the dimensional analysis, the experimental results obtained in forced convection heat transfer can be correlated by equation of the form

Rate of heat transfer through convection is given by:

$$Q = hA\ (T_s - T_{av})$$

Where ‘h’ is the average convective heat transfer coefficient,
‘A’ the area of heat transfer, Ts is the heated surface temperature and
Tav is the average fluid temperature.

DESCRIPTION:

The apparatus consists of a blower unit fitted with the test pipe. Nichrome band heater surrounds the test section. Four thermo couples are embedded on the test section and two thermo couples are placed in the air stream at the entrance and exit of the test section to measure the air inlet and outlet temperatures. Test pipe is connected to the delivery side of the blower along with the orifice to measure flow of air through the pipe. Input to heater is given through Dimmerstat and measured by voltmeter and ammeter. Airflow is measured with the help of orifice meter and the manometer fitted on the board.

PROCEDURE:

(1) Put on the supply and adjust the variac to obtain the required heat input.
(2) Switch on the blower unit and adjust the flow of air using gate valve of blower to a desired difference in manometer (4 or 5 cms alternately)
(3) Wait till the steady state is reached.
(4) Take the readings of thermocouples T1 - T6.
(5) Note down a) Voltmeter reading ‘V’ volts.
b) Ammeter reading ‘A’ amps.
(6) Repeat the same procedure for different heat inputs and also for different flow rates of air & tabulate the values.

SPECIFICATIONS:

Pipe diameter D_0 = 32 mm
Pipe diameter D_i = 27 mm
Length of the test section L = 610 mm
Orifice diameter d = 16 mm
Dimmerstat 0-2 Amps, 230 V AC

Volumetric flow rate

$$q_0 = C_d \; a \; \sqrt{2 \, g \, h_a} \qquad m^3 / sec.$$

Where, C_d = Co-efficient of discharge of Orifice = 0.62,
a = Area of orifice of air intake = $(\pi d^2 / 4)$ = m^2
d = Diameter of Orifice = 14mm
g = acceleration due to gravity = 9.81 m / sec^2

$$h_a \text{ (in meters of air column)} = \frac{h_{water} \; \rho_{water}}{\rho_{air}} \quad \text{OR} \quad h_a = \frac{h_w \; \rho_w}{\rho_a}$$

h_{water} = Head in meters of water column or mercury column = L.H.S. – R.H.S. = (in m).

ρ_{water} = 1000 Kg / m^3, $\rho_{mercury}$ = 13600 Kg / m^3,

ρ_{air} = 1.154 Kg / m^3

Velocity of flow through pipe

$$V = \text{Velocity} = \frac{\text{Vol. flow rate}}{\text{Area of the pipe}} = \frac{q_0}{\frac{\pi D_0^2}{4}} = \frac{m}{Sec}$$

Work Sheet

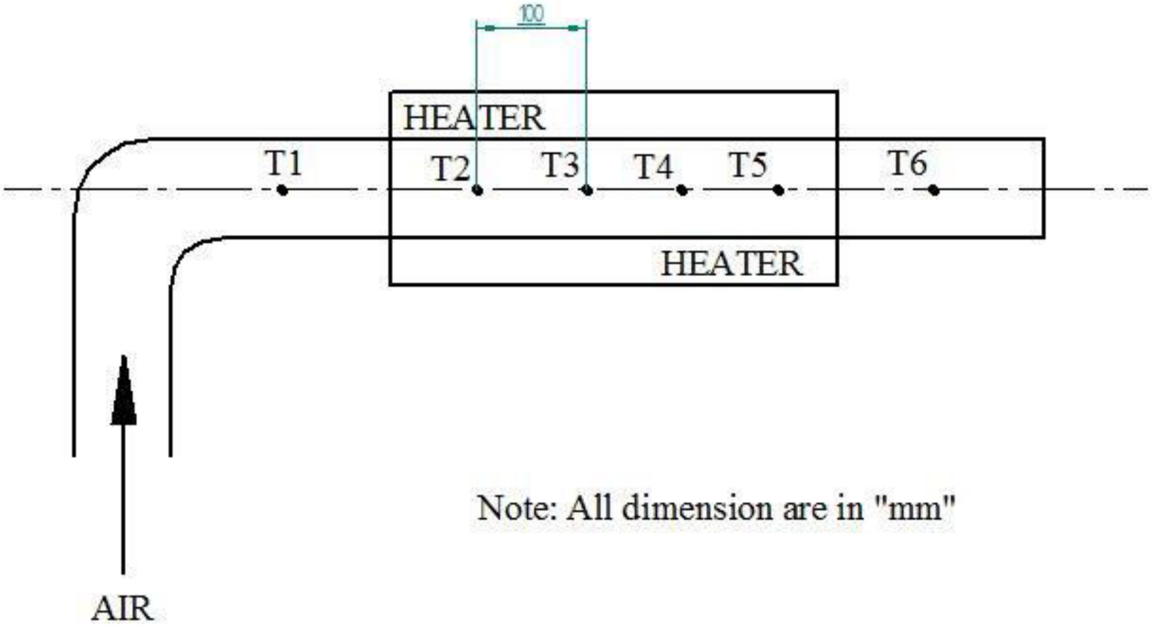
RESULT:

SL No.	$h_{experimental}$	Volume flow rate	Velocity
1.			
2.			
3.			

SPECIFICATION

FORCED CONVECTION

Pipe material : G.I
OD of pipe : 32 mm
ID of pipe : 27 mm
Length of Test section : 610 mm
Distance between two consecutive thermo couple (T1 to T4) : 100 mm



Work Sheet

Date: Faculty signature

TABULAR COLUMN: -

Sl. No.	Dimmer stat Reading		Black – Plate					Test plate					Ambient Temp.
	W_1	W_2	V_1	I_1	T_1	T_2	T_3	V_2	I_2	T_4	T_5	T_6	T_7

SPECIFICATION: -

Diameter of test plate =120 mm (0.12 m)
Diameter of black plate =120 mm (0.12 m)
Enclosure size =550 x 300 x 300 mm

CALCULATION: -

1. **Emissive power of black plate (according to Stefan Boltzmann law)**

$$E_b = \sigma \triangle T^4$$

Where σ = Stefan Boltzmann constant
$= 5.67 \times 10^{-8}\ W/m^{2\ 0K4}$
$\triangle T$ = Average surface temp.

$$\triangle T^4 = \left(\left(\frac{T_1 + T_2 + T_3}{3} + 273^0 K \right)^4 - (T_7 + 273)^4 \right)$$

2. **Emissive power of Grey body (Test specimen)**

$$E_g = \sigma \triangle T^4$$

Where $\sigma = 5.67 \times 10^{-8}$

$$\triangle T^4 = \left(\left(\frac{T_4 + T_5 + T_6}{2} + 273^0 K \right)^4 - (T_7 + 273)^4 \right)$$

3. **Emissivity** $\varepsilon = \dfrac{E_g}{E_b}$

Experiment No.6 **Date: _ / _ /_**

EMISSIVITY MEASUREMENT

AIM: -

To determine the emissivity of the given surface (Test plate)

INTRODUCTION: -

Thermal radiations are emitted by all substance at all temperatures. Thermal radiations are electromagnetic waves and do not required any medium for propagation. All substance or bodies can emit radiations and have also the capacity to absorb all or a part of radiation coming from surroundings. The emissive power is the radiant energy per unit area from the surface of the body and is denoted by E. Emissivity is the ratio of emissive power of the surface to the emissive power of the black surface, at the same temperature &

is denoted $\in = \frac{E}{E_b}$.

