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P.R.E.

OBJECTIVES:

The main objective of the experiment is to study:

(i) the temperature distribution in parallel and counterflow heat exchanger

(ii) the heat transfer rate in the two runs.

(iii) the heat transfer coefficient in parallel and counter flow runs, and

(iv) the effectiveness of the given heat exchanger

AIMS:

Heat exchangers are used in various engineering applications, particularly in the field of thermal and fluid systems. The concept of heat transfer in parallel and counter flow heat exchanger ~~with~~ aims to underpin the efficient and sustainable operation of many industrial process and systems, contributing to energy conservation, process optimization and technological advances.

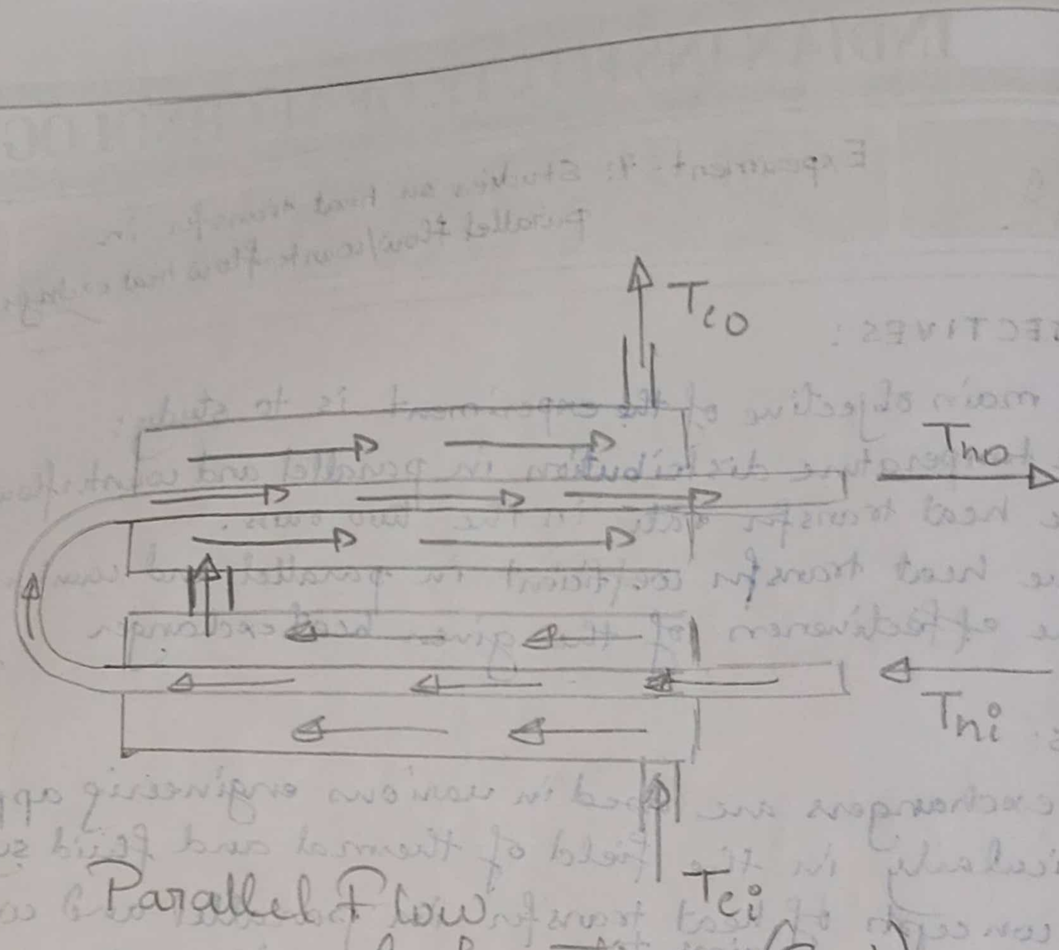
THEORY:

Heat exchangers are devices in which heat is transferred from one fluid to another. The necessity for doing this arises in a multitude of industrial applications. Common examples of best heat exchangers are radiators of car, the condensor at the back of a domestic refrigerator and the steam boiler of a thermal power plant.

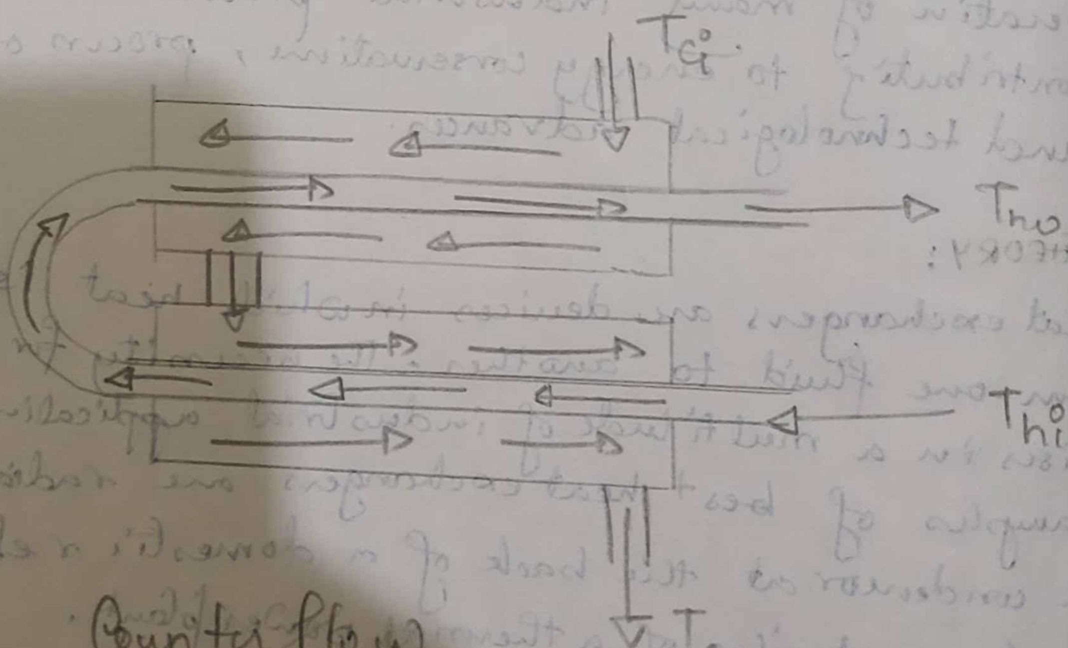
Heat exchanger are classified in 3 categories:

(i) Transfer type

(ii) Storage type



Parallel Flow Configuration (Fig 1)



Counter flow Configuration (Fig 2)

(iii) Direct contact type.

A transfer type of Heat exchanger is one in which both fluids, pass simultaneously through the device and heat is transferred through separating walls. In practice most of the Heat exchanger used ~~the~~ are transferred types ones.

The transferred type exchangers are further classified according to flow arrangements as:

1. Parallel flow, in which ~~flow~~ fluids flow in the same direction
2. Counter flow in which they flow in opposed direction
3. Cross flow in which they flow at right angles to each other.

Simple example of transferred type of Heat exchanger can be of a tube in tube type arrangement. One fluid flowing through the inner tube and other through the annulus surrounding it. The heat transfer takes place across the walls of the inner tube.

APPARATUS USED:

The apparatus consists of a tube in tube type concentric tube Heat exchanger. The hot fluid is hot water which is obtained from an electric geyser and it flows through the annulus. The hot water flows always

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in one direction and the flow rate which is controlled by means of a value. The cold water can be admitted at one of the end enabling the Heat exchanger to run as parallel flow apparatus or a counter flow apparatus. or a counter flow apparatus. This is done by value operating as shown in fig. ~~The main objectives of this experiment is to study~~

SPECIFICATIONS:

(i) Inner tube (I.D) = d_i = 8.10 mm   Material: G.I.
O.D = d_o = 13.17mm

(ii) Outer tube (I.D) = D_i = 27.5mm   Material: G.I.
O.D = D_o = 33.8mm   ~~Material = G.I~~

(iii) Length of Heat exchanger = L = 2m

PROCEDURE:

(i) Switch on the mains and start the experiment.
(ii) Turn on the tap to start flow of water.
(iii) Wait for some time so that water in the storage tank gets heated uniformly.
(iv) Turn on the pump for hot water and keep its flow rate at 43 LPH. Similarly adjust flow rate of cold water at 125LPH
(v) Now allow the system to reach the steady state.
(vi) By default the setup was ~~of~~ at counter mode. Note

(iii) Repeat the

Studies of Heat Transfer in ~~Expt~~ Parallel - counter flow heat exchanger.

S.no:	t (s)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	F_h (LPH)	F_c (LPH)	Mode.
1.	12	54.5	45.6	35.2	38	43	125	Parallel
2.	14	54	45.2	37.8	35.8	43	123	Counter

14/8/23

down the accurate reading of T_1, T_2, T_3 and T_4 and the flow rate of both cold and hot water.

(iii) Repeat the process for parallel flow operation

(iiii) Repeat the whole process for different flow rates.

OBSERVATIONS:.

Sl. no:	time (s)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	F_c (LPH)	F_h (LPH)	Mode.
1.	12	54.5	45.6	35.2	38	125	43	Parallel
2.	14	54	45.2	37.8	35.8	123	43	Counter
3.		53.5	44.6	37.1	35.2	114	38	Counter
4.		53.8	44.9	34.7	37.4	112	38	Parallel.

SAMPLE CALCULATIONS!

Parallel flow:-

$q_H = m_H c_{pH} (T_{hi} - T_{ho})$.

$= F_h \times \rho \times c_{pH} (T_1 - T_2)$.

$= 43 \times 1 \times 1 \times (54.5 - 45.6)$ kcal / hr.

$= 382.67$

$q_c = m_c c_{pc} (T_{co} - T_{ci}) = 125 \times 1 \times 1 \times (38 - 35.2)$

$= 358.4$ kcal/hr.

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LMTD :

$$\Delta T_i = T_{hi} - T_{ci} = T_1 - T_3 = 54.5 - 35.2 = 19.3$$

$$\Delta T_0 = T_{ho} - T_{co} = T_2 - T_4 = 45.6 - 38 = 7.6$$

$$\Delta T_m = \frac{\Delta T_i - \Delta T_0}{\ln\left(\frac{\Delta T_i}{\Delta T_0}\right)} = \frac{11.7}{0.932} = 12.55.$$

Effectiveness -

$$\varepsilon = \frac{m_c}{m_h}\frac{C_{pc}}{C_{pH}}\frac{(T_{co} - T_{ci})}{(T_{ho} - T_{hi})} = -\frac{F_c}{F_h}\frac{C_{pc}}{C_{pH}}\frac{(T_{co} - T_{ci})}{(T_{ho} - T_{hi}}$$

$$= \frac{125}{43} \times \frac{(38 - 35.2)}{-(45.6 - 54.5)}$$

$$= 0.915.$$

$$q_{avg} = (q_h + q_c)/2 = 370.55 \text{ kcal/m}.$$

$$U_{ri} = \frac{q}{A\,\Delta T_m} = \frac{370.55}{\pi d_i L \times 12.55} = \frac{370.55}{\pi \times 8.10 \times 2 \times 10^{-3}}$$

$$= 7.28 \times 10^3$$

$$U_{ro} = \frac{q}{A\,\Delta T_m} = \frac{370.55}{\pi d_o L \quad 12.55} = \frac{370.55}{\pi \cdot 13.17 \times 2 \times 10^{-3}}$$

$$= 4.48 \times 10^3.$$

Counter flow :

$T_{hi} = 54^\circ C$ $\quad T_{ho} = 45.2^\circ C$.

$T_{ci} = 35.8^\circ C$ $\quad T_{co} = 37.8^\circ C$.

$q_h = 43 \times (54 - 45.2) = 378.4$ k cal/hr.

$q_c = 123 \times (37.8 - 35.8) = 246$ k cal/hr.

$q = \frac{q_h + q_c}{2} = 312.2$ k cal/hr.

$\varepsilon = \frac{\dot{m}_c C_{pc} (T_{co} - T_{ci})}{\dot{m}_H C_{pH} (T_{HO} - T_{Hi})} = 0.314$

LMTD:

$$LMTD = \Delta T_m = \frac{\Delta T_i - \Delta T_o}{\ln\left(\frac{\Delta T_i}{\Delta T_o}\right)}$$

$\Delta T_i = 54 - 37.8 = 16.2$.

$\Delta T_o = 45.2 - 35.8 = 9.4$

$$\Delta T_m = \frac{16.2 - 9.4}{\ln\left(\frac{16.2}{9.4}\right)} = 12.5^\circ C.$$

$U = q/A\Delta T_m$

$U_{r_i} = \frac{312.2}{\pi \times 8.10 \times 2 \times 10^{-3}} = 6.13 \times 10^3$ $\quad U_{r_o} = 3.77 \times 10^3$

RESULTS:

In the experiment, both parallel flow and counter flow ~~ex~~ configurations were tested. The obtained results indicated that the counter flow configuration exhibited ~~higher~~ lower values of LMTD and heat transfer rate (q) compared to parallel flow. This highlights the advantages of ~~counter~~ parallel flow in terms of enhanced heat transfer efficiency. ~~The overall heat transfer coefficient (U) remained same in both configurations.~~

We got an erroneous observation as the parallel flow should have ~~higher~~ lower values.

DISCUSSION:

The experimental results emphasise the importance of flow arrangements in heat exchanger. In industrial setting, choosing the appropriate flow arrangement can lead to increased energy efficiency and improved overall performance. The outcomes of this experiment provide engineers with a deep understanding of heat exchanger.

CRITICAL COMMENTS:

- Inaccurate temperature reading due to faulty temperature sensors and misplacement of sensors.
- Sufficient time should be given to allow uniform flow rates.

• Premature assumptions of steady state may lead to incorrect observations.

REMARKS:

So to ensure the accuracy and reliability of the experimental results, several consideration should be addressed. Calibrating temperature sensors and utilizing precise thermometers are essential steps to minimize measurement errors.

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DATE | Experiment 4: Studies on heat transfer through composite wall | SHEET NO.

OBJECTIVES: Aim

To study conduction heat transfer through composite wall.
To determine total thermal resistance and thermal conductivity of composite wall.
To calculate thermal conductivity of one material in composite wall.
To plot temperature profile in composite wall.

AIM:

Conduction heat transfer through composite walls is important in optimizing heat transfer in various engineering application. The experiment aims to aid engineers in thermal insulation design, material selection, create energy efficient appliance and academic understanding of industrial processes.