DESCRIPTION: -

The experimental set up consists of two circular copper plates identical in size and is provided with heating coils at the bottom. The plates are mounted on asbestoses cement sheet and are kept in an enclose so as to provide undistributed natural convection surroundings.

The heat input is varied by dimmer stat and is measured by Ammeter and Voltmeter with the help of switches. The temperature of the plates is measured by thermocouples; separate wires are connected to diametrically opposite points to get average surface temperature of the plates. Another thermocouple is kept the enclosure to read the ambient temperature of the enclosure.

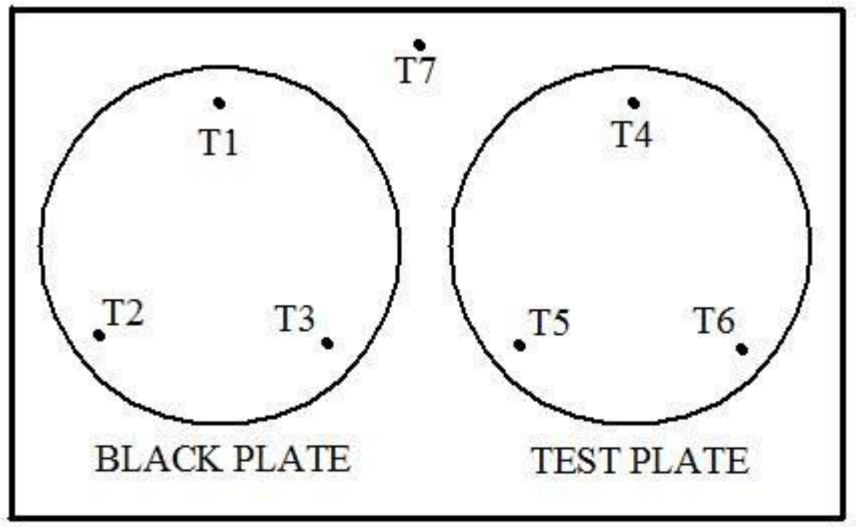
Plate (1) = Black plate and plate (2) is test plate whose emissivity is to be determined.

PROCEDURE: -

1. Switch on the supply and select one of the plates.
2. Keep the rotary switch on Black plate and adjust the dimmer stat to obtain the required heat input.
3. Wait till the steady state is reached.
4. Note the value of V and I and take the readings of thermocouples T1, T2 &T3 Change the toggle switch to test plate and adjust dimmer stat to a valve slightly lesser than the applied black plate.
5. Note the steady temperature of T_4 T_5 & T_6
6. Repeat the experiment for different heat inputs.

EMISSIVITY MEASUREMENT APPARATUS

Circular Plate material : Copper
Test plate dia : 120 mm
Black plate dia : 120 mm



Work Sheet

Date: Faculty signature

SPECIFICATIONS:

1. Hemisphere enclosure diameter = 20 mm (0.02 m)
2. Water jacket diameter = 20 mm (0.02 m)
3. Water jacket height = 107 mm (0.107 m)
4. Test disc diameter (Copper) = 20 mm (0.02 m)
5. Test disc thickness = 1.8 mm (0.0018 m)
6. Density of the test disc = 8.93 Kg / m^3
7. Mass of the disc = 6.8×10^{-3} kg

TABULAR COLUMN:

Temperature Readings					Time in Sec for which T_6 is noted												
T_1	T_2	T_3	T_4	T_5	0	10	20	30	40	50	60	70	80	90	100	110	120

Experiment No.7 **Date: _ / _ /_**

STEFAN BOLTZMANN APPARATUS

AIM:

To determine the Stefan Boltzmann Constant for the given material

INTRODUCTION:

The most commonly used law of thermal radiation is the Stefan Boltzmann's law which states that thermal radiation (heat flux) or emissive power of black surface is directly - proportional to the fourth power of absolute temperature of the surface and given by

$q/A = \sigma\ T^4$ k cal/hr-m^2

The constant of proportionality σ is called the Stefan Boltzmann's Constant and has value of 5.67 X 10^{-8} W/m^2 k^4

DESCRIPTION:

The apparatus consists of flanged copper hemisphere, fixed on a flat non-conducting plate. The outer surface of hemisphere is enclosed in a metal water jacket used to heat to some suitable constant temperature. The hemispherical shape is chosen solely on the grounds that it simplifies the task of drawing the water on to the hemisphere Five Thermocouples are attached to the inner surface of the hemisphere. A test disc which is mounted on bakelite plate fitted in a hole drilled in the center of base plate. Thermocouple is used to measure the temperature of test disc.

When the test disc is inserted at the start of a stop watch, the response of temperature change of disc with time is measured to calculate the Stefan Boltzmann constant

PROCEDURE:

1. Fill the water in the upper tank.
2. Switch on the immersion heater and heat it up to its boiling points
3. Remove the test disc before allowing the boiling water into the lower tank.
4. Switch off the heater and open the valve and allow the water into the lower tank.
5. Wait until the steady state is reached.
6. Note down the thermocouple readings T1, T2, T3, T4, T5 and T6.
7. Insert the test disc and start the stop watch simultaneously & note down the temperature of T_6 at every sixty seconds interval.
8. Draw the graph of temperature Vs time and calculation dT/dt.

CALCULATIONS:

$$\sigma = \frac{m * S\,(dT/dt)}{A_d\,(Ts^4 - T_d^4)} \quad (W/m^2 - {}^0K^4)$$

$$A_d = \text{Surface area of the disc} = \frac{\pi\, d^2}{4} \text{ in } m^2$$

$$Ts = \text{Surface temperature} = \frac{T_1+T_2+T_3+T_4+T_5}{5} + 273\ {}^0K$$

T_d = Disc Temperature = $T_6 + 273\ {}^0K$, where T_6 is taken at zeroth second.

Note: -

m = Mass of disc = 6.8×10^{-3} Kg

S = Specific heat of the disc = 0.385×10^3 KJ/kg ^0K

Also Q = $m \times S * \left(\frac{dT}{dt} \right)$

Q = $\sigma A_d (Ts^4 - T_d^4)$

σ = $W/m^2\ {}^0K^4$

Graph:

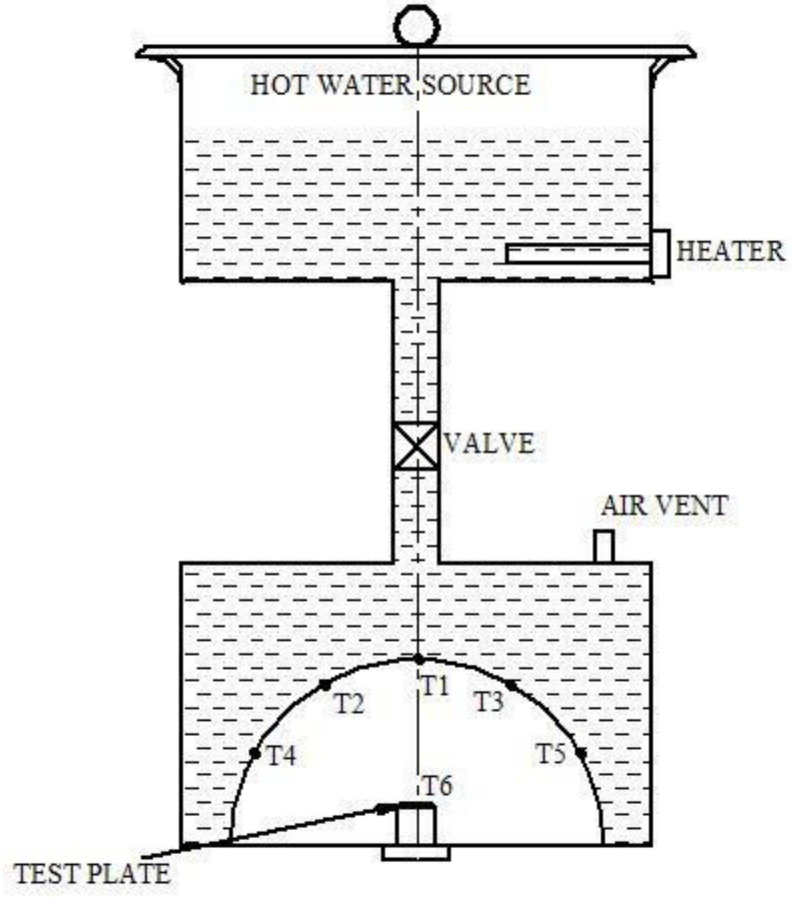
Disc temperature v/s time

STEFAN BOLTZMANN APPARATUS

Test disc:

Material – Copper
Dia meter – 20 mm
Thickness – 1.8 mm
Mass – 6.8×10^{-3} kg
Hylam sheet – 6mm thick , 325 mm dia

Work Sheet



STEFAN BOLTZMANN APPARATUS

Work Sheet

Date: Faculty signature

OBSERVATION AND TABULOR COLUMN:

SI. No.	Type of Flow	Flow rate of cold water,V_c,(1pm)= m_c,Kg/min (assuming ρ= 1.0 kg/lit)	Flow rate of hot water,V_h (Ipm)= m_h,Kg/min (assuming ρ = 1.0 kg/lit)	Temperature °C				
				T_1	T_2	T_3	T_4	T_5
1	Parallel				☒			
2	Counter					☒		

DATA:-

Inside diameter of the outer tube	Di = 28 mm
Length of the pipe	L = 1450 mm
Inside dia of inner tube	di = 9.5 mm
Outside dia of the inner tube	do = 12.5 mm
Specific heat of water	Cw = 4187 J/kgk or 4.19 kj / kg K
Thermal conductivity of stainless steel,	K_{ss} = 150 W / mK
Thermal conductivity of copper	Kc = 385 W / mK

T_1 = T_{ci} = Cold water inlet
T_2 = T_{co} = Cold water outlet (Counter flow)
T_3 = T_{co} = Cold water outlet (Parallel flow)
T_4 = T_{hi} = Hot water inlet
T_5 = T_{ho} = Hot water outlet

Experiment No.8 **Date: _ / _ /_**

PARALLEL FLOW & COUNTER FLOW HEAT EXCHANGER

OBJECTIVE:-

To determine the following for (i) Parallel flow heat exchanger and (ii) Counter flow heat exchanger

- Log mean temperature difference (LMTD)
- Overall heat transfer co – efficient (Experimental)
- Overall heat transfer coefficient (Theoretical)

INTRODUCTION:

Heat exchangers are devices in which heat is transferred from one fluid stream to another, without mixing of the two. The temperature of the hot fluid decreases and the temperature of the cold fluid increases as both of them flow through the heat exchanger. An ideal heat exchanger (100% efficient heat exchanger) is one in which there are no heat losses: meaning that the net transferred from the hot fluid goes entirely to the cold fluid.

In the Parallel Flow Heat Exchanger both the fluid streams move in the same direction .in the Counter Flow Heat Exchanger the two streams move in opposite directions. Radiator in an automobile, a boiler, an air preheated, an economizer in a boiler power plant, a condenser, an evaporator in a refrigerator etc are common examples of heat exchanger.

EXPERIMENTAL SETUP:

As shown in the figure, the experimental setup consists of a horizontal inner Copper tube surrounded by an outer stainless steel tube. While hot water flows through the inner tube, cold water flows in the annulus between the inner and the outer tubes, An electric immersion heater is used to heat the water in an insulated storage tank. The heater is automatically switched off or on by the thermostat which senses the temperature of the hot water in the tank and maintain the set temperature. The water can thus be heated to a predetermined temperature and held constant at that level. Heated eater is flown through the heat exchanger with the help of a water pump. The flow rate of hot water can be regulated by suitably manipulating the discharge valve and the by pass valve across the pump. The flow rate can be measured by closing the discharge valve leading to the tank and opening the drain valve and noting the time for flow of a liter of water in to a graduated jar. After measurement the collocated water is immediately poured back to the tank.

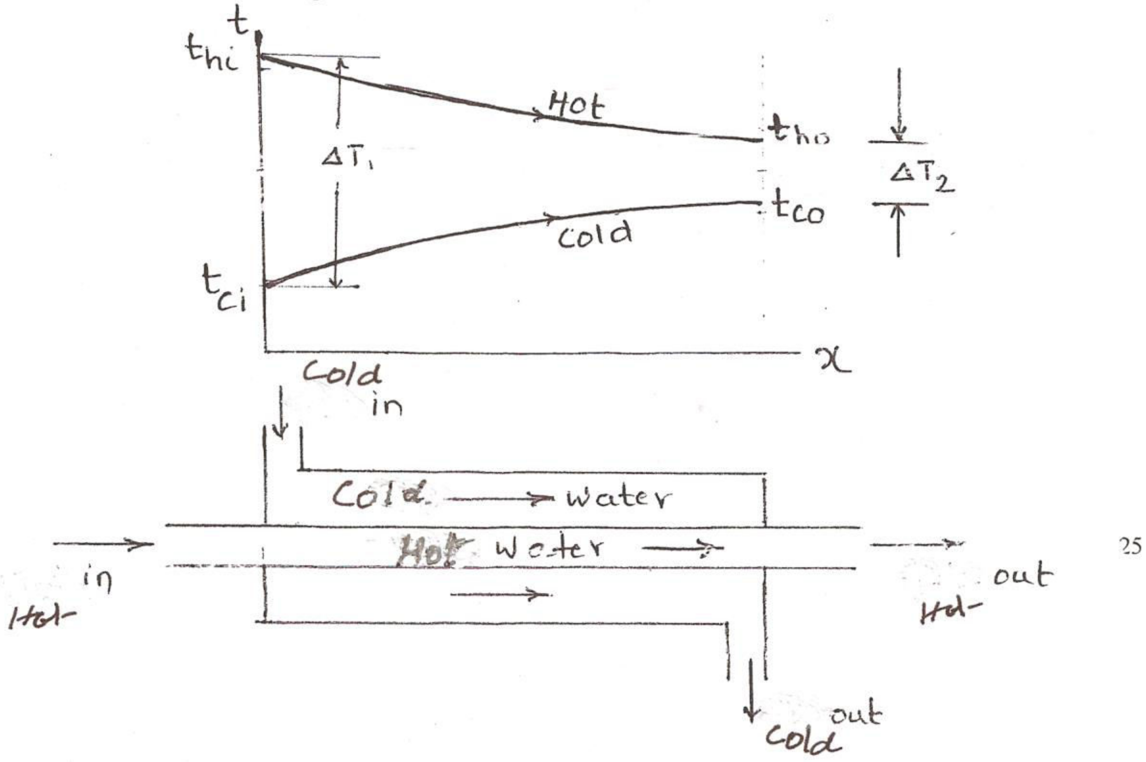
Cold water from the overhead tank flows through the heat exchanger .Its flow can be regulated using a control valve and the flow rate is measured with help of a rotometer. By operating appropriately the directional control valves the direction of flow of the cold water can be

CALULATIONS:

A) Parallel Flow Heat Exchanger

1.Log Mean Temperature Difference:

Given below is the temperature profile (temperature vs Length of the heat exchanger) in a parallel flow heat exchanger)



With respect to this figure LMTD is evaluated from:

$$\text{LMTD} = \frac{\triangle T_1 - \triangle T_2}{\mathrm{In}\left[\dfrac{\triangle T_1}{\triangle T_2}\right]} \qquad (1)$$

Where, $\triangle T_1 = (T_{hi} - T_{ci})$ and $\triangle T_2 = (T_{ho} - T_{co})$.

changed to make the heat exchanger work in either the parallel flow mode or in the counter flow mode. Temperature sensors indicate the temperature at different locations. The outer tube is sufficiently insulated to minimize the heat loss.