APPARATUS:

The apparatus consist of a heater sandwiches between two asbestos sheets. Three slabs of different materials are provided on both sides of heater, which forms a ~~complete~~ composite structure. A small press frame is provided to ensure the perfect contact between the slabs, a variac is provided for varying the input to the heater and measurement of input

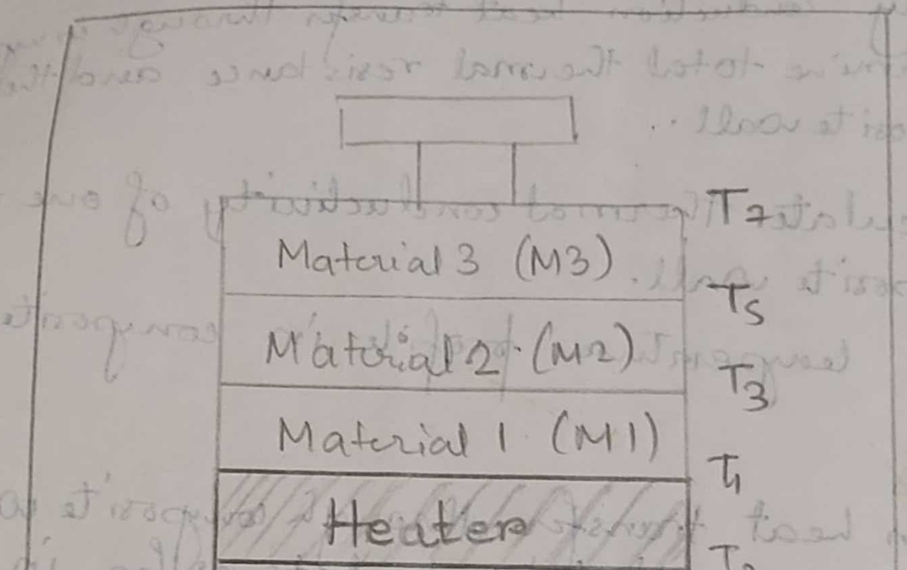

Fig1: Schematic Diagram of Composite Wall

power is carried out by a digital voltmeter and digital ammeter. Temperature sensors are embedded between inter faces of the slabs, to read the temperature at the surface. The experiment can be conducted at various values of power input and calculations can be made accordingly.

SPECIFICATIONS:

$d = 0.25 m$

$x_1 = 0.02 m$.

$x_2 = 0.015 m$

$x_3 = 0.012 m$.

$K_{m1} = 52 W/m^\circ C$.

$K_{m2} = 1.4 W/m^\circ C$

$K_{m3} = 0.12 W/m^\circ C$.

THEORY:

When a temperature gradient exists in a body there is an energy transfer from the high temperature region to the low temperature region. Energy is transferred by conduction and heat transfer rate per unit area is proportional to the normal temperature gradient.

$$\frac{q}{A} \propto \frac{\Delta T}{\Delta x}$$

When proportinality constant is inserted,

$$q = -kA\frac{dT}{dx}.$$

Where q is heat transfer rate, and $\frac{\Delta T}{\Delta x}$ is temperature gradient in the direction of heat flow. The positive constant k is called thermal conductivity of the material.

A direction of Fourier's law is the plane wall Fourier's equation.

$$q = \frac{-kA}{\Delta x}(T_2 - T_1).$$

where the thermal conductivity is considered constant. The wall thickness is Δx, and T_1 and T_2 are surface temperature.

The heat flows may be written as.

$$q = -k_{M_1}A\frac{\Delta T_1}{\Delta x_1} = -k_{M_2}\frac{A\Delta T_2}{\Delta x_2} = -k_{m_3}\frac{A\Delta T_3}{\Delta x_3}$$

PROCEDURE:

1. Switch on the main power supply 220 AC single phase, 50 Hz.
2. Increase slowly the input to heater by the ~~by voltmeter~~

Expt: Heat Transfer through Composite Wall

V	I	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
55	0.42	41.2	42.1	40.3	40.7	37.4	37.5	34.7	34.6
"	"	41.8	42.8	41.3	41.6	37.9	38.2	35.8	34.7
"	"	42.6	44.0	42.3	42.3	38.5	38.7	35.5	35.6
"	"	~~42.8~~	~~44.1~~	~~42.5~~	~~42.3~~	~~38.7~~	~~38.7~~	~~35.6~~	~~35.8~~

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Observations

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dimmerstat starting from

3. Adjust the heat in

... sensors

... intervals ...

... indicating stea...

... the read...

...s:

T_2 (°C)	T_3 (°C)	T_4 (°C)
42.1	40.3	40.7
42.8	41.3	41.6
44	42.3	42.3

CALCULATIONS:

$Q = 55 \times 0.42 = 23.1$

$q = 11.55$ W.

$A = \frac{\pi d^2}{4} = \frac{\pi \times 0.25^2}{4} =$

$T_1' = \frac{42.6 + 44.0}{2}$

dimmerstat starting from zero volt position.

3. Adjust the heat input by voltmeter and ammeter.

4. Temperature sensors readings are taken at frequent intervals till consecutive readings are same indicating steady state.

5. Note down the readings.

OBSERVATIONS:

V (V)	I (A)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)	T_7 (°C)	T_8 (°C)
55	0.42	41.2	42.1	40.3	40.7	37.4	37.5	34.7	34.6
55	0.42	41.8	42.8	41.3	41.6	37.9	38.2	35.8	34.7
55	0.42	42.6	44	42.3	42.3	38.5	38.7	35.5	35.6

Mention the thermocouple naming which you corrected

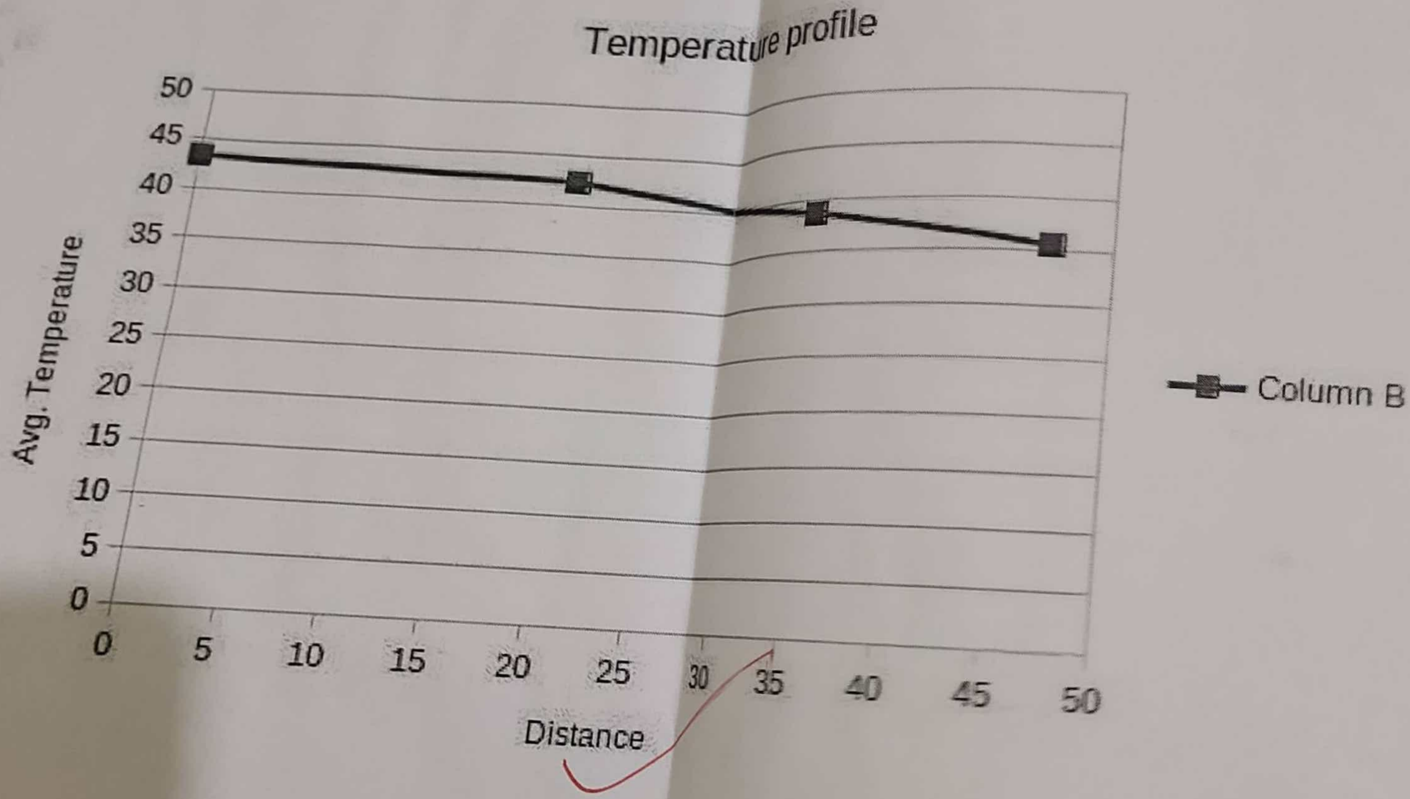
CALCULATIONS:

$Q = 55 \times 0.42 = 23.1\ W$

$q = 11.55\ W$.

$A = \frac{\pi d^2}{4} = \frac{\pi \times 0.25^2}{4} = 0.049\ m^2$

$T_1' = \frac{42.6 + 44.0}{2} = 43.3$



Temperature Distribution Plot.

Kew = $\frac{qx}{A(T_1' - T}$

Total thermal resistance

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$$T_3' = \frac{42.3 + 42.3}{2} = 42.3\,^\circ C.$$

$$T_5' = \frac{38.5 + 38.7}{2} = 38.6\,^\circ C.$$

$$T_7' = \frac{35.5 + 35.6}{2} = 35.6\,^\circ C.$$

$$K_{m_1} = \frac{11.55 \times 0.02}{0.049 \times (43.3 - 42.3)} = 4.71 \text{ W/m}^\circ C$$

$$K_{m_2} = \frac{11.55 \times 0.015}{0.049(42.3 - 38.6)} = 0.96 \text{ W/m}^\circ C$$

$$K_{m_3} = \frac{11.55 \times 0.012}{0.049 \times (38.6 - 35.6)} = 0.94 \text{ W/m}^\circ C$$

$$K_{ew} = \frac{q x}{A(T_1' - T_2')} = \frac{11.55 \times 0.047}{0.049 \times (43.3 - 35.6)}$$

$$= 1.44 \text{ W/m}^\circ C.$$

$$\text{Total thermal resistance} = \frac{0.02 + 0.015 + 0.012}{1.44 \times 0.049} = 0.667.$$

RESULT:

- Thermal conductivity of composite wall is ~~1.265~~ 1.44 W/m°C
- Total thermal resistance of wall is 0.667 K/W
- Individual thermal conductivity are 4.71 W/m°C, 0.96 W/m°C and 0.94 W/m°C respectively.

DISCUSSION:

Unlike what was written in the manual, we did the experiment considering constant voltage. We were reading the temperature values after every 10 minutes. Eventually we took in different sets of readings. ~~B~~ Practically, steady ~~state~~ state can never be reached. However when the temperature variation is very less we can consider that to be steady state. Also the readings in the machine has to be of some precision, so it generally becomes equal to each other after some time.

The arrangement and numbering of the i value for Ti was incorrect in this experiment.

Also theoretically the temperature reading above and below the heater should be same be cause we have same set of materials in both sides and are of the same size. However they are slightly different in experiment. So we take the mean value.

CRITICAL COMMENTS:

- The discrepancies in thermal conductivity values for power rating may be attributed to measurement uncertainties or transient effect
- Achieving steady state is crucial for obtaining accurate and reliable results
- Better insulation would guarantee less heat loss through unwanted ways, thus giving accurate results.

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DATE | EXPERIMENT- 8 : Studies on Radiative Heat Transfer in Stefan-Boltzmann Apparatus | SHEET NO.

~~OBJECTIVES:~~ AIM: To experimentally determine the Stefan-Boltzmann constant.

OBJECTIVES: The aim of this experiment is to investigate the radiative heat transfer between a test disc and a flanged copper hemisphere, utilizing the Stefan-Boltzmann law. The stefan boltzmann law states that the emissive power of a ~~power~~ perfect black body is directly proportional to the fourth power of its absolute temperature.

THEORY: Radiative heat transfer is an important mode of energy transfer that occurs through electromagnetic waves. The Stefan-Boltzmann law, a fundamental ~~equation~~ equation in radiative heat transfer, expresses the ~~in~~ relationship between the radiative heat flux (emissive power) of a black body and its absolute temperature.

$$E = \sigma T^4$$

where -

- E is the radiative heat flux (emissive power)
- σ is the Stefan-Boltzmann constant
- T is the temperature of black body.

In this experiment, a flanged copper hemisphere

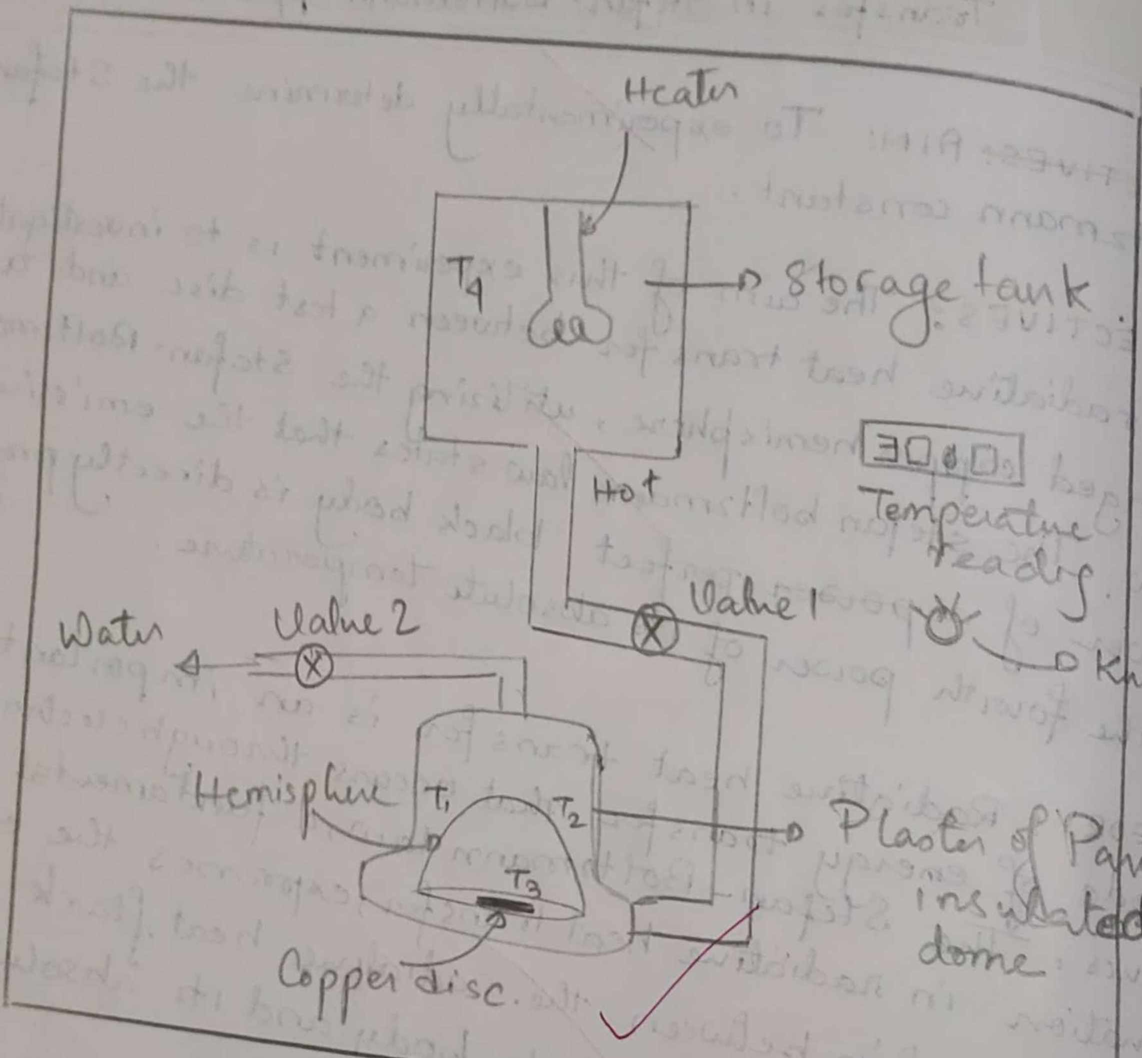

Fig1. Experimental setup for Stefan Boltzmann ~~constant~~ Apparatus

encloses a test ~~tube~~ disc. The outer ~~space~~ surface of the hemisphere is heated by a water jacket. By monitoring the temperature of test disc and the hemisphere and knowing the temperature of the water jacket, the radiation heat transfer of between the two surfaces can be analyzed.