PROCEDURE:

1. Connect the electrical panel to a 230 v, 15 A power socket and the Rota meter inlet to a ½" water source
2. Operate appropriate valves and select the heat exchanger to work in either parallel flow or counter flow mode
3. Open the inlet flow control valve of the Rota meter and allow the cold water to flow through the heat exchanger , set the flow rate to any desired rate of discharge
4. Check the hot water tank is filled with water to ¾ its full capacity
5. Start the hot water pump and set the flow rate by operating the by pass and inlet valves and measure the set flow rate with a measuring jar against time and record it (let the hot water flow be higher the cold water flow rate) and connect it back to sump as the hot water circulation is a closed Circuit Flow.
6. Switch "on" the heater and wait till the hot water inlet temperature reaches a steady state.
7. Record the temperature T_1, T_3, T_4, T_5 in case of parallel flow and T_1, T_2, T_4, T_5, in case counter Flow
8. Tabulate all the observation and calculate
9. To close the experiment switch "off" the heater, stop the hot water pump and close the cold water flow control valve

2.Experimental Overall Heat Transfer Coefficient Based on inside area (Ui):

Heat Lost by hot stream of water, $Q_h = \dfrac{m_h C_w (T_{hi} - T_{ho})}{60}$ W

Heat gained by cold stream of water, $Q_c = \dfrac{m_c C_w (T_{co} - T_{ci})}{60}$ W

Under ideal conditions (When the efficiency of heat exchanger is 100%), Q_h will be equal to Qc in magnitude. In practice they may differ marginally depending upon the quality of the setup. Hence, experimentally, the rate of heat transfer, Q, between the hot and cold streams can be taken to be the mean of the two. Therefore:

$$Q = \frac{Q_h + Q_c}{2} \quad \text{W} \qquad (2)$$

$$\text{And, Experimental } U_i = \frac{Q}{A_i\,(\text{LMTD})} \quad \text{W / m}^2\text{ K} \qquad (3)$$

Where, Ai = $\pi d_i L$ with d_i in m.

3. Theoretical Overall Heat Transfer Coefficient:

$$Ui = \frac{1}{\dfrac{1}{hi} + \dfrac{d_i}{K_c}\,\text{In}\left[\dfrac{d_i}{d_o}\right] + \dfrac{d_i}{d_o}\left[\dfrac{1}{h_o}\right]} \qquad (4)$$

To find the inside heat transfer coefficient (h_i):

For cold water stream which is getting heated up , based on Dittus – Boelter equation (available in Data Books) , for fully developed flow , with $0.6 < Pr < 100$, and $2500 < Re < 1.25 \times 10^6$ > L/d>60:

$$Nu = 0.023\, Re^{0.8}\, Pr^{0.4} \qquad (5)$$

Work Sheet

Where Re and Pr are evaluated for the bulk mean temperature of $T_{m,c} = \dfrac{T_{co} + T_{ci}}{2}$

$$Re = \frac{\rho V d_i}{\mu} = \frac{4(m_c/60)}{\pi d_i \mu} \qquad (6)$$

$$Pr = \frac{\mu c_p}{K_w} = \frac{\mu c_w}{Kw} \qquad (7)$$

and its value for water can either be (1) directly obtained from data for the bulk mean temperature , $T_{m,c}$ or (ii) can also be evaluated by noting from data books the values of μ and K_w for water at $T_{m,c}$

Using the values of Re and Pr from Eqs. (6) and (7) in Eq. (5) get the value of Nu.

$$\text{Then as } Nu = \frac{h_i d_i}{K_w}, \quad hi = \frac{Nu k_w}{d_i} \quad W/m^2K \qquad (8)$$

To find the outside heat transfer coefficient (h_o)

For hot water stream in the annulus, which is getting cooled , based on Dittus – Boelter equation (available in Data Books) , for fully developed flow , with $0.6 < Pr < 100$, and $2500 < Re < 1.25 \times 10^6$ and $L/d > 60$:

$$Nu = 0.023\, Re^{0.8}\, Pr^{0.3} \qquad (9)$$

Where Re and Pr are evaluated for the bulk mean temperature of $Tm,h = \dfrac{T_{hi} + T_{ho}}{2}$

$$Re = \frac{\rho V(Di - do)}{\mu} = \frac{4(m_h/60)}{\pi(Di - do)\mu} \qquad (10)$$

Work Sheet

$$Pr = \frac{\mu c_p}{K_w} = \frac{\mu c_w}{K_w} \qquad (11)$$

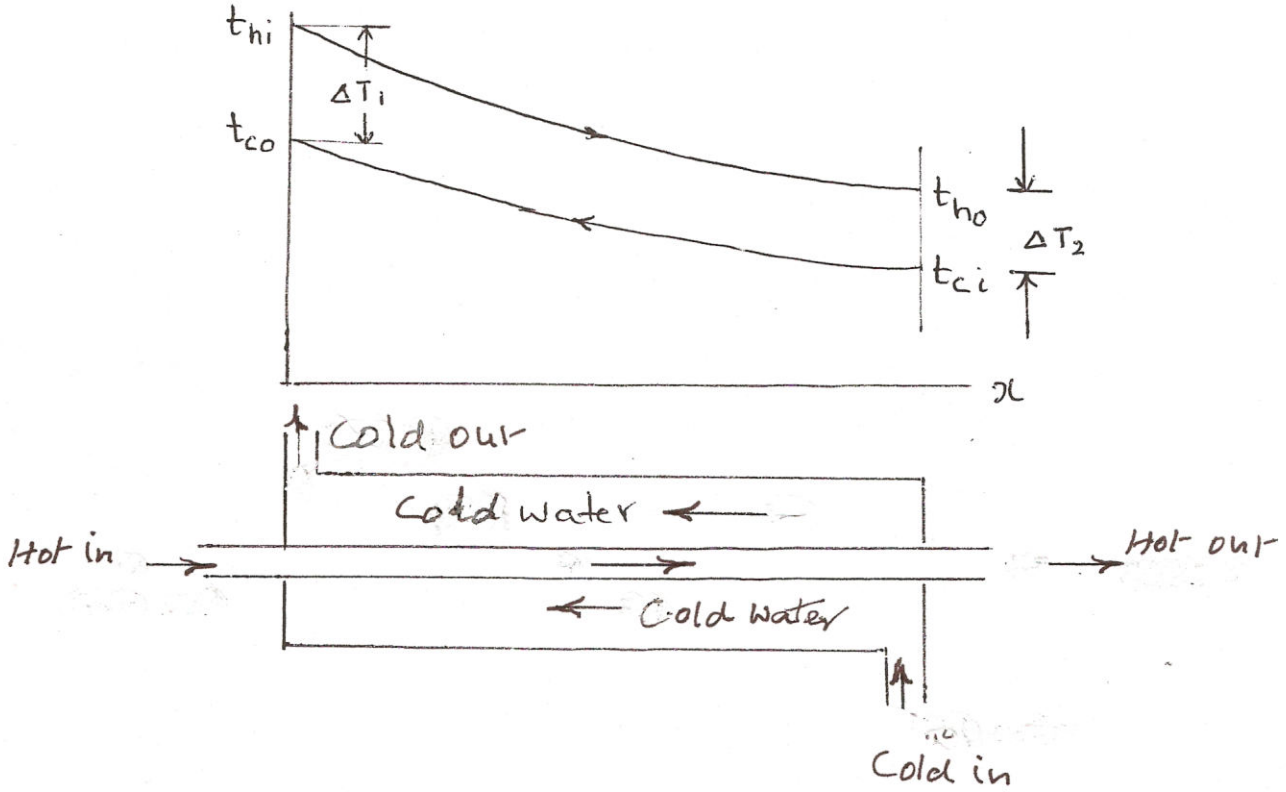
And its value for water can either be (i) directly obtained from data books for the bulk mean temperature , $T_{m,h}$ or (ii) can also be evaluated by noting from data books the values of μ and K_w for water at $T_{m,h}$

$$\text{Then, as } Nu = \frac{hi(Di - do)}{Kw}, \; hi = \frac{NuK}{(Di-do)} \quad W/m^2K \qquad (12)$$