APPARATUS REQUIRED:

The apparatus consist of a flanged copper hemisphere fixed on a flat non-conducting plate. A test disc made of copper is fixed to the plate. Thus 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. Three Cr. Al thermocouples are attached at three strategic places on the surface of the hemisphere to obtain the temperature. The disc is mounted on a Bakelite sleeve which is fitted in a hole drilled at the centre of the base plate. Other Cr. Al thermocouples are fixed to the disc to record its temperature

Exp. 8

$T_1 = 38.4^\circ C$ $T_2 = 43.4^\circ C$ $T_3 = 27.9^\circ C$ $T_4 = 95.5^\circ C$

T_3		T_3		T_3	
29.6		46.1	38	54.6	73
30.1		46.5	39	54.8	74
30.5		46.9	40	55.	75
31.1		47.0	41	55.1	76
31.6		47.5	42	55.3	77
32.1		47.7	43	55.4	78
32.5		48.0	44	55.5	79
33.6		48.4	45	55.6	80
34.1		48.7	46	55.8	81
34.5		49.0	47	56.	82
35.1		49.1	48	56.1	83
35.6		49.6	49	56.2	84
36.0		49.7	50	56.4	85
36.4		50.0	51	56.5	86
37.0		50.3	52	56.6	87
37.5		50.4	53	56.8	88
37.9		50.8	54	56.7	89
38.4		50.9	55	56.8	90
38.8		51.1	56	57.0	91
39.1		51.4	57	57.1	92
39.6		51.7	58	57.2	93
40.1		52.0	59	57.2	94
40.4	23	52.1	60	57.3	95
40.9	24	52.3	61	57.4	96
41.3	25	52.6	62	57.5	97
41.6	26	52.8	63	57.5	98
42.1	27	52.5	64	57.6	99
42.9	28	53.2	65		
42.8	29	53.3	66		
43.3	30	53.5	67		
43.7	31	53.6	68		
44.0	32	53.9	69		
44.5	33	54.2	70		
44.7	34	54.2	71		
45.2	35	54.4	72		
45.4	36				
45.8	37				

SPECIFICATIONS:

Diameter of disc = 20 mm.

Thickness of disc = 1.5 mm

Mass of the disc = 5g

Specific heat of the test Disc (C_p) = 380 J/kg K.

Inner Diameter of the hemispherical surface = 200 mm

PROCEDURE:

1. Fill the tank with water and switch on the heater
2. Check the temperature of water by means of thermocouple provided. After achieving the temperature about 90°C open the valve and allow the water to enter into the metallic tank.
3. Put off the heater supply. Now take initial readings.
4. Note down the temperature of the disc at an interval of 10 seconds for 5 to 10 minutes (until steady state is achieved)
5. Plot a graph between disc temperature and time.

OBSERVATION TABLE:

Time (s)	Temperature (°C)
0	29.6
10	30.1
20	30.5
30	31.1

Time (s)	Temperature of Disc (oC)
40	31.6
50	32.1
60	32.5
70	33.6
80	34.1
90	34.5
100	35.1
110	35.6
120	36.0
130	36.4
140	37.0
150	37.5
160	37.9
170	38.4
180	38.8
190	39.1
200	39.6
210	40.1
220	40.4
230	40.9
240	41.3

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~~SPECIFICATIONS:~~

Time (s)	Temperature of disc (°C)
~~240~~	41.6
250	42.1
260	42.4
270	42.8
280	43.3
290	43.7
300	44.0
310	44.5
320	44.7
330	45.2
340	45.4
350	45.8
360	46.1
370	46.5
380	46.9
390	47.0
400	47.5
410	47.7
420	~~48.0~~
430	48.0

Time (s)	Temperature (°C)
440	48.4
450	48.7
460	49.0
470	49.1
480	49.6
490	49.7
500	50.0
510	50.3
520	50.4
530	50.8
540	50.9
550	51.1
560	51.4
570	51.7
580	52.0
590	52.1
600	52.3
610	52.6
620	52.8
630	52.9
640	53.3
650	53.3
660	53.5
670	53.6
680	53.9
690	54.2
700	54.2

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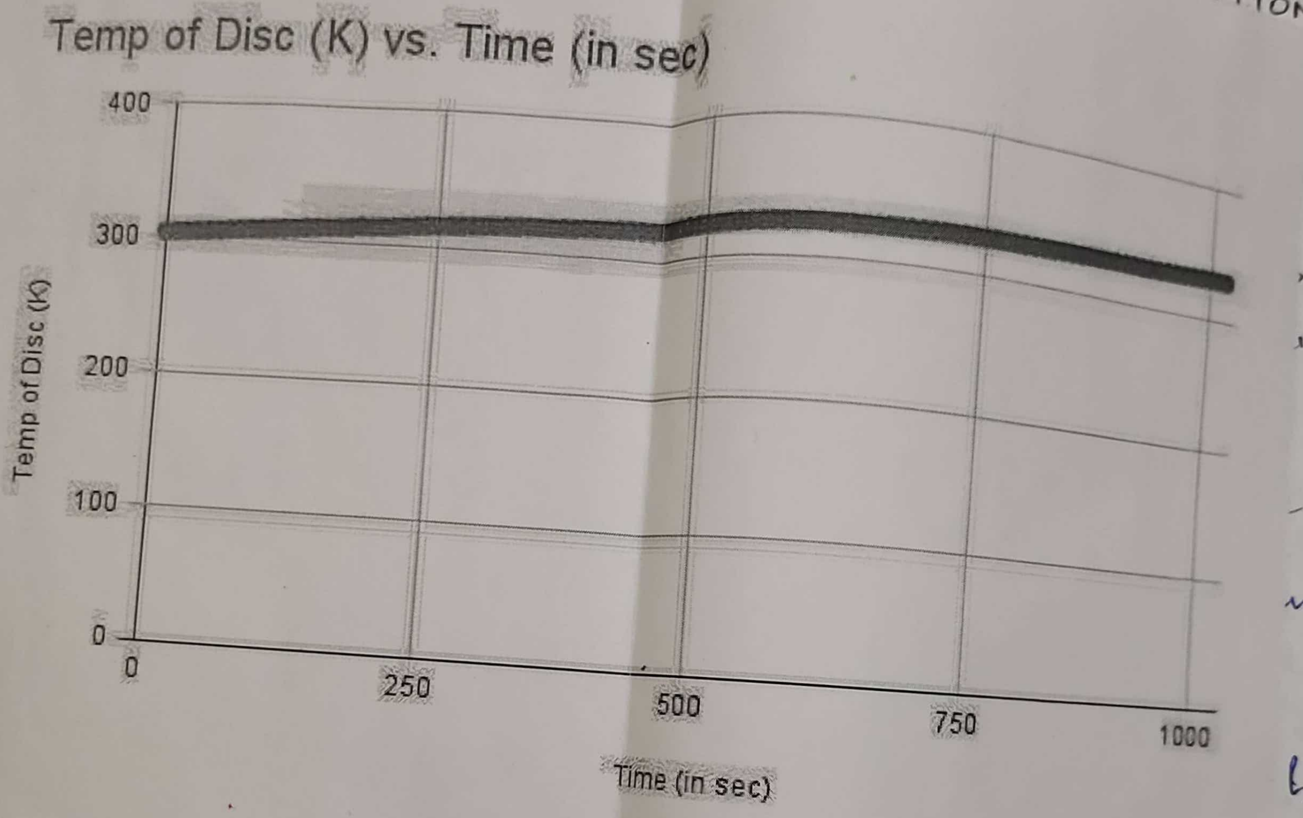
Time (s)	Temperature of Disc (°C)
710	54.4
720	84.6
730	55.
740	55.1
750	55.3
760	55.4
770	55.5
780	55.6
790	55.8
800	56.
810	56.1
820	56.2
830	56.4
840	56.5
850	56.6
860	56.8
870	56.7
880	56.8
890	
900	57.0
910	57.1
920	57.2
930	57.3
940	57.4
950	57.5
960	57.5
970	57.6.
980	



TIONS :

we get slop

258 K/s

, T= 0.025

isc (A_D) = cs

= 4

of disc at

perature of

balance,

change of hea

= Net energy

$$mC_p \frac{dT}{dt} = \sigma A_D (T_{avg}^4 -$$

$$\sigma = mC_p \frac{dT}{dt} \times \frac{1}{A_D (T_{avg}}$$

CALCULATIONS:

From the plot we get slope of the line graph as 0.0258 K/s.

Thus $\frac{dT}{dt} = 0.0258$ K/s

Equation $\rightarrow T = 0.0258t + 303.1$ K.

Area of disc (A_D) = CSA + Area of Top surface

$= 4.084 \times 10^{-4} m^2$

Temperature of disc at $t = 0$ (T_D) = 303.1K.

Average Temperature of hemisphere (T_{avg})

$= \frac{1}{2}(T_1 + T_2) = 313.9$K

By heat balance,

Rate of change of heat capacity of disk

= Net energy radiated on the disk.

$$mC_p\frac{dT}{dt} = \sigma A_D(T_{avg}^4 - T_D^4)$$

$$\sigma = mC_p\frac{dT}{dt} \times \frac{1}{A_D(T_{avg}^4 - T_D^4)} = \frac{5\times10^{-3} \times 380 \times 0.0258}{4.084\times10^{-4}\times(313.9^4 - 303.1^4)}$$

$= 9.46 \times 10^{-8}$ W/m²K⁴

DISCUSSION:

The data obtained was used to plot a graph of temperature against time. Temperature was seen to be increasing with time and the rate in increase of temperature was found to be decreasing until steady state was achieved. Now temperature became almost constant and the rate of change in temperature became almost 0.

Since no body is black body in real life, the experimentally obtained value of Stefan - Boltzman constant was found to be different than the actual body. But this value should come out less than $5.67 \times 10^{-8}\ W/m^2 K^4$. Suprisingly the value obtained was more. This is mainly because there is a mismatch ~~see~~ in the values in manual and experimental setup.

CRITICAL COMMENTS:

(i) Relevant points observed during the experiment includes the time taken for thermal equilibrium to be reached, the consistency of temperature readings and the stability of the heating source.

(ii) Precautions to be taken include ensuring proper insulation of the apparatus to minimize heat loss to the surroundings, accurate temperature measurement, and avoiding disturbances to the experimental setup during data collection

(iii) Possible sources of error include inaccuracies in temperature measurement due to calibration issues or thermocouple placement, heat loss to the environment and uncertainties in the water temperature used to heat the hemisphere.

CONCLUSION.

In conclusion the experiment allows us to explore the principles of radiative heat transfer and its dependence on temperature. By analyzing the temperature-time data we can determine the Stefan Boltzmann constant., a fundamental parameter in radiative heat transfer. The experiment highlights the significance of accurate temperature measurement and thermal equilibrium in obtaining reliable results in heat transfer studies.

DATE

Experiment 9: Determination of overall heat transfer coefficient in dropwise and filmwise condensation

SHEET NO.

AIM: To determine the individual heat transfer coefficient in filmwise condensation or dropwise condensation using condensation apparatus.

OBJECTIVE:

Condensation is one of many important processes occuring in process industries and power plants. Thus our objective is to enhance our understanding about different condensation process.

THEORY:

Steam may condense on to a surface in two distinct ways, known as filmwise and dropwise. During condensation, very high heat fluxes are possible and the heat provided can be quickly transferred from the condensing surface to the cooling medium heat exchanger can be compact and effective using steam.

Dropwise condensation (gold plated copper tube) - The vapour condenses in the form of droplets on the surface of the condenser. The droplets are of different sizes and glides down from the

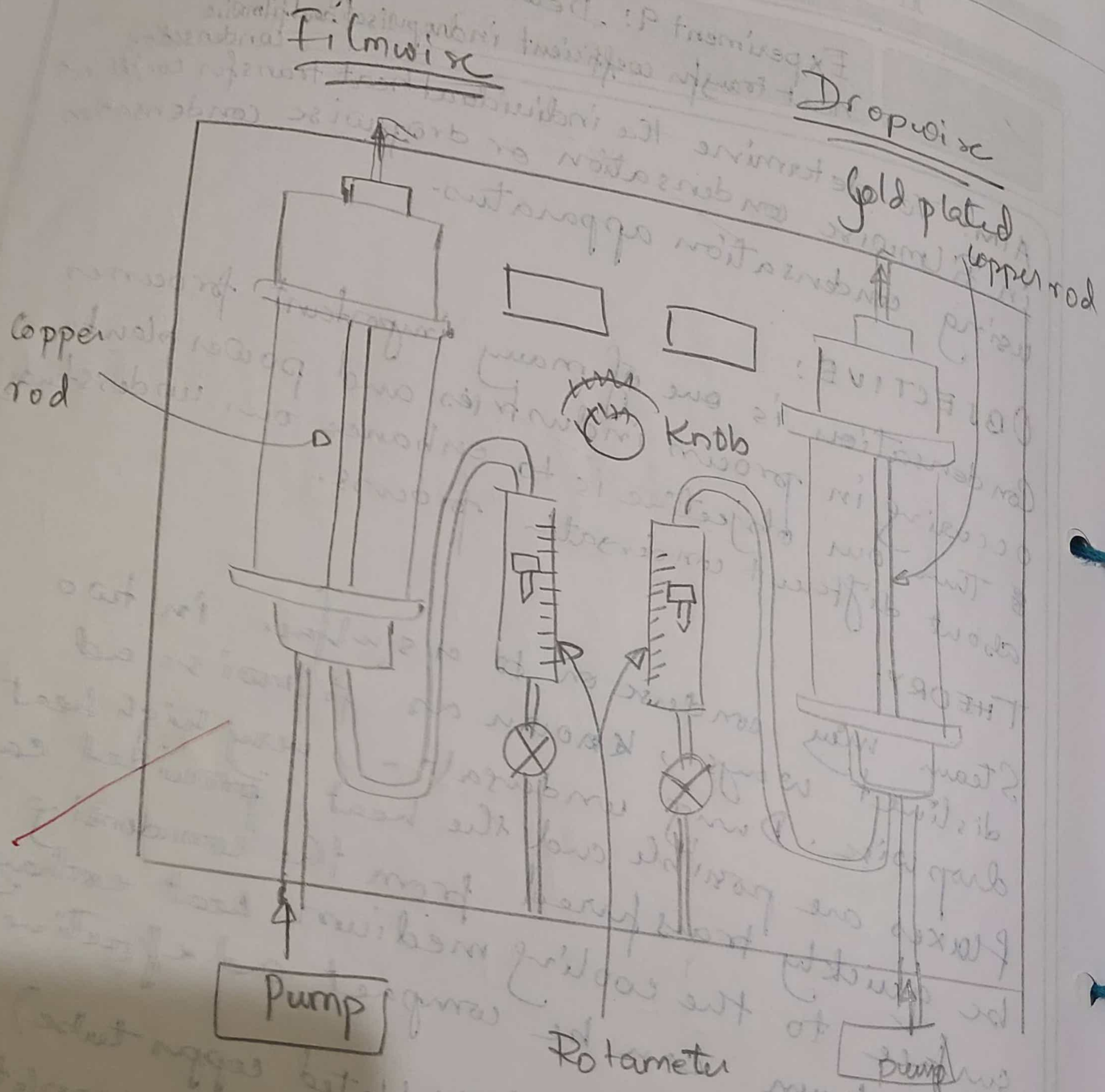


Fig 1. Filmwise and Dropwise Apparatus

surface without forming an insulating layer on the surface of condenser. As a result, the overall heat ~~ex~~ transfer coefficient is higher in comparison to filmwise condensation (upto 10 times larger)

Filmwise condensation (plain copper tube)
The vapour condenses in the form of a thin film that wets the surface of the condenser body, adding extra resistance to heat transfer. This results in lower overall heat transfer coefficient and a lower rate of condensation.

APPARATUS REQUIRED:
The apparatus consists of 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 voltage regulator.

SPECIFICATIONS:

Filmwise and dropwise:

inner diameter = d_i = 11 mm

Outer diameter = d_o = 12.7 mm

Length of tube = L = 250 mm.

PROCEDURE:

- Start the furnace and set initial steam pressure of around 1.5 kg/cc.
- Allow the cooling water to flow through the condenser with a flowrate of 30 cc/s
- Switch on the heater, adjust the voltage to be around 150V. Wait till steam pressure rises by 0.5 kg/cc.
- Open the valve and let the steam to flow slowly through the glass chamber. Maintain steam pressure by increasing or decreasing voltage across the heater.

Dropwise

T_1	T_4	T_5	T_7	T_9
49.3	51.2	53.9	100.7	101.3

Filmwise:

T_1	T_2	T_3	T_6	T_8
48.1	49.6	51.1	85	102

Observations

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- Note down water flow rate temperature (T_1, to T_5) and proceed to calculations.

OBSERVATION TABLE:

a) Filmwise condensation

Flowrate (M_w) (cm^2/s)	Density (ρ_s) (kg/cm^2)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_6 (°C)	T_8 (°C)
30	1	48.1	49.6	51.1	85.0	102

b) Dropwise condensation

Flowrate (M_w) (cm^2/s)	Density (ρ_s) (kg/cm^2)	T_1 (°C)	T_4 (°C)	T_5 (°C)	T_7 (°C)	T_9 (°C)
30 ~~cm^3/s~~	1	49.3	51.2	53.9	100.7	101.3

CALCULATIONS:

Area 'A_o' of tube $= \pi d L = \pi \left(\frac{12.7}{1000}\right) \times \left(\frac{250}{1000}\right)$

$= 0.003175\ m^2$

(a) Dropwise Condensation

Heat picked up by water $Q = mC_p(T_5 - T_1)$

$= 0.01 \times 4187 \times (53.9 - 49.3)$

$= 192.602\ W.$

Mean Temperature

$$T_m = \frac{T_5 - T_4}{\ln\left(\frac{T_7 - T_4}{T_7 - T_5}\right)} = \frac{53.9 - 51.2}{\ln\left(\frac{100.7 - 51.2}{100.7 - 53.9}\right)}$$

$= 48.14°C$

Overall heat transfer coefficient $= U = \frac{Q}{A T_m} = \frac{192.602}{0.003175 \times 48.14}$

$= 1260.1173\ W/m^2K.$

External surface heat transfer coefficient

$$h = \frac{q}{A_0 (T_7 - T_4)} = \frac{192.602}{0.003175 \times (100.7 - 51.2)}$$

$= 1225.4959\ W/m^2K.$

b. Filmwise condensation

$$Q = mC_p(T_5 - T_1) = 0.01 \times 4187 \times (52.1 - 48.1)$$
$$= 125.61 \text{ unit}$$

Mean temperature difference

$$T_m = \frac{T_3 - T_2}{\ln\left(\frac{T_6 - T_2}{T_6 - T_3}\right)} = \frac{51.1 - 43.6}{\ln\left(\frac{85 - 49.6}{85 - 51.5}\right)}$$
$$= 34.64\,°C$$

$$U = \frac{Q}{T_m A} = \frac{125.61}{34.64 \times 0.003175} = 1142.0959 \text{ W/m}^2\text{K}$$

$$h = \frac{Q}{A_0 (T_6 - T_2)} = \frac{125.61}{0.003175 \times (85 - 49.6)} = 1117.5764 \text{ W/m}^2\text{K}.$$

RESULTS AND DISCUSSION

The overall heat transfer coefficient obtained for filmwise and dropwise condensation are: 1142.0959 W/m²K and 1260.1173 W/m²K respectively.
— This reveals that dropwise condensation exhibits

higher heat transfer coefficient than filmwise.

Reason:

- For dropwise condensation there is more surface area available unlike filmwise condensation. Thus there is more surface area for heat transfer.
- Filmwise condensation showed lower h due to presence of condensate film, which increases thermal resistance.

CRITICAL COMMENTS:

- We find that difference in surface area available for heat transfer make considerable difference on the h value for dropwise and filmwise condensation.
- ~~The~~ Dropwise condensation has both more surface area available for heat transfer as well as overall heat transfer coefficient than filmwise condensation.
- The experiment assumes ideal condition and does not account for surface fouling
- Variation in voltage and water flow rate might ~~not~~ impact steam pressure and thus h.

- Precision of temperature measurements could influence accuracy of calculated heat transfer coefficient.

CONCLUSION:

~~The experiment sheds light on heat transfer characteristics in a pin fin heat exchanger. By analyzing temperature distribution, determining heat transfer coeff~~

Dropwise condensation exhibited higher heat transfer. This can be used to optimize heat exchanger design and industrial process where condensation plays a vital role.

Further, condensation behavior depends on fluid properties, different surfaces, operational conditions etc..

DATE	Experiment - 2: Studies on Heat Transfer in Pin-Fin apparatus.	SHEET NO.

AIM: 1. To plot the variation of temperature along the length of pin under forced convection.

2. To determine the value of heat transfer coefficient under forced convection condition and to find:

a). Theoretical values of temperature along the length of the fin

b) Effectiveness and efficiency of the pin fin for insulated end condition.

OBJECTIVES:

The objectives of this experiment is to enhance our understanding of heat transfer mechanism, improving the efficiency of various systems, and developing technologies that have a positive impact on multiple industries and the environment.

THEORY:

Heat transfer from a heated surface to the ambient environment is represented by the equation

$q = h \times A \times \Delta T$ where h = heat transfer coefficient (W/m^2K)

ΔT = temperature difference (K)

A = area of heat transfer normal to heat flow (m^2)

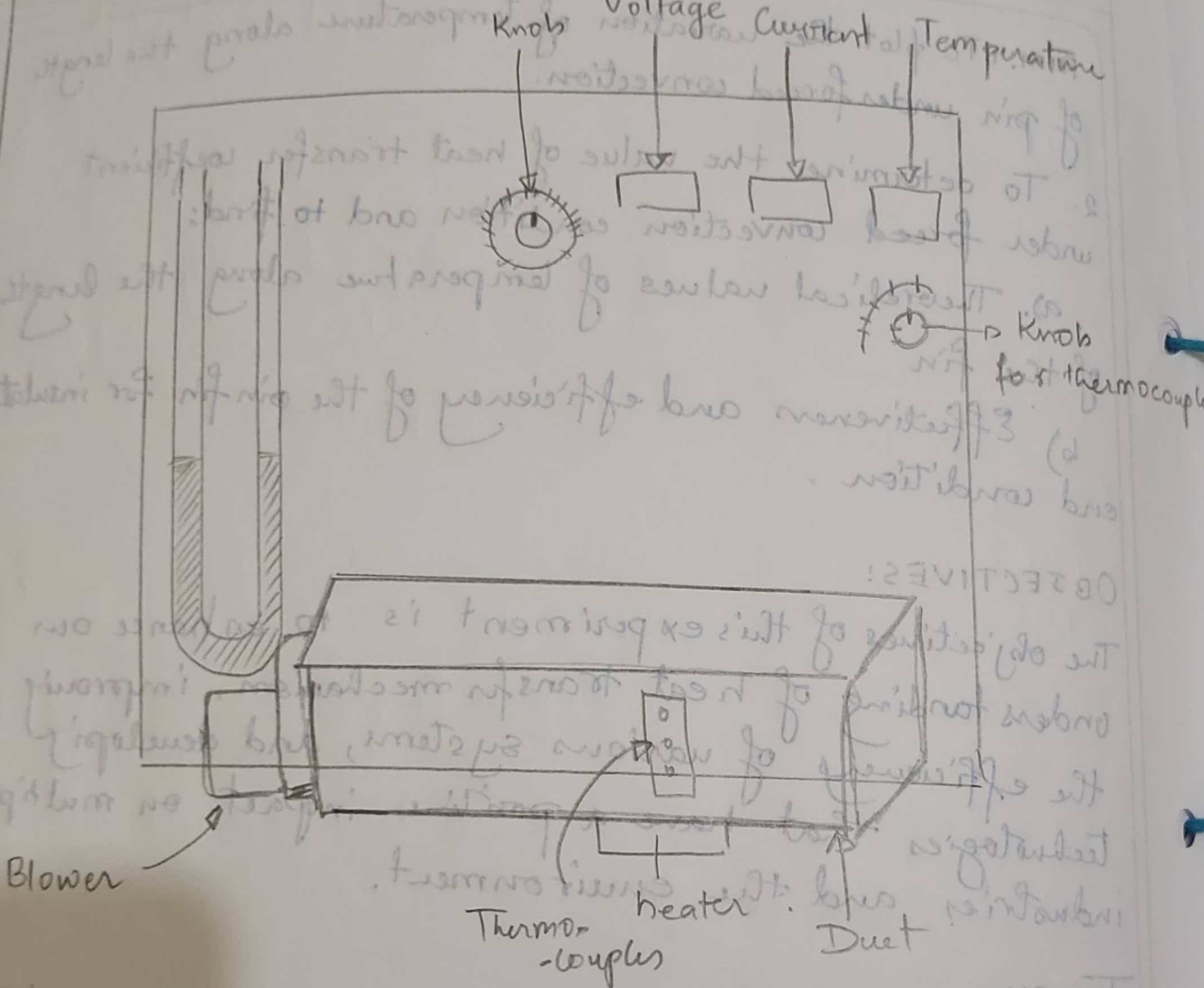

Fig1. Pin-Fin Apparatus

When increasing h or ΔT is not feasible enhancing A becomes necessary. This is achieved by attaching extended surfaces called fins. The cross section of the fin can vary, such as circular, rectangular, triangular or parabolic

Heat transfer from fins with insulated end

$$\frac{\theta}{\theta_0} = \frac{T - T_\infty}{T_0 - T_\infty} \frac{\cosh(mLx)}{\cosh(mL}$$

APPARATUS REQUIRED:

A pin fin heat exchanger consists of slender pin fins attached to a baseplate, designed to efficiently dissipate heat from a source. Cooling air or fluid passes over the fins, extracting heat, while a solid baseplate conducts it away from the source. These heat exchanger are crucial for cooling electronic components and high power devices, optimizing heat transfer for improved performance and reliability.

SPECIFICATIONS:

Length of fin = 150 mm

Diameter of fin = 12 mm

Thermal conductivity of material = 110 W/mK.

Diameter of orifice = 0.02 m

Width of duct = 0.15 m.

Breadth of duct = 0.1 m.

Coefficient of discharge of the orifice = 0.61

Density of the manometric fluid = 1000 kg/m³

PROCEDURE:

- ~~Start the process and set initial steam pressure of around 1.5 kg/cm²~~.
- ~~Allow the cooling water to flow through one of the condenser (which is selected) with a flow rate of around.~~
- Connect the equipment to the power supply
- set the thermocouple selector switch to zero
- Adjust the heaters power input using the

Expt. 2 Heat Transfer through pin-fin apparatus

Heat input			Pressure drop of water	Temperature (°C)					
V	I	P		T_1	T_2	T_3	T_4	T_5	T_6
43	0.19	8.17	2cm	84.0	62.0	56.6	53.1	50.2	40.5
43	0.19	8.17	3 cm	80.7	60.2	55.3	51.8	49.3	40.2
43	0.19	8.17	2.7cm	79.1	59.3	54.6	51.4	48.8	40.3
44	0.2	8.80	2.7	77.9	58.6	54.0	50.7	48.2	40.0
44	0.19	8.36	2.7	76.9	58.0	53.9	50.3	48.0	40.4
44	0.19	8.36	~~2.27~~ 3	75.9	57.4	53.1	50.0	47.6	40.2
44	0.19	8.36	3	75.3	57.2	52.9	50.0	47.7	40.3
50	0.23	11.5	0.7	78.8	58.4	54.2	51.1	48.8	40.7
50	0.22	11.0	1	76.9	58.8	54.5	51.3	48.9	40.8
50	0.22	11.0	1.2	77.7	59.1	53.8	50.2	47.7	39.9
51	0.23	11.73	1.8	79.5	59.2	54.0	51.4	48.0	40.2
50	0.22	11.0	1.3	79.5	59.9	54.1	51.5	48.1	40.5

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dimmerstat knob.

- Start the blower and let the air flow rate using the manometer.
- Tabulate time vs temperature data at an interval of about 3 minute.
- Record temperature T_1 to T_6 and manometer differences.
- Repeat the experiment for different power inputs.