Using the valves of hi and ho from Eqs.(8) & (12) in Eq . (4) get the value of Theoretical U_i

Work Sheet

B) Counter Flow Heat Exchanger:



1. Log Mean Temperature Difference:

Given below is the temperature profile (temperature vs Length of the heat exchanger) in a counter flow heat exchanger.
With respect to this figure LMTD is evaluated from:

$$\text{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln\left[\dfrac{\Delta T_1}{\Delta T_2}\right]} \qquad (1)$$

Where, $\Delta T_1 = (T_{hi} - T_{co})$ and $\Delta T_2 = (T_{ho} - T_{ci})$

Work Sheet

Experimental and Theoretical Overall Heat Transfer Coefficients are evaluated following the same steps as given under Parallel Flow Heat Exchanger.

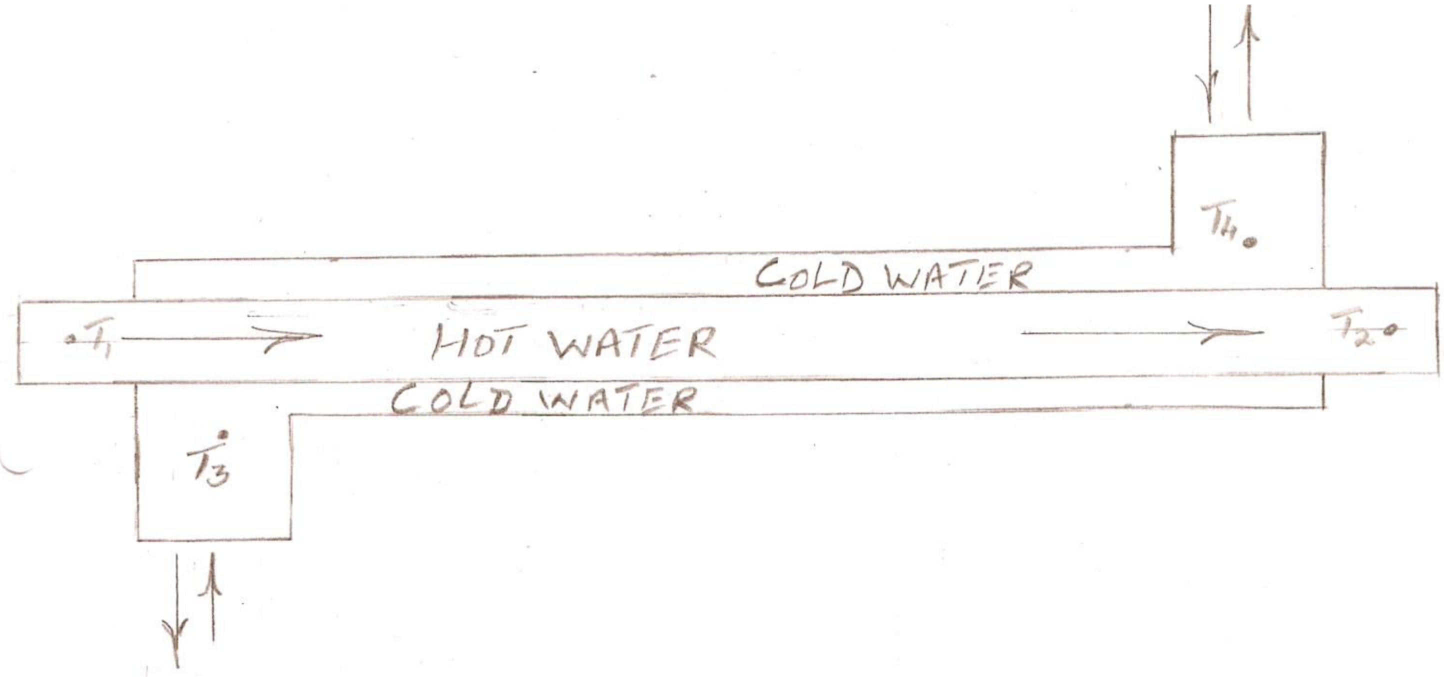
Present the findings in the followings Table:

Type of Heat Exchanger	LMTD	Experimental U_i, in W / m^2 K	Theoretical U_i, in W / m^2 K
Parallel Flow			
Counter Flow			

SPECIFICATION

PARAELL FLOW AND COUNTER FLOW HEAT EXCHANGER

Outer pipe (SS)	Parallel Flow	Counter Flow
OD – 31.5	T_1 – Hot water inlet	T_1 – Hot water inlet
ID – 28mm	T_2 – Hot water outlet	T_2 – Hot water outlet
Inner pipe (copper)	T_3 – Cold water inlet	T_4 - Cold water inlet
OD – 12.5mm	T_4 – Cold water outlet	T_3 – Cold water outlet
ID – 9.5mm		
Effective length - 1450		



Work Sheet

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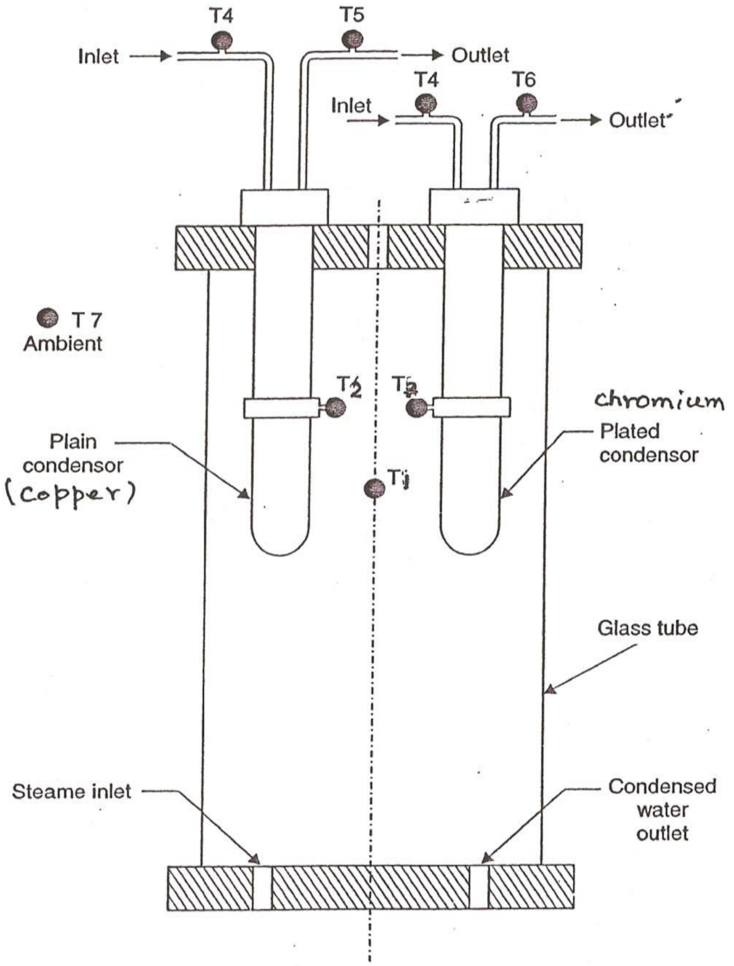


Dropwise and Filmwise Condensation

Experimental setup

Experiment No.9 **Date: _ / _ /_**

FILMWISE AND DROPWISE CONDENSATION:

AIM:

To determine the individual Heat Transfer Coefficient and overall heat transfer coefficient in Film wise' condensation or 'drop wise' condensation using Condensation Apparatus

INTRODUCTION:

Condensation of steam is one of many important processes occurring in process industries and power plants .Steam is generally condensed as it transfers heat to a cooling medium. During condensation very high heat fluxes are possible and hence heat has to be quickly transferred from the condensing surface to the cooling medium in the condenser working as a heat exchanger

Steam may condense on a surface in two distinct modes, known as 'Film wise Condensations 'and 'Drop Wise Condensation' for the same temperature difference between the steam and the condensing surface. 'Drop wise 'condensation is much more effective than 'film wise condensation 'and for this reason, the former is desirable.

FILM WISE CONDENSATION: (Copper Condenser)

Unless specially treated, most materials are wet table and as condensation occurs a film of condensate spreads over the surface. The thickness of the film depends upon a number of factors such as (i) the rate of condensation, (ii) the viscosity if the condensate and (iii) orientation of condensing surface, whether vertical, horizontal or inclined. As fresh vapor condenses on top of film, the heat of condensation has to pass by conduction through the film to the metal surface beneath .As the film thickness; it flows downward and drips from the low points leaving the film intact and at an equilibrium thickness.

DROP WISE CONDENSATION: (Chromium Plated)

By treating the condensing surface specially, such as plating it with chromium, it can be made 'non–wettable '. As steam condenses, generally, a large number of spherical beads cover the surface. As condensation proceeds, the beads become large, coalesce, and then trickle downwards from the condensing surface. The moving bead gathers on the static beads along its trail. The 'Bare' surface offers very little resistance to the transfer of heat and very high heat fluxes are therefore possible.

SPECIFICATIONS:

Copper Tube Condenser for Film wise Condensation

- Inner diameter , di = 17mm
- Outer diameter , do = 19.2mm
- Length of the tube, L = 150mm

Chromium Plated Condenser for Drop wise Condensation:

- Inner diameter , di = 17mm
- Outer diameter , do = 19.2mm
- Length of the tube, L = 150 mm

Temperatures (°C)

- T_1 = Water inlet
- T_2 = Water outlet of copper condenser
- T_3 = Water outlet of Plated Condenser
- T_4 = Surface copper condenser
- T_5 = Surface plated condenser
- T_6 = Glass chamber (steam)

OBSERVATION TABLE:

Film wise condensation (Copper Condenser) (Plain)

SI. No.	Water flow rate, Mw lpm (≈ kg /min)	Steam Pressure,Ps Kg /cm^2 (≈ bar)	Temperature °C			
			T_1	T_3	T_5	T_6

EXPERMENTAL SETUP:

The equipment consists on a metallic container in which steam generation takes place. A suitable electric heater is installed in the lower portion of the container which heats water and facilitates steam generation .To regulate the rate of steam generation the input voltage to the heater can be altered by means of a voltage regulator. An opening is provided in the cover for filling water. The glass cylinder houses two water cooled copper condensers, one of which is chromium plated to promote drop wise condensation and the other is in its natural state to give film wise condensation. A pressure gauge is provided to measure the steam pressure. Separate cooling water connections are provided to the two condensers. A Rota meter is provided to measure flow rate of cooling water through the condenser. A multi–channel digital temperature indicator is provided to measure temperature of steam, condenser surfaces, condenser cooling water inlet and outlet.

PROCEDURE:

1. Fill the steam generator with water to a little over half, checking the water level in the tank by a level indicator.
2. Allow the cooling water to flow through one of the condensers, which is selected for the test, and note down the water flow rate from the Rota meter. It is recommended to have the flow rate between 1 – 2 lpm
3. Switch ON the heater. Adjust the voltage across heater to be around 150 V as indicated by the voltmeter. Wait till steam pressures rises to 0.5 kg/cm
4. Allow the Steam Slowly to flow through the glass Chamber, as the steam flows over the selected test section it gets condensed and falls to the bottom of the glass container and drains out through the drain valve. Maintain the pressure in the steam generator constant by increasing or decreasing the voltage across the heater according to the variation in the pressure. Depending up on the type of the condenser selected drop wise or film wise condensation can be visualized
5. Note down the water flow rate, steam pressure, temperatures T_1 to T_6 and enter them in the table given below:
6. Proceed for calculation

Drop wise condensation : (Chromium Plated)(Coated)

SI. No	Water flow rate, Mw lpm (≈ kg/min)	Steam Pressure, Ps Kg/cm^2 (≈ bar)	Temperature ^oC			
			T_1	T_2	T_4	T_6

PRECAUTIONS:

1. Do not start heater supply unless water is filled in the steam generator to nearly ¾ of its capacity. If water is insufficient in the steam generator the heater burns out.
2. Operate gently the selector switch of temperature indicator as well as control valves.

CALCULATIONS:

(A) Film wise Condensation;

The overall heat transfer coefficient based on inner surface area is given by:

$$U_i = \frac{1}{\left[\frac{1}{h_i} + \left(\frac{d_i}{d_o}\right) + \frac{1}{h_o}\right]} \qquad (1)$$

Inner Heat Transfer Coefficient, hi:

$$Nu = 0.023\,(Re)^{0.8}\,Pr^{0.4} \qquad (2)$$

All properties of water, required to evaluate Re and Pr are found from Data books for the bulk mean temperature, T_w given by:

$$T_w = \frac{T_1 + T_3}{2}$$

The properties required are, with usual notations ρ, μ , K and Pr.

Work Sheet

Reynolds number is given by: $Re: = \frac{\rho V d_i}{\mu} = \frac{4(m_c/60)}{\pi d_i \mu}$ (3)

The prandtl No.is given by: $Pr = \frac{\mu Cp}{K_w} = \frac{\mu C_w}{K_w}$ (4)

and its value for water can either be (i) directly obtained from data books for the bulk mean temperature , T_w or (ii) can also be evaluated by noting from data books the values of μ and K_w for water at T_w

Using the values of Re and Pr from Eqs. (3) and (4) in Eq.(2),get the value of Nu.

Then, as $Nu = \frac{h_i d_i}{K_w}$, $hi = \frac{Nu K_w}{d_i}$ W/m^{2}K (5)

Outside Heat Transfer Coefficient , h_o :

$$h_o = 0.943 \left(\frac{K^3 \rho^2 H_{fg}}{\mu L\,(T1-T3)} \right)^{0.25} \quad (6)$$

Where the properties found from data books for bulk temperature of the condensing steam, Ts, given by:

$$Ts = \frac{T_6 + T_5}{2}$$

And H_{fg} is the enthalpy of vaporization at T_1, which can be got, be from steam tables. It should be converted to J/kg.