~~OBSERVATION TABLE~~

CALCULATIONS:

Considering the first observation,

For surface temperature

$$T_s = \frac{1}{5}(T_1 + T_2 + T_3 + T_4 + T_5)$$

$$= 56.64°C.$$

$$T_6 = 40.3°C$$

$$T_{avg} = \frac{56.64 + 40.3}{2} = 48.47°C$$

At $T = 47.47^\circ C$

$\vartheta = 17.8 \times 10^{-8} m^2/s$

$Pr = 0.705$

$K = 27.97 \times 10^{-3}$

$$\vartheta_0 = C_d \times \sqrt{\frac{2gh(\rho_m - \rho_a)}{\rho_a(1-\beta^4)}}$$

$$\vartheta_0 = 0.62 \sqrt{\frac{2 \times 9.8 \times 0.03 \times (1000 - 1.27)}{1.12 \times \left(1 - \left(\frac{0.04}{0.42}\right)^4\right)}}$$

$= 14.2048 \, m/s.$

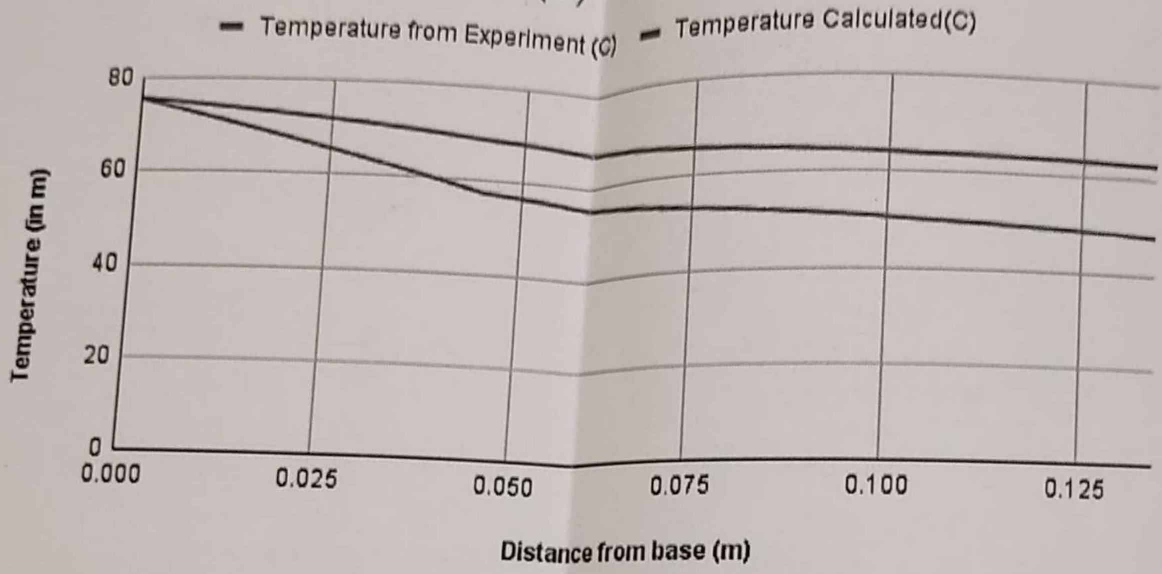
$$\vartheta|_{airduct} = \frac{\vartheta_0 \times \pi d^2}{A\,(l \times b)} = 0.2976 \, m/s.$$

$$Re = \frac{\rho V D}{\mu} = \frac{0.2976 \times 0.012}{17.8 \times 10^{-8}}$$

$= 200.62.$

$$h = \frac{Nu\,K}{D} = \frac{0.683 \times Re^{0.466}\, Pr^{1/3} \times K}{D}.$$

Distance from base (m) vs Temperature from Experiment (C) and Temperature Calculated(C)



Distance from base	Temperature from experiment (°C)	Temp from calculation (°C)
0	75.3	75.49
0.045	37.2	68.55
0.075	53	65.50
0.105	50	63.53
0.135	47.7	62.56

Effectiveness of pin

$$\varepsilon = \sqrt{\frac{PK}{h_c A}} \tanh(mL) = 37.15$$

Efficiency of pin $= \eta = \frac{\tanh(mL)}{mL}$

$= 74.86\%$

RESULTS AND DISCUSSION:

The convective heat transfer coefficient is 16.76 W/m^2K

The effectiveness of pin is 37.15.

The efficiency of fin is η = ~~81~~ 74.76%.

Temperature increases with decrease in x.

Pinfin HE are commonly used in electronics cooling, aerospace application and various industries where ~~the~~ effective heat dissipation is required. The design of pinfin apparatus can be customized to meet specific thermal management requirements for different application.

CRITICAL COMMENTS:

- The experiment assumes ideal conditions which might differ from real world scenarios.
- The temperature readings are recorded at steady state. Theoretically, it is not possible to achieve it. But we are assuming it when variation is small.
- Variation in power input and accuracy of temperature measurements could impact calculated parameters.

CONCLUSION:

The experiment sheds light on heat transfer characteristics in a pin fin heat exchanger. By analyzing temperature distribution, determining heat transfer coefficient and evaluating effectiveness and efficiency of pin fin, we gained valuable insights into the practical application of extended surface for heat transfer enhancement.

DATE | EXPERIMENT 6: DETERMINATION OF CRITICAL HEAT FLUX | SHEET NO

OBJECTIVES:

We determine and study the critical heat flux point of the critical heat flux apparatus. The experiment set up is designed to study the pool boiling phenomenon up to critical heat flux point. The heat flux from the wire is slowly increased by increasing the applied voltage across the test wire and the change over from natural convection to nucleate boiling can be seen.

It is necessary to study the critical heat flux to help design systems that can safely handle heat generation in places like Nuclear and Thermal power plant. Understanding critical heat flux can be valuable in medical applications like sterilization, cryopreservation (freezing biological tissues) and other processes that involve rapid temperature changes. In essence, studying the critical heat flux point is necessary to ensure safety, optimize efficiency, design effective systems, and our understanding of heat transfer phenomenon. It has broad implications across various industries and scientific disciplines, contributing to the development of safer, more efficient, and technologically advanced solutions.

THEORY:

Boiling is a phase transition process in which a liquid substance changes into a vapor or gas state due to input of heat energy. The phase transition takes place when the liquid is in contact with a surface that is at a temperature higher than the saturation temperature of the liquid.

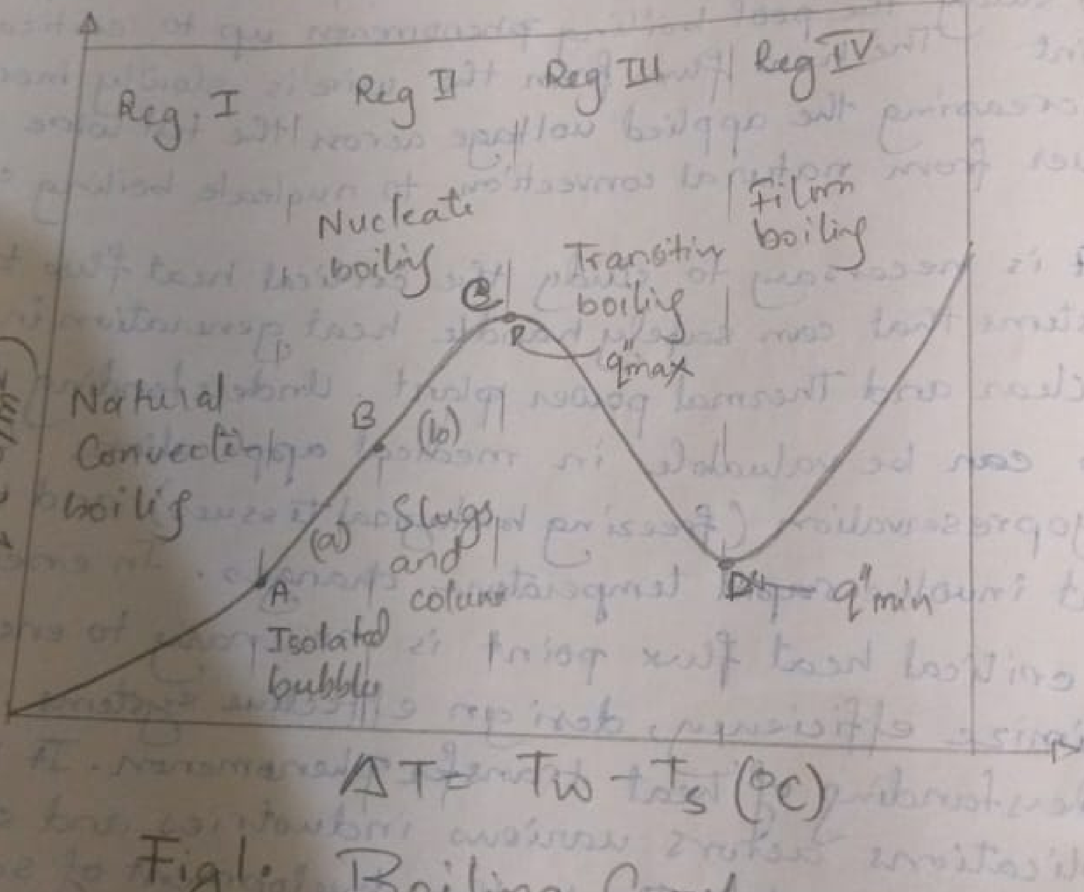


Fig 1. Boiling Curve

There are different types of boiling, the type depending upon the temperature difference between the surface of the liquid. The different types of boiling is illustrated in Fig. 1.

It can be seen from Fig1 that the boiling curve can be divided into three regions:
(i) Natural convection region
(ii) Nucleate boiling region
(iii) Film boiling region.

The region of natural convection occurs at low temperature differences (of the order 10°C or less). Heat transfer from the heated surface to the liquid ~~surface by~~ in its vicinity causes the liquid to be superheated.
As the temperature difference ($T_w - T_s$) is increased nucleate boiling starts. In this regim, it is observed that bubbles start to form at certain locations. In the part II(a) bubbles are formed at a low rate, then they condense and do not reach the free surface. The rate of formation of bubble at II b increases. Some of the bubbles now rise all the way to the free surface.

With increasing temperature difference, a stage is finally reached when the rate of formation of bubble is so high, that they start to coalesce and blanket the surface with a vapor film.

This is the beginning of the region III (film boiling). In the first part of the region III a. the vapor film is unstable, so that film boiling may be occuring on a portion of the heated surface area, while nucleate boiling may be occuring on the remaining area. In the second part III b. a stable film covers the entire surface. The temperature difference in this region is of order of 1000°C and consequently radiative heat transfer across the vapour film is also insignificant.

It will be observed from Fig 1. that the heat flux does not increase in a regular manner with the temperature difference. We can see how the temperature of heating surface changes as the heat flux steadily increases from O. Upto the point A, natural convection boiling and then nucleate boiling occur and the temperature of the heating surface is obtained by reading off the value $(T_w - T_s)$ from the boiling curve and adding to it the value of T_s. If the ~~temperature of the~~ heat flux is increased even a little beyond the value of A, the temperature of the surface will shoot up to the value

As the boiling process transitions to the film boiling regime, the heat transfer becomes less efficient due to the vapour layer that forms between the heated

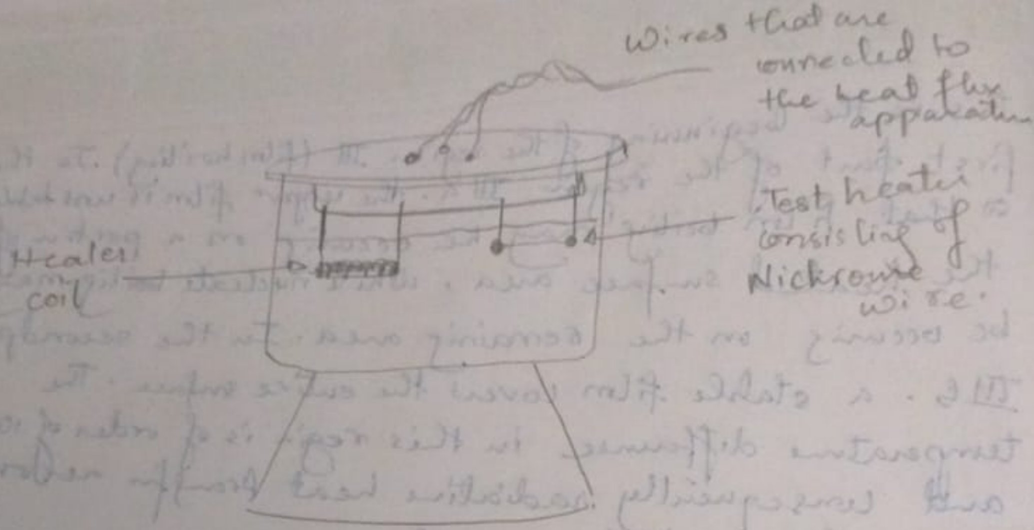


Fig 2. Cylidrical glass Container.

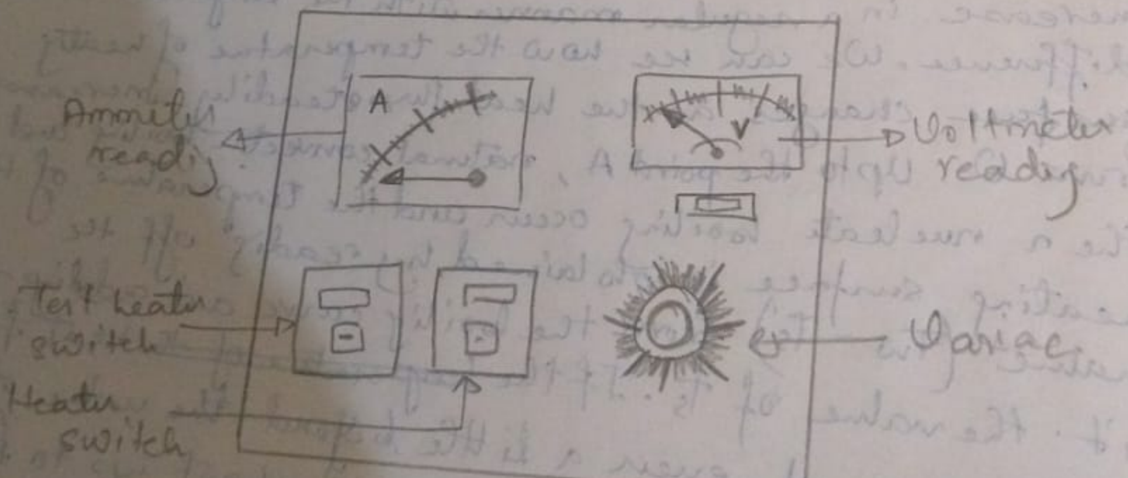


Fig3. Critical Heat Flux Apparatus

surface and the liquid. this leads to a higher temperature difference between the surface and the liquid, ~~thus~~ resulting in a decrease in the overall heat transfer rate.

It is important to consider these complex interactions and changing mechanisms when designing and analyzing systems involving boiling heat transfer. The relationship between heat flux and temperature difference is a critical factor in determining the efficiency and safety of such systems.

APPARATUS REQUIRED:

(i) Nichrome wire

(ii) Power supply.

(iii) Critical heat flux apparatus (shown in fig 2.)

The apparatus consists of cylindrical glass container housing the test heater and a heater coil for initial heating of the water. This heater coil is directly connected to the mains and the test heater is connected in series while a voltmeter across it reads the current and voltage.

(iv) Thermometer.

SPECIFICATIONS:

1. Glass container - diameter = 200mm.
   Height = 100mm
2. Heater for initial heating - Nichrome heater (R1) - 1kW
3. Test heater - Nichrome wire size

4. Length of test heater = 100mm
5. Dimmerstat for test heater = 10 amp, 260V
6. Voltmeter for test heater = 0 to 50/100 V
7. Ammeter for test heater = 0 to 10 Amps
8. Thermometer 0 to 100°C.

PROCEDURE :

1. We take 3-4 L of distilled water in the container.
2. Check if both the heaters are completely submerged.
3. Connect the heater coil and test heater wire across the studs and make necessary electrical connections.
4. Switch on the heater coil.
5. Keep it on till ~~the~~ we get the required bulk temperature (45°C, 55°C and 65°C)
6. Switch off heater coil.
7. Switch on ~~heater~~ test heater wire
8. Very gradually increase the voltage across it by slowly changing the variac from the position to other and stop a while at each position.
9. We keep on increasing the voltage till wire breaks.

Expt. Critical Heat Flux Apparatus (C)

Bulk temp(°C)	Ammeter reading (A)	Voltmeter reading (V).
45°C	6.4	66
55°C	7	72
65°C	7.2	74 .

length of wire = 100 mm
Area = 6.063×10^{-5} m^2

Calculation

1. $q_1 = \frac{VI}{A} = 69.668 \times 10^5$ J/m^2

2. $q_2 = \frac{VI}{A} = 83.127 \times 10^5$ J/m^2

3. $q_3 = \frac{VI}{A} = 87.877 \times 10^5$ J/m^2

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and carefully note the voltage and current at this point.

10. We repeat this experiment by altering the bulk temperature of water.

OBSERVATIONS :

Length of wire = 100 mm
Area of cross section of wire = $6.063 \times 10^{-5}\ m^2$

	Bulk temperature (°C)	Ammeter reading (A)	Voltmeter reading (V)
1.	45°C	6.4	66
2.	55°C	7	72
3.	65°C	7.2	74

CALCULATIONS :

1. $V = 66V$, $I = 6.4A$; $A = 6.063 \times 10^{-5}\ m^2$

$$q = \frac{VI}{A} = \frac{66 \times 6.4}{6.063 \times 10^{-5}}\ J/m^2$$

$$= 69.68 \times 10^{5}\ J/m^2$$

2. $V = 72V$, $I = 7A$, $A = 6.063 \times 10^{-5}$.

$$q = \frac{VI}{A} = \frac{72 \times 7}{6.063 \times 10^{-5}}\ J/m^2 = 83.13 \times 10^{5}\ J/m^2$$

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3. $V = 74V$, $I = 7.2A$, $A = 6.063 \times 10^{-5} m^2$

$$Q = \frac{VI}{A} = \frac{74 \times 7.2}{6.063 \times 10^{-5}} = 87.88 \times 10^5 \ J/m^2$$

RESULTS AND CONCLUSION :-

The calculated value for the critical heat flux is found to be:

(i) $Q = 69.68 \times 10^5 \ J/m^2$ for a bulk temperature of 45°C

(ii) $Q = 83.13 \times 10^5 \ J/m^2$ for a bulk temperature of 55°C

(iii) $Q = 87.88 \times 10^5 J/m^2$ for a bulk temperature of 65°C.

Zuber has given the following equation for calculating the peak heat flux in saturated pool boiling.

$$q''_{max} = 0.149 \, h_{fg} \rho_v \left[\frac{\sigma g (\rho_l - \rho_v)}{\rho_v^2} \right]^{1/4}$$

It can be observed that the critical heat flux goes on decreasing as the bulk temperature approaches the saturation T as expected.

The experimental value of critical heat flux at the saturation temperature is comparable to that obtained by Zuber's correlation.

DISCUSSION:

Studying critical heat flux is necessary in many field of science and engineering. It can provide insights into the behaviour of materials at high heat flux conditions. This is important for developing materials that can withstand extreme thermal conditions in various applications. Efficient heat transfer is crucial for energy efficient systems. By understanding CHF, engineers can optimize heat transfer processes. leading to more energy efficient systems and reduced energy consumptions. In fire safety engineering, it is important to predict and manage ~~firefighting~~ heat transfer in fire fighting efforts. It helps design effective cooling strategies for firefighting equipments and structures exposed to high heat flux.

~~CRITICAL COMMENTS~~:

We can observe that the critical heat flux increases with the increase in temperature of the bulk liquid. We can verify the illustration in Fig 1. From the observations we have got.

CRITICAL COMMENTS:

Precautions:

1. Keep variac to 0 voltage position before starting the experiments.
2. Take sufficient amount of distilled water in the container so that both the heaters are completely immersed.
3. Connect the test heater across the studs tightly
4. Do not touch the water or terminal points after putting the switch in on position.
5. Very gently operate the variac in steps and allow sufficient time in between.
6. After the attainment of critical flux condition decrease slowly the voltage and bring it to zero.

Source of error:

1. Even though we were stirring the water time to time to make the temperature uniform, there might still be some non uniformity as the heated coil was again immersed into the water.
2. At some point the heater coil turned red hot and started burning. This can be a major flaw in the process.
3. There can be errors in reading the values as it

required multiple members to observe the working.

4. The water was not changed for each experiment.

5. The thermometer might take some time to show readings.

Possible improvements:

(i) We can change the water at each run to prevent any pre included natural convection.

(ii) We can use a automated stirrer to prevent non-uniformity in the temperature.

(iii) Recording videos of the set up to obtain more accurate result.

EXPERIMENT-5.1 Studies on Heat Transfer by Natural Convection.

OBJECTIVES:

To study the convection heat transfer in natural convection
To find out the heat transfer coefficient of vertical cylinder in natural convection.

Natural convection heat transfer plays a crucial role in the design of various engineering systems, including heat exchangers, cooling systems, electronic devices, and energy efficient buildings. Understanding the heat transfer mechanism involved in natural convection helps engineers optimize these systems for efficient operation and desired performances. In scenarios where heat dissipation is critical, such as electronic devices and power plants, understanding natural convection can help prevent overheating and ensure safe operation. Proper cooling systems are essential to prevent thermal damage and potential catastrophic failure.

THEORY:

Convection is the mode of heat transfer that occurs in fluids due to the movement of the fluid itself. It involves the transfer of heat through the bulk movement of the fluid, driven by temperature

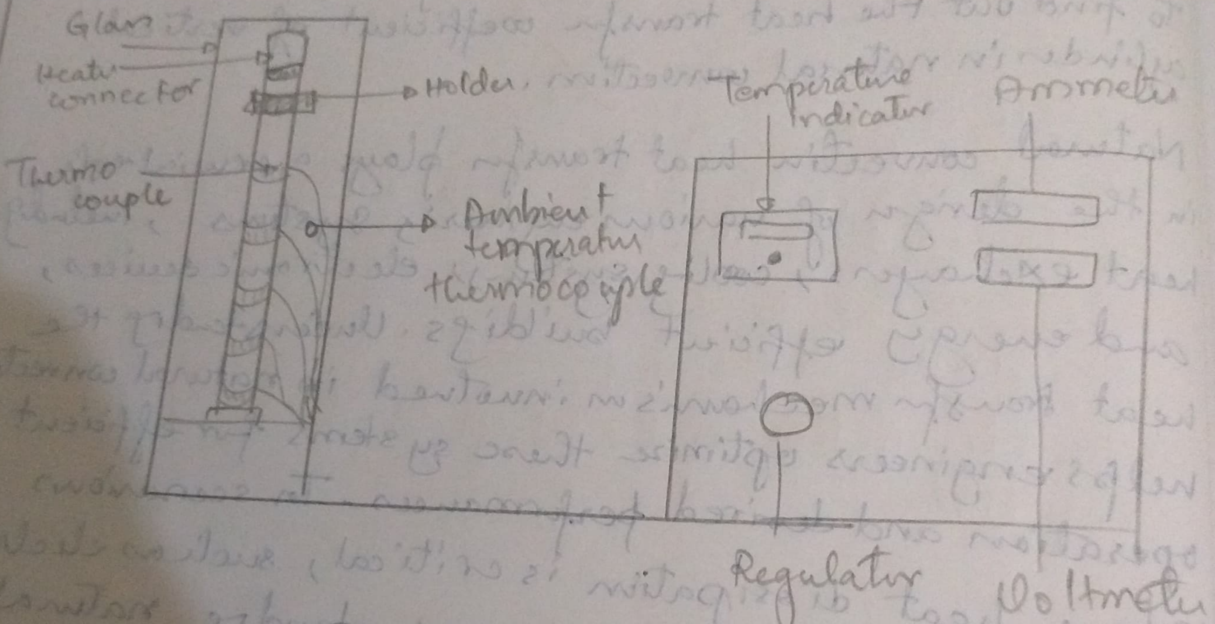

Fig 1: Natural Convection Apparatus

differences within fluid.
Convection is further classified as natural convection and forced convection. If mixing motion takes place due to density difference caused by temperature gradient, then the process of heat transfer is known as heat transfer by natural or free convection.
If the mixing motion is induced by some external means such as a pump or blower, then the process is known as heat transfer by forced convection.

Natural convection is due to the temperature difference between the surface and the fluid and is not created by an external agency.
The setup is designed and fabricated to study the natural convection phenomenon from a vertical cylinder in terms of average heat transfer coefficient.
The heat transfer coefficient is given by -

$$h = \frac{Q_a}{A(T_s - T_a)}$$

APPARATUS REQUIRED:

(i) Natural Convection Apparatus.

The apparatus consists of a brass filled in a rectangular

duct in a vertical fashion. The duct is open at the top and bottom and forms an enclosure and serves the purpose of undisturbed surrounding. One side of it is made up of glass/acrylic for visualization.
A heating element is kept in a 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 using seven temperature sensors. The heat input to the heater is measured by digital ammeter and voltmeter and can be varied by dimmerstat.

(ii) Powersupply.

PROCEDURE :

1. Clean the apparatus and make it free from dust first
2. Ensure that all ON/OFF switches given on the panels are OFF
3. Ensure that the variac knob is at ZERO position, given on the panel.
4. Switch on the panel with the help of Mains ON/OFF switch given on the panel.

Heat transfer in Natural Convection.

S. no:	V	I	T_1	T_2	T_3	T_4	T_5	T_6	T_7 (°C),	$T_8 = T_{amb}$.
1.	50	0.27	45.6	46.8	47.7	48.3	48.2	46.5	45.5	31.8
2.	50	0.27	45.6	46.8	47.6	48.2	48.1	46.3	45.4	31.9
3.	60	0.33	45.9	46.7	47.5	48.6	48.2	46.4	45.4	31.3.
4.	60	0.33	45.7	47.1	48.2	49.2	48.8	46.8	45.7	31.0

5. Fix the power input to the heater with the help of Variac, Voltmeter and Ammeter provided.
6. After 30 minutes record the temperature of test section at various points in each 5 min interval
7. If temperature reading is same for all three readings, assume steady state.
8. Record final temperature.

Closing procedure–

1. When experiment is over, switch off heater first
2. Adjust Variac at 0.
3. Switch off the panel ~~at~~ with the help of Mains ON/OFF switch given on the panel.
4. Switch off power supply to panel.

OBSERVATIONS.

S.no:	V (volts)	I (amp)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)	T_7 (°C)	$T_8 = T_{amb}$ (°C)
1.	50	0.27	45.6	46.8	47.7	48.3	48.2	46.5	45.5	31.8
2.	50	0.27	45.6	46.8	47.6	48.2	48.1	46.3	45.4	31.9
3.	60	0.33	45.4	46.7	47.5	48.6	48.2	46.4	45.4	31.5
4.	60	0.33	45.7	47.1	48.2	49.2	48.8	46.8	45.7	31.0

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CALCULATIONS :

1. $V = 50$, $I = 0.27$, $d = 0.038m$, $L = 0.5m$

$Q = VI = 50 \times 0.27 = 13.5\,W$

Avg Temp of cylinder$(T_s) = \frac{\sum_{i=1}^{7} T_i}{7} = \frac{328.6}{7} = 46.94°C$

Ambient temp $= T_8 = 31.8°C = T_a$

Area $= \pi d L = \pi \times 0.038 \times 0.5 = 0.0597\,m^2$

Heat Transfer coefficient $(h) = \cancel{\frac{Q}{A} / (T_s - T_a)}\ \frac{Q}{A(T_s - T_a)}$

$= \frac{13.5}{0.0597} / (46.94 - 31.8)$

$= \cancel{3423.62\ W/m^2}$

$14.934\ W/m^2$

2. $V = 60$ $I = 0.33$, $d = 0.038\,m$, $L = 0.5m$

$Q = VI = 60 \times 0.33 = 19.8\,W$

Avg temp $= T_s = \frac{\sum_{i=1}^{7} T_i}{7} = \frac{328.2}{7} = 46.889\ °C$.

Ambient temp $= T_a = T_8 = 31.5°C$.

Area $= \pi d L = 0.0597\,m^2$

Heat Transfer coefficient $= h = \frac{Q}{A} / (T_s - T_a) = \frac{19.8}{0.0597 \times 15.4}$

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~~h = 5102.799 = 1510.80 W/m²~~ h = 21.54 W/m²

CONCLUSION AND RESULTS :

The calculated value for the average heat transfer is found to be 14.94 W/m² at V = 50V and 21.54 W/m² at V = 60 V and I = 0.33A.

We observe a gradual increase in T_i value, which peaks at a certain i and then again gradually decreases. This trend is followed in each of the experiment we have done.

DISCUSSION:

studying natural convection is crucial for advancing our understanding of fluid dynamics, heat transfer and a wide array of applications in engineering, environmental sciences, material sciences and more. It enables us to optimize processes, design efficient systems and develop solutions that impact various aspects of our modern world.

In our experiment we ~~can~~ observe the temperature across various temperature sensors and note them

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We can see that the temperature value T_i increase from i = 1 to 4 then again gradually decrease from 4 to 8. The temperature T_8 is the ambient temperature and is found to be around 32°C.
We repeat the experiment for a particular set of V and I twice, and get almost same of observation for both.
We observe that the ~~temper~~ current reading in the ammeter was fluctuating and was not constant at all time. The temperature reading were also changing over the time, ~~too~~ but the change was very less.
The temperature change took some time to register ~~as~~ when the voltage was changed.

CRITICAL COMMENTS:

Bethare different.

Precautions:-
1. Never run the apparatus, if power supply is less than 180 volts and above than 230 volts.
2. Never switch ON mains power supply before ensuring that all the ON/OFF switches given on the panel are OFF position.
3. Operate selector switch of temperature indicator gently
4. Always keep the apparatus free from dust.

Possible Sources of Error:

(i) Fluctuating ~~curr~~ ammeter reading might lead to incorrect reading.

(ii) The temperature readings were also not constant throughout. Thus it might lead to errors.

(iii) We observed different ambient temperature, in different experiment, which should not be the case.

(iv) Inner apparatus fault.

Possible improvements.

(i) Creating an adiabatic setup to prevent external heat from altering the ambient temperature.

(ii) Conducting multiple runs and taking the modal value.

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DATE | EXPERIMENT-3: Studies on heat transfer in vertical condenser. | SHEET NO.

AIM: (i) To find out the overall heat transfer coefficient
(ii) Steam side coefficient.
(iii) Water side coefficient
(iv) Draw Wilson plot.

OBJECTIVES:

The objectives of studying heat transfer in a vertical condensor encompass enhancing efficiency through optimized design and advanced materials, while analyzing heat transfer mechanism, fluid dynamics and fouling to ensure improved performance and reliability

THEORY:

Vertical condensor are crucial components in various industries for converting vapor back into liquid form by releasing its latent heat. The condensation process involves transferring the temperature of the coolant. Despite functioning as a heater due to the ~~coolant~~ temperature increase, the primary focus is on the condensation action. To enhance heat transfer efficiency, heat exchanger principle can also be employed.