Using the values of h_i and h_o obtained from Eqs. (5) and (6) in Eq. (1) find the value of U_i in W/m^2 K.

Work Sheet

Drop wise Condensation:

Using the similar steps followed in the earlier case, U_i in drop wise condensation can also be evaluated.

In this case, Bulk mean temperature of cooling water, $T_w = \dfrac{T_1 + T_2}{2}$ and

Bulk mean temperature of condensing steam, $Ts = \dfrac{T_6 + T_4}{2}$

RESULTS :

Sl. No.	Heat Transfer Coefft.in W/m^2K	Film wise Condensation	Drop wise Condensation
1	h_i		
2	h_o		
3	U_i		

Work Sheet

Date: Faculty signature

SPECIFICATION:

Material	:	Copper rod.
Diameter, d	:	25 mm (0.025 m)
Length, L	:	500 mm (0.5m)
Thermometer Spacing	:	75 mm (0.075m)
Ammeter reading	:	(amps)
Voltmeter reading	:	(volts)
Q, heat supplied	:	V*A = W (watts)
Room Temp, T_R	:	^{0}C

Observations:

Time in Min.	T_1	T_2	T_3	T_4	T_5	T_6
0						
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

Experiment No.10 **Date: _ / _ /_**

TRANSIENT HEAT CONDUCTION

AIM:

To obtain temperature profile for conduction through a copper rod heated by a constant source and to compare theoretically predicted temperature distribution under transient conductions.

APPARATUS:

Transient heat conduction set-up; thermocouples; stop watch/clock.

INTRODUCTION:

A Heat transfer process which is time dependent is designated as an unsteady state or transient heat transfer. There are large numbers of situations where changes in condition result in transient temperature distribution. Unsteady state heat transfer generally occurs before steady state operating conditions.

Transient temperature distribution results in manufacture of bricks, Cooking and freezing of food and in heat and cold treatment of metals.

The Temperature distribution for a body subjected to constant heat flux condition is given by

$$T\,(X,t) = Ti + \frac{(2Q)}{K * A} \sqrt{}\,\{(\alpha * T)[\,(1/\sqrt{}\Pi\,)\ e^{-Z}\,\Lambda^{2} + Z * \mathrm{erf}(Z) - Z]\,\}$$

EXPERIMENTAL SET-UP:

The experimental setup consists of a metal rod, one end of which is heated by an electrical heater while the other end projects inside a cooling water jacket. The whole rod is insulated with asbestos rope and covered with S.S. Sheet.

Six thermocouples are placed on the rod for temperature measurement.

The heater is provided with a Dimmerstat for controlling the heat input, water under the constant head is circulated through the jacket and its flow rate and temperature rise are measured using Rotameter and thermocouples.

Calculations:

Voltmeter reading V: (volts)

Ammeter reading I: (amps)

Total heat supplied Q

Q = V x I = (watts)

Thermal diffusivity of the material is calculated by

$$\alpha = \frac{K}{\rho C p} = m^2/s$$

ρ = Density of material (Copper) = 8954 Kg/m^3

Cp = Specific heat of material (Copper) = 381 J/Kg.K

K = Thermal conductivity (Copper) = 386 W/m.K

Cross sectional area of the copper rod, A =

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

Diameter, d = 0.025 m

Calculate the Valve of Z using the formula:

$$Z = \frac{X}{2\sqrt{\alpha * T}}$$

Where T is the time.
From this, Calculate the error function valve of Z from the Data Hand Book i. e., Erf(Z) taking particular time (say T = 900 secs) substitute in the T theoretical equation.

Temperature (^{0}C) T experimental = Values are obtained detained directly from the experiment at deferent time.

PROCEDURE:

1. Heat the cylindrical shaped material (copper rod) by electrical heating at Constant rate by adjusting the current and voltage
2. Adjust the flow of water to 2-3 liters/min using rotameter.
3. Note the readings of the Ammeter and the Voltmeter.
4. Note down the initial temperature at 6 different positions, say, at distances 0.1, 0.2 & 0.3 m from the heat source.
5. Start the stop watch and note the temperature indicated by the thermocouples at a various points recorded at 5 min. interval.
6. Continue to note the temperature till constant temperature is attained.
7. The calculations are performed to obtain temperature profile and compared with theoretical valves obtained.
8. **Temperature Profile:** Theoretical temperature and experimentally observed temperature versus distance from the hot source is drawn on a graph sheet for 15 & 30 minutes time intervals.

Serial No.	Time (T) secs	Distance X m	Temperature T experimental ^{0}C	Z	Erf(Z)	Temperature T experimental ^{0}C
1.	300	X1 = 0 (near the heater) X2 = 0.1 X3 = 0.2 X4 = 0.3 X5 = 0.4 X6 = 0.5 X7 = 0.6				
2.	480	X1 = 0 X2 = 0.1 X3 = 0.2 X4 = 0.3 X5 = 0.4 X6 = 0.5 X7 = 0.6				

Plot a graph of temperature v/s distance at a particular time (*T*) (say *T* = 900 secs)

Similarly it can be plotted for different time (say *T* = 3000 secs)

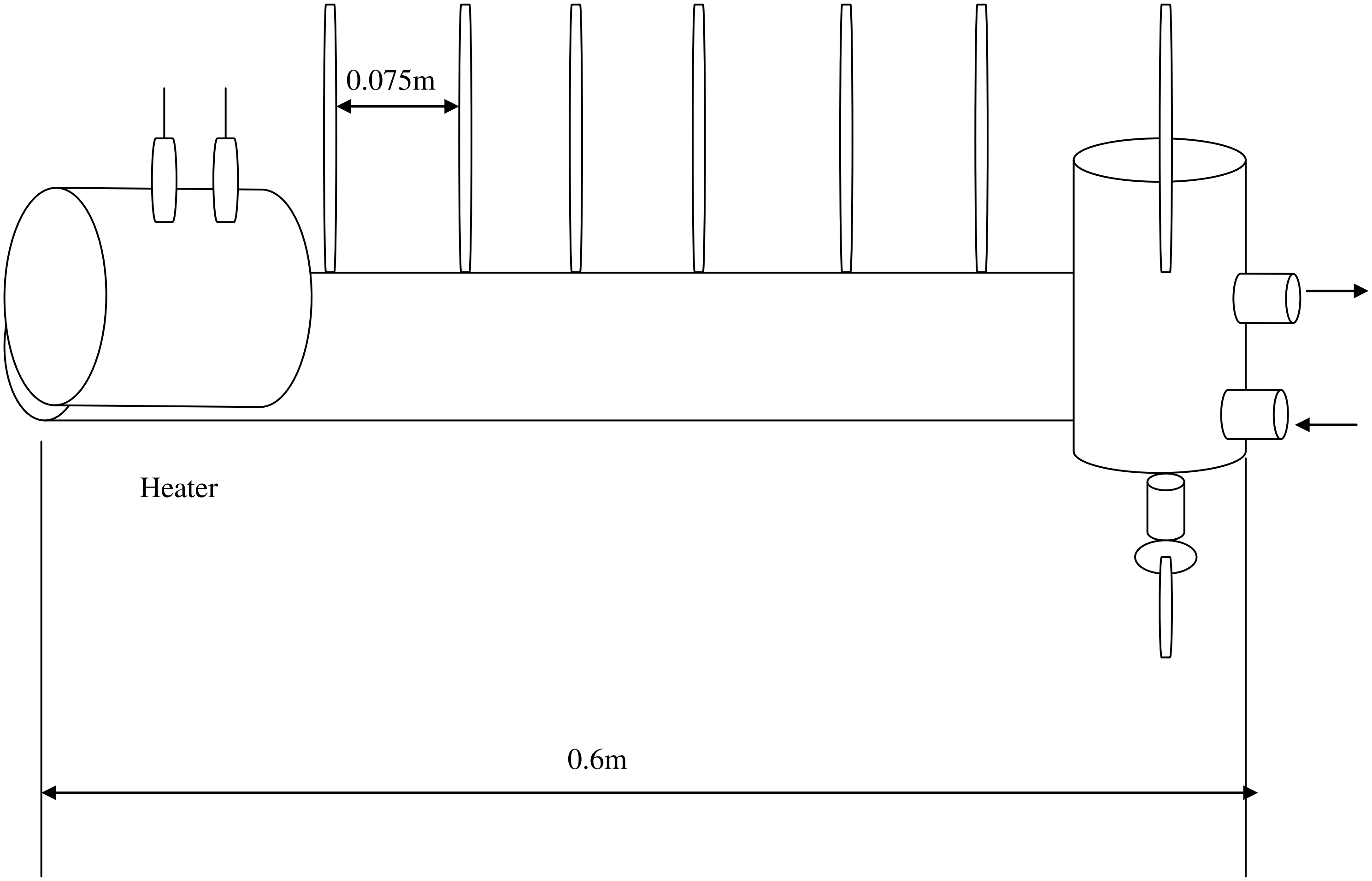
TEMPERATURE POINTS:

T_1 = temperature at distance X_1 = 0 from heater (next to the heater)
T_2 = Temperature at distance X_2 = 0.1 m from heater
T_3 = Temperature at distance X_3 = 0.2 m from heater
T_4 = Temperature at distance X_4 = 0.3 m from heater
T_5 = Temperature at distance X_5 = 0.4 m from heater
T_6 = Temperature at distance X_6 = 0.5 m from heater
T_7= Temperature at distance X_7 = 0.6 m from heater
T_8 = Water Inlet Temperature.

WorkSheet

RESULT:

The heat conduction experiment is conducted under transient conditions and the temperature conduction through the rod heated by a constant heat flux is obtained and compared with theoretical valves.



WorkSheet

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VIVA QUESTIONS AND ANSWERS

1. Define Heat transfer?

Heat transfer can be defined as the transmission of energy from one region to another region to temperature difference.

2. What are the modes of heat transfer?

1. Conduction
2. Convection
3. Radiation

3. What is conduction?

Heat conduction is a mechanism of heat transfer from a region of high temperature to a region of low temperature with in a medium (Solid, liquid or Gases) or different medium in direct physical contact.

In conduction, energy exchange takes place by the kinematics motion or direct impact of molecules .Pure conduction is found only in solids.

4. State Fourier's law of conduction.

The rate of heat conduction is proportional to the area measured normal to the direction of heat flow and to the temperature gradient in that direction.

5. Define Thermal conductivity.

Thermal conductivity is defined as the ability of a substance to conduct heat.

6. List down the three types of boundary conditions.

1. Prescribed temperature.
2. Prescribed heat flux.
3. Convection boundary conditions.

7. Define convection.

Convection is a process of heat transfer that will occur between solid surface and a fluid medium when they are at different temperatures. Convection is possible only in the presence of fluid medium.

8. Define Radiation

The heat transfer from one body to another without any transmitting medium is known as radiation .It is an electromagnetic wave phenomenon.

9. State Newton's law of cooling or convection law.

Heat transfer by convection is given by Newton's law of cooling

$Q = hA\,(Ts- T\ )$

Where;-

A - Area exposed to heat transfer in m^2

h - Heat transfer coefficient of the surface in K

Ts-Temperature of the surface in K

T - Temperature of the fluid in K

10. Define overall heat transfer co-efficient.

The overall heat transfer by combined modes is usually expressed in terms of an overall conductance or overall heat transfer co-efficient Heat transfer, Q

11. Define fins or extended surfaces.

It is possible to increase the heat transfer rate by increasing the surface of heat transfer. The surfaces used for increasing heat transfer are called extended surfaces sometimes known as fins

12. State the applications of fins.

1. Cooling of electronic components.
2. Cooling of motor cycle engines.
3. Cooling of small capacity compressors
4. Cooling of transformers

13. Define fin efficiency.

The efficiency of a fin is defined as the ratio of actual heat transferred to the maximum possible to heat transferred by the fin.

η=Qfin/Qmax

14. **Define Fin effectiveness.**

Fin effectiveness is the ratio of heat transfer with fin to that without fin

Fin effectiveness = Q with fin/Q without fin.

15. What is meant by steady state heat conduction?

If the temperature of a body does not vary with time, it is said to be in a steady state and that type of conduction is known as steady state heat conduction.

16. What is meant by transient heat conduction or unsteady state conduction?

If the temperature of a body varies with time, it is said to be in a transient state and that type of conduction is known as transient heat conduction or unsteady state conduction

17. What is Periodic heat flow?

In Periodic heat flow, the temperature varies on a regular basis Example;

1. Cylinder of an IC engine.
2. Surface of earth during a period of 24 hours

18. What is non Periodic heat flow?

In non Periodic heat flow, the temperature at any point within the system varies non linearly with time. Example:

1. Heating of an ingot in furnace.
2. Cooling of bars

19. What is meant by Newtonian heating or cooling process?

The process in which the internal resistance is assumed as negligible in comparison with its surface resistance is known as Newtonian heating or cooling process.

20. What is meant by Lumped heat analysis?

In a Newtonian heating or cooling process the temperature throughout the solid is considered to be uniform at a given time. Such an analysis is called Lumped heat capacity analysis.

21. What is meant by infinite solid?

A solid which extends itself infinitely in all directions of space is known as infinite solid. In infinite solids, the biot number value is in between0.1 and 100.0.1 < Bi< 100

22. Define Biot number.

It is defined as the ratio of internal conductive resistance to the surface conductive resistance.

$$Bi = \frac{\text{Internal conductive resistance}}{\text{Surface conductive resistance}}$$

23. What is the significance of Biot number?

Biot number is used to find Lumped heat analysis, Semi infinite solids and infinite solids If Bi< 0.1 Lumped heat analysis. Bi= 0.1 < Bi< 100

24. What are the factors affecting the thermal conductivity?

1. Moisture
2. Density of material
3. Pressure
4. Temperature
5. Structural of material.

25. What are Heislers charts?

In Heislers chart, the solutions for temperature distributions and heat flows in plane walls, long cylinders and spheres with finite internal and surface resistance are presented. Heislers charts are nothing but a analytical solutions in the form of graphs

26. Explain the significance of thermal diffusivity.

The physical significance of thermal diffusivity is that it tells us how fast heat is propagated or it diffuses through a material during changes of temperature with time.

27. What are the types of heat exchanger?

The types of heat exchanger are as follows.

1. Direct contact heat exchangers.
2. Indirect contact heat exchangers
3. Surface heat exchangers
4. Parallel flow heat exchanger

28. What is meant by LMTD?

We know that the temperature difference between the hot and cold fluids in the heat exchangers varies from point to point. In addition various modes of heat exchanger are involved. Therefore based on concept of appropriate mean temperature difference, also called logarithmic mean temperature difference

29. What is meant Fouling factor?

We know, the surfaces of heat exchangers do not remain clean after it has been in use for some time .The surface become fouled with scaling or deposits .The effect of these deposits affecting the value of overall heat transfer co efficient. This effect is taken care of by introducing an additional thermal resistance called fouling resistance.

30. What is black body?

Black body is an ideal surface having the following properties.

1. A black body absorbs all incident radiation, regardless of wave length and direction.
2. For a prescribed temperature and wave length, no surface can emit more energy than black body

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