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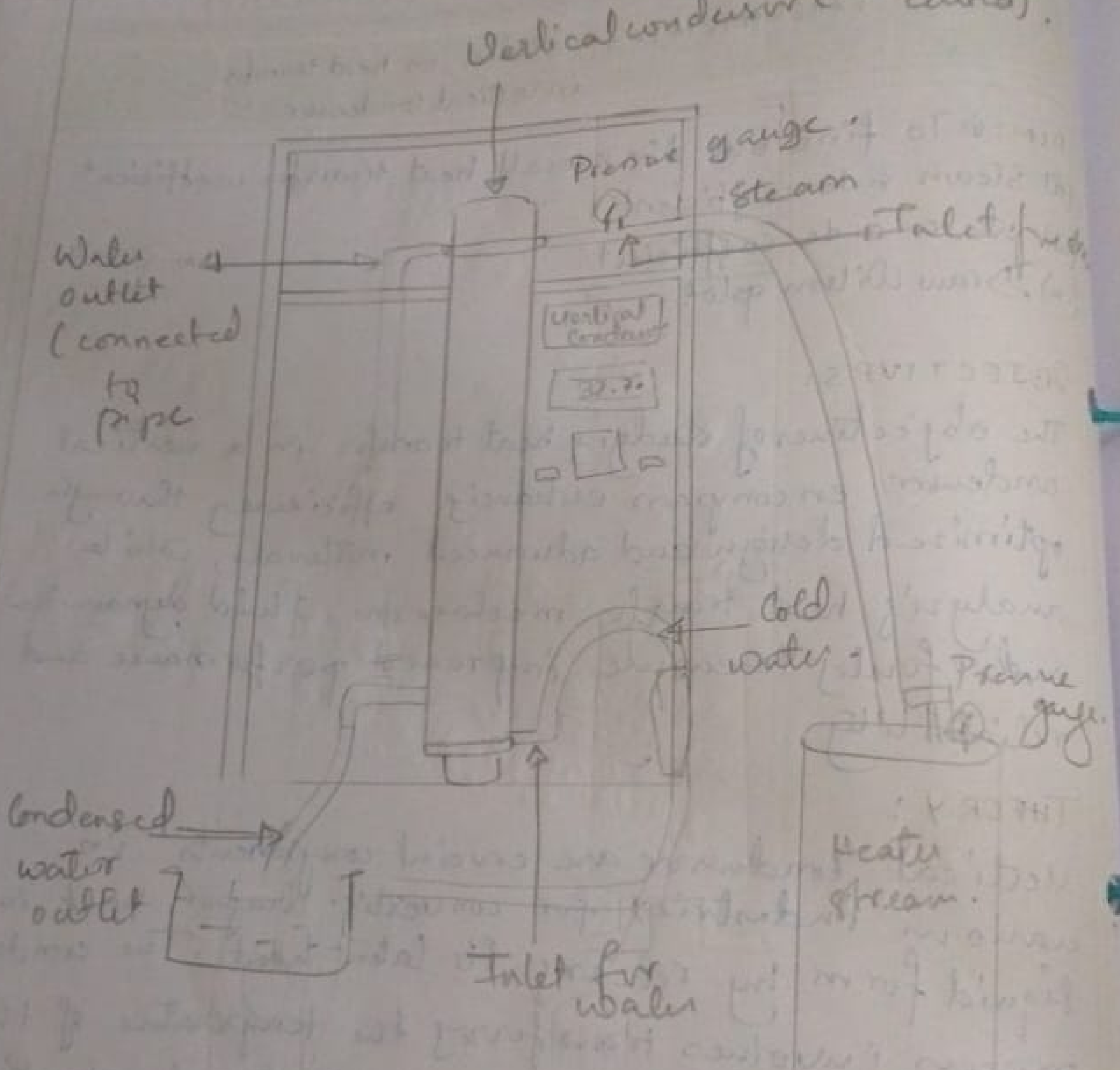

Fig 1. Vertical Condenser Apparatus

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APPARATUS:

The vertical condensor is mounted ~~to~~ on a square tube frame. On one side of the condensor is connected by a monoblock pump with bypass valve. An acrylic rotameter is provided to note the flowrate of water allowed to condensor. A steam boiler withe accesories is provided to with a condensate measuring tank is provided to collect the condensate. Panel board is mounted on the front with temperature indicator and selector switch, D.P switches for heater and for the pumps.

SPECIFICATIONS:

1. Shell length = 1000mm
   Shell diameter = 150mm
   Material = M.S
   Insulation = Asbestos cloth.

2. Tube length = 1020 mm
   Tube diameter = 12mm
   Material = M.S
   No. of tubes = 14

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3. Boiler height = 450 mm
Boiler diameter = 350 mm
Material = M.S
Heaters = 2 Kw / 2 Nos

4. Pump H.P = 0.5 HP Monoblock
Make = Lubi / Any reputed

5. Pump Tank Capacity = 36 L approx
Material = SS
Size = 300 × 300 × 400.

6. Digital Temperature indicator
No. of digits = 4
Range = 400°C
Resolution = 1°C.

7. Thermocouples type = C-Al
No. of thermocouples = 4

8. Condensate Tank / Jar. = 36 L
Material = SS
Size = 300 × 300 × 400 mm.

Expt - 3

$P = 0.9\ kg/cm^2$

Q	T_1	T_2	T_3	T_4	V (2min)
30	108.3	43.0	42.1	91.6	285
40	107.3	44.3	42.3	83.3	295
50	108	43.3	42.5	86.0	940

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Observation Table

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PROCEDURE:

Put on the heater and allow the
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= temperature of
ndenser (°C)

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PROCEDURE:

1. Put on the heater and allow the steam to generate
2. Open steam valve ad set its pressure to desired value
3. Put on the coolig water pump ad set its flow rate to desired value.
4. Keep the condensate outlet open ad measure the amount collected in 120 secs.
5. Note steam pressure, flow rates and temperature
6. Repeat it for different water flow rates.

OBSERVATION:

Steam pressure $= 0.9\ kg/cm^2$

T_1 = Temperature of steam inlet to condensor (°C)

T_2 = Temperature of condensate outlet from condensor (°C)

T_3 = Temperature of water inlet (°C)

T_4 = Temperature of water outlet (°C)

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T_3 = Temperature of water inlet (°C)
T_4 = Temperature of water outlet (°C)

T_1	T_2	T_3	T_4	Cooling water flow rate Q (cm³/s)	condensation flow rate (2min)
108.3	43	42.1	91.6	30	285
107.3	44.3	42.3	83.3	40	295
108	43.3	42.5	86.0	50	440

CALCULATIONS:

$\rho_w = 997$ kg/m $\rho_c = 0.579$ kg/m³

Latent heat of vaporisation = $L = 2360$ kJ/kg.

Thermal heat conductivity = $k = 0.604$ W/mK.

Viscosity = $\mu = 0.5465$ cp.

Water quantity = $M_w = \frac{q_w}{t_w} \times 10^{-6} \times 3600 \times \rho_w$ kg/hr

$M_w = \frac{30 \times 120}{120} \times 10^{-6} \times 3600 \times 997$ kg/hr

$= 107.676$ kg/hr.

2. Heat transfer of water

$$q_w = M_w C_{pw} (T_4 - T_2) = 107.676 \text{ kcal/hr.}$$

3. Heat given out by a system

$$q_c = \frac{Q_c}{t_c} \times 10^{-6} \times 3600 \times \rho_c \times L \text{ kcal/h}$$

$$= \frac{235}{120} \times 10^{-6} \times 3600 \times 0.597 \times 540.15$$

$$= 2.76 \text{ kcal/hr.}$$

4. $$LMTD = \frac{T_4 - T_3}{\ln\left(\frac{T_2 - T_3}{T_1 - T_4}\right)} = \frac{91.6 - 42.1}{\ln\left(\frac{42.1 + 108.3}{108.3 - 51.6}\right)}$$

$$= 35.94°C.$$

5. Heat Transfer Surface Area

$$A = \pi d_o L N \text{ m}^2$$

$$= \pi \times 12 \times 10^{-5} \times 1.02 \times 14$$

$$= 0.538 \text{ m}^2$$

6. Experimental overall H T coefficient

$$U = \frac{q_w}{A \times LMTD} = \frac{5320.962}{0.538 \times 35.94}$$

7. Cooling water velocity through tubes

$$V = \frac{Q_w}{\pi/4 \, d_i^2 N} = \frac{30 \times 10^{-6}}{\frac{\pi}{4}(12 \times 10^{-3})^2 \times 14} = 0.01895 \, m/s$$

8. Water side heat transfer coefficient

$$Re = \frac{\rho v d}{\mu} = 413.75 \quad Pr = \frac{\mu C_p}{K} = 3.783$$

$$h_i = 1.86 \left[Re \, Pr \, \frac{x d_i}{l} \right]^{2/3} \times (K/d_i)$$

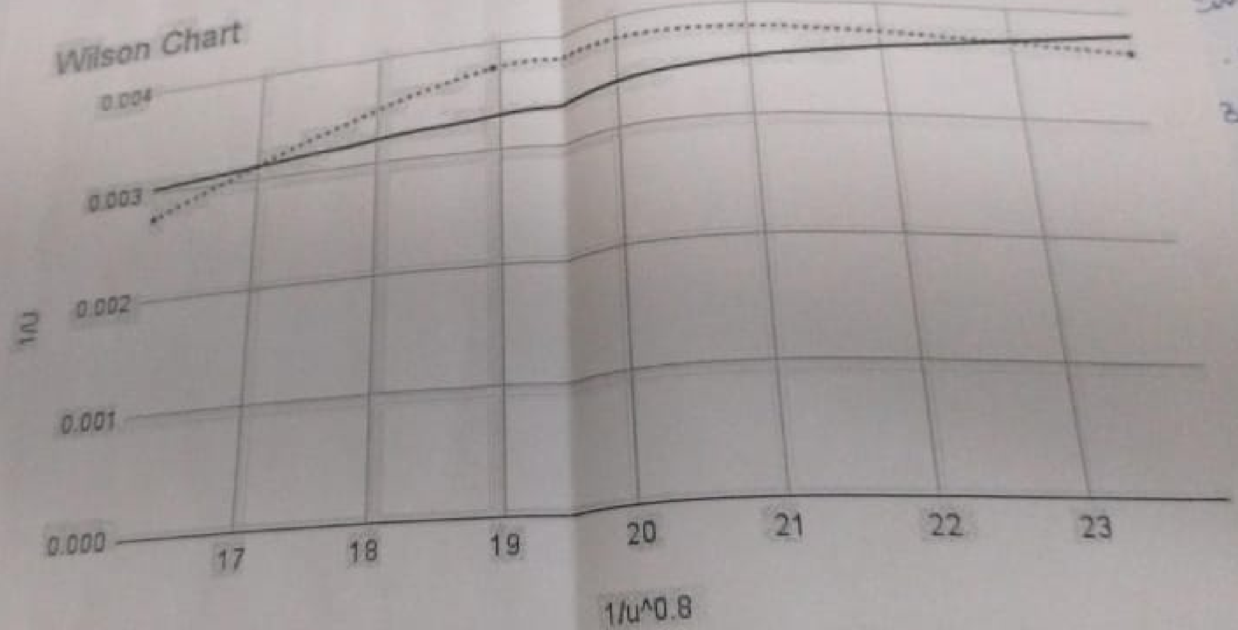
$$= 247.33 \, W/m^2K$$

RESULTS:

For $Q = 30 cm^3/s$

$U = 275.65 \, kcal/hr \, m^2 \, ^\circ C$

$v = 0.0189 \, m/s$.



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For $Q = 40 \, cm^3/s$

3 kcal/hm² °C

3 m/s

cm³/s

.939 kcal/hm² °C

31 m/s

Involves cont
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For $Q = 40 \, cm^3/s$

$U = 265.88 \, kcal/hr\,m^2\,°C$

$v = 0.0253 \, m/s$.

For $Q = 50 \, cm^3/s$.

$U = 363.939 \, kcal/hr\,m^2\,°C$

$v = 0.031 \, m/s$.

DISCUSSION:

The experiment involves controlling the steam pressure, water flow rate and condensate outlet while noting down relevant parameters such as steam pressure, inlet and outlet temperatures, steam and water flow rates and other ways.

Typically, as steam condenses its temperature decreases while the ~~con~~ coolants temperature increases. The heat transfer coefficient was also calculated using appropriate formulaes. The efficiency of the condensation process can be evaluated by comparing the calculated heat transfer rate with the theoretical heat transfer rate.

CRITICAL COMMENTS:

1. Noteworthy observations during the experiment encompass steady state conditions, stable temperature readings, consistent flow rates and pressure adjustments.

(ii) Precautions to consider involve maintaining a steady flow rate of cooling water, ~~adjustments~~ adjusting steam pressure carefully, preventing leaks, and ensuring accurate temperature measurements.

(iii) Possible sources of error include inaccuracies in temperature measurement due to sensor calibration or placement, fluctuations in flow rates and losses in heat transfer efficiency due to imperfect insulation or heat exchanger fouling.

CONCLUSION:

In conclusion, this experiment provides insights into the heat transfer mechanisms of vertical condensers and their role in converting vapor into liquid form.

By analyzing temperature changes and flow rates the effectiveness of the condensation process can be understood. Understanding these factors is essential for optimizing condensor designing in practical application.

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DATE | EXPERIMENT-10 Determination of thermal conductivity of liquid. | SHEET NO

AIM: To determine the thermal conductivity of a liquid (toluene)

OBJECTIVES: (i) To measure the heat flow rate through a liquid sample
(ii) To calculate the thermal conductivity of the liquid sample

There are varied application of liquids in a lot of heating processes in industries. Thus it is important to learn about the thermal conductivity of a liquids, so as to design optimal processes.

THEORY:
The heat transferred by conduction is given by:

$$Q = -kA\frac{\Delta T}{\Delta x}$$

where,

Q = rate of heat transfer

A = area normal to the direction of heat flow

ΔT = temperature drop across bottom, and top surface of liquid

Δx = thickness of test layer along the direction of heat transfer.

K = thermal conductivity of test substance

Thermal conductivity is a property of material that describes its ability to conduct heat

Heat carried away by cooling water

$$q = M_w C_p (T_{out} - T_{in})$$

where,

M_w = water flow rate

C_p = specific heat of water at a temperature $\frac{(T_{in}+T_{out})}{2}$

T_{out} = outlet temperature

T_{in} = inlet temperature

~~Ex~~ APPARATUS REQUIRED:

The apparatus consists of a heater that is placed at the bottom of the container. The container has two liquids water and toluene. There are 4 thermocouples placed in the apparatus that measures:

1. Temperature of liquid surface (top plate)
2. Temperature of liquid surface (bottom plate)
3. Water inlet temperature to cooling jacket
4. Water outlet temperature

Expt 10 Thermal Conductivity of Liquid

Voltmeter Ammeter Q

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PROCEDURE:

- Measure flow rate of water by checking the amount of water collected in 30 seconds
- Turn on the heater and set V = 40V, I = 0.24A
- Note the temperature T_1, T_2, T_3, T_4 at an interval of 10 minutes
- stop when steady state is achieved.

OBSERVATIONS:

water flow rate (mL/s)	Voltmeter reading (V)	Current reading (A)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)
0.22	40	0.24	45.1	42.7	35.4	39.3

CALCULATIONS:

Heat input = $Q = V \times I \times 0.86$

$= 40 \times 0.24 \times 0.86$

$= 8.256$ kcal/hr.

Heat removed through water $Q = \cdot M_w C_p \Delta T$

$= 13.2 \times 0.01 \times 60 \times 10^{-1} \times (39.3 - 35.4)$

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Expt 10 Thermal Conductivity of Liquid

meter Ammeter Q

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$= 3.088 \text{ kcal/hr}$

Thermal conductivity (K) = $q_{rem} \Delta x / (T_1 - T_2)$

$$= \frac{3.088 \times 12 \times 10^{-3}}{0.0037 \times (45.1 - 42.7)}$$

$= 4.063 \text{ kcal/hr m}^\circ\text{C}$

RESULTS & DISCUSSION:

Based on the calculations the thermal conductivity of the experimental liquid (toluene) was found to be 4.063 kcal/hr m°C

The experiment was conducted to determine thermal conductivity of a liquid using a heated plate. At steady state heat gained by liquid from ~~plate~~ it was equal to heat loss to flowing water.

The flow of coolant water was kept almost constant throughout the experiment and the

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Exp+10 Thermal Conductivity of Liquid

Voltmeter Ammeter Q

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temperature sensors values were recorded at steady state.

CRITICAL COMMENTS:

- It is important to use a stabilized single phase A.C supply to ensure accurate results.
- To ensure one dimension heat transfer approximation, the liquid height should be kept small
- The apparatus should be free from dust
- Flow rate of coolant is kept constant

~~CONSTANT~~ CONCLUSION:

In conclusion, the experiment was successful in determining the thermal conductivity of liquid using heated plate and cooling water. The precautions mentioned above should be taken while performing the experiment to ensure accurate results. Our experimental value is different from theoretical value because it was not possible to follow all precautions.

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DATE

EXPERIMENT-1 Determination of thermal conductivity of metal.

SHEET NO.

AIM: To determine the thermal conductivity of a metal

OBJECTIVES: The objective of this experiment is to study the heat flow rate and thermal conductivity when a metal rod is used. It is important to note the thermal conductivity of a metal due to its varried application in the industry due to its good conductivity.

THEORY:

1. Thermal conductivity: It is property of a material that quantifies how efficiently a substance conducts heat. It depends on factors such as the materials state, crystal structure, temperature and pressure.

2. Heat transfer in the metal bar: The metal bar is heated at one end using an electric heater, and heat a conducted along the length of the bar. Since the bar is insulated from the surrounding, the primary mode of heat transfer is axial conduction. The ~~Since~~ heat conducted ~~along the length of the bar~~ ~~the bar~~ at steady state results in a temperature profile within the rod ($T = f(x)$)

3. Heat Transfer equation: Heat absorbed by cooling water is calculated using $Q = mC_p\Delta T$

Heat conducted through the rod in axial direction $Q = -A\frac{dT}{dx}$

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At steady state, $Q = Q'$

$$\Rightarrow k = \frac{m C_p \Delta T}{-\left(A \frac{dT}{dx}\right)}$$

APPARATUS:

The apparatus consists of a metal bar, one end of which is heated by an electric heater while the other end of the bar projects inside the cooling water jacket. The middle portion of the bar is surrounded by a cylindrical shell filled with asbestos insulating powder. The temperature of the bar is measured at different section while the radial temperature distribution is measured by separated temperature sensors at two different section of the insulating shell.

The heater is provided with a dimmerstat for controlling the heat input. Water under constant head conditions is circulated through the jacket and its flow rate and temperature rise are noted by two temperature sensors provided at the inlet and outlet of the water.

SPECIFICATIONS:

1. Length of the metal bar = 450 mm
2. Diameter of the metal bar = 25 mm
3. Test length of the bar = 235 mm
4. Total no. of temperature sensors in the set up = 12 Nos
5. No. of temperature sensors mounted on the bar = 6 Nos
6. No. of temperature sensors mounted on the insulation shell = 4 Nos

PROCEDURE:

1. The metal wire is heated at one end
2. The temperature of the bar is measured at different sections
3. The radial temperature distribution is measured by separate temperature sensors at two different sections of the insulating shell.
4. Water is circulated and its flow rate and temperature were noted at its inlet and outlet.

OBSERVATIONS:

Time (mins)	T_1 (°C)	T_2 (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)	T_6 (°C)	T_7 (°C)	T_8 (°C)	T_9 (°C)	T_{10} (°C)	T_{11} (°C)	T_{12} (°C)
20	98.5	91.3	83.1	75.3	67.7	60.4	56.6	56.4	50.5	48.4	41.1	41.8

Time taken to achieve steady state

CALCULATIONS:

Flow rate of water = $\frac{320 \text{ mL}}{30 \text{ sec}}$ = 0.64 lpm

ρ_{water} @ 38.6°C = 0.992 kg/L

Mass flow rate of water = $0.64 \times 0.992 \times 60$

= 38.09 kg/hr

= 0.0105 kg/s

C_p of water @ 38.8°C

= 4.13 kJ/kg°C

= 4130 J/kg°C

$\Delta T = T_{12} - T_{11}$

$= 41.8 - 41.1 = 0.7$

$q = M_w C_p \Delta T = 0.0105 \times 4130 \times 0.7$

$= 30.35$ J/s.

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$A = 5.067 \times 10^{-4}$

From graph

$$\frac{dT}{dx} = -0.192\ °C/mm = -192\ °C/m$$

$$\therefore K_{copper} = Q\left(-A\frac{dT}{dx}\right)^{-1}$$

$$= 30.35 \times (5.067 \times 10^{-4} \times 192)^{-1}$$

$$= 311.965\ \cancel{kcal/hr\,m°C}\ J/hr\,m\,°C$$

Actual value of $K_{copper} = 332\ \cancel{kcal}\ J/hr\,m\,°C$

$$\%\ error = \left|\frac{332 - 311.965}{332}\right| = 6.03\%$$

RESULTS & DISCUSSIONS:

The experimental value of thermal conductivity of copper calculated is ~~318~~ 311.965 W/m°C

Since there will be some heat loss because of insulation correspondingly value of k measured will also decrease. This is the reason for the error in result compared to theoretical value

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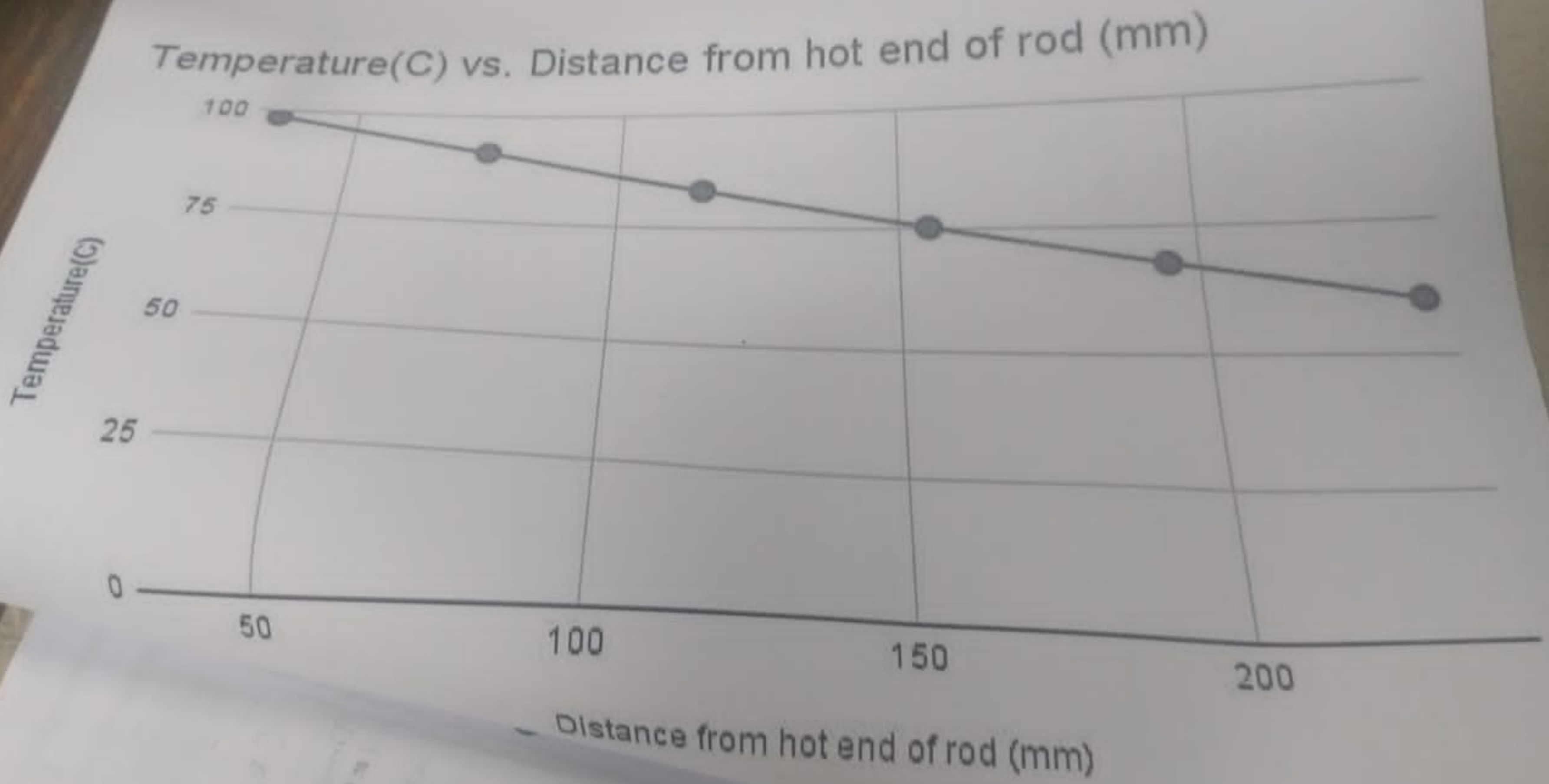
of k of copper given in textbook. It can be verified by reading of temperature sensors fixed in the insulation.

CRITICAL COMMENTS:

- It is necessary to carefully calculate the length since it is used to calculate the effective heat transfer area.
- Mass flow rate cannot be increased because it can have adverse effect on other parameters, changing temperature values if altered.
- Precautions such as slight increment of voltage current supply should be taken care of to avoid risks.

CONCLUSION:

This experiment provides insights into importance of thermal conductivity in various engineering applications despite certain assumptions and potential heat losses, the obtained result provides valuable insights.


Temperature(C) vs. Distance from hot end of rod (mm)
Temperature(C)
100
75
50
25
0
50
100
150
200
Distance from hot end of rod (mm)

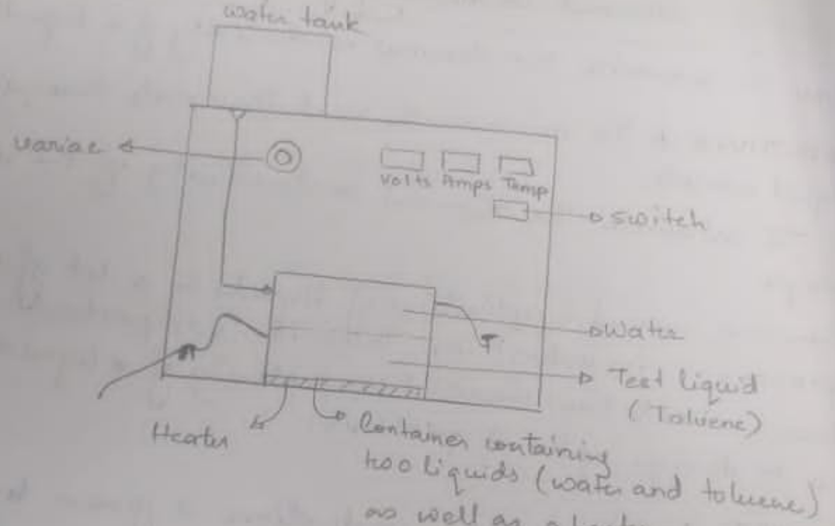


Fig 1. Apparatus for determining thermal conductivity of liquid

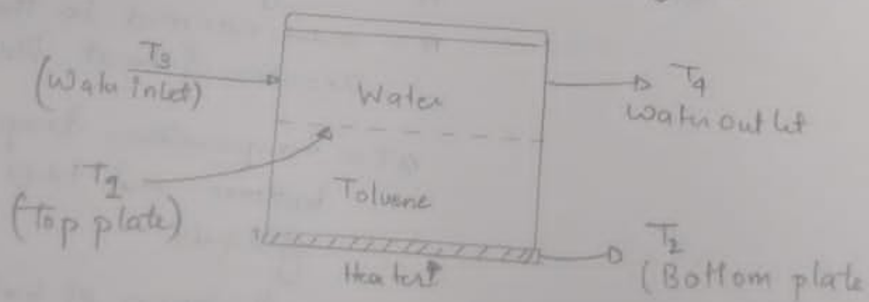


Fig 2. Position of the thermocouples

Expt 1. Thermal Conductivity of Metal Rod.

Time	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
0	90.7	83.7	75.6	68.0	60.6	53.3	47.4	48.8	43	41	38.6	39.3
5 min	90.3	83.6	75.5	67.8	60.3	53.1	47.3	48.6	42.6	40.8	41.2	41.9
10	88.7	81.6	73.6	65.7	58.8	50.9	46.4	46.8	41.5	38.6	42.2	42.9
15	93.4	86.3	78.3	70.5	63	53.7	51.6	52	45.7	43.7	41.5	42.2
20	97.5	91.3	83.1	75.3	67.7	60.9	56.4	56.4	50.5	47.4	41.1	41.8

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...dy state

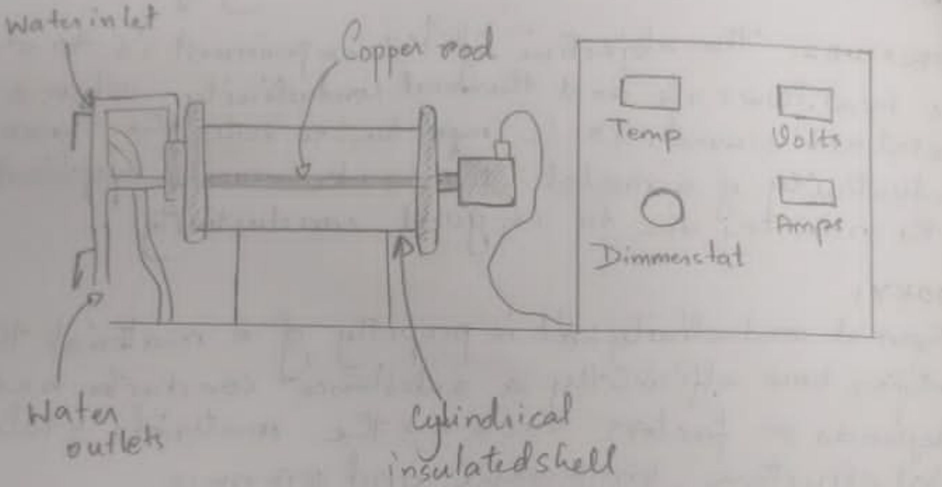

Fig 1: Apparatus for determining thermal conductivity of metals

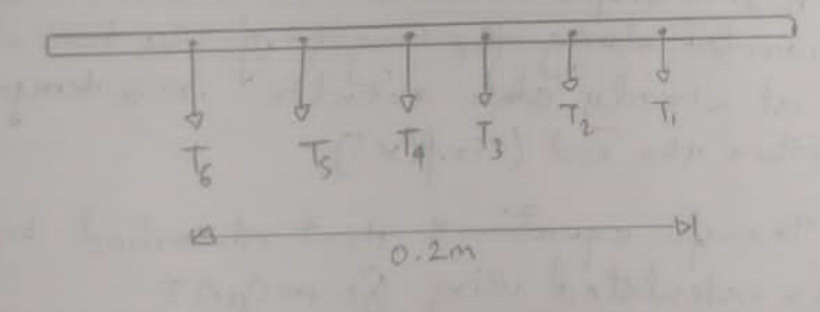

Fig 2. Copper Rod

Expt 10 Thermal Conductivity of Liquid

Voltmeter	Ammeter	Q
40	0.24	6.6 mL/30 sec

Q	V	A	T_1	T_2	T_3	T_4
			36.2	33.8	31.1	31.8
			38.6	36.1	32.1	33.2
			~~35.9~~ 41.3	38.9	33.6	35.9
			42.3	40	34.1	36.9
			43.6	41.3	34.8	38.1
			44.2	42	35.1	38.9
			45.1	42.7	35.4	39.3

[illegible]
4/9/23