THERMAL CONDUCTIVITY OF METAL BAR

AIM :

To determine the thermal conductivity of metal bar.

INTRODUCTION :

Thermal conductivity of a substance is a physical property, defined as the ability of a substance to conduct heat. Thermal conductivity of material depends on chemical composition, state of matter, crystalline structure of a solid, the temperature, pressure and wheather or not it is a homogeneous material.

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 the asbestos insulating powder. The temperature of the bar is measured at different section while the radial temperature distribution is measured by separate temperature sensors at two different sections in the insulating shell.

The heater is provided with a dimmerstat (Thermostat) 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	:	450mm
2.	Dia of the Metal Bar	:	25mm
3.	Test length of the bar	:	235mm
4.	Total no. of temperature sensors in the setup	:	12 Nos. 8
5	No. of Temp. Sensors mounted on bar	:	6 Nos.
6.	No. of temperature sensors mounted in the insulation shell	:	4 Nos.

7.	No. of temp. sensors mounted on water jacket	:	2 Nos.
	Type of Temperature Sensors	:	RTD PT-100
8.	Heater coil	:	Nichrome heater
9.	Cooling Jacket Dia	:	100mm
10.	Length of cooling jacket	:	75mm
11.	Temperature indicator	:	Digital Temperature Indicator 0°C to 199.9°C and least count 0.1°C with multichannel switch.
12.	Dimmerstat for heater coil	:	2A/230V
13.	Digital Voltmeter	:	0 to 250 Volts
14.	Digital Ammeter	:	0 to 2.5 Amp.

THEORY :

The heater will heat the bar on its end one and heat will be conducted through the bar to the other end.

Since the rod in insulated from outside , it can be safely assumed that the heat transfer along the copper rod is mainly due to axial conduction and at steady state the abconducted shall be equal to the heat absorbed by water at the cooling end. The heat conducted at steady state shall create a temp. profile within the rod. (T = f(x))

The steady state heat balance at the rear end of the rod is :

Heat absorbed by cooling water = Q = $M.C_p\Delta T$

where

M = mass flow rate of cooling water , kg/hr

C_p = specific heat of water , Kcal/kg°C

ΔT = temp. rise of cooling water = $(T_{12} - T_{11})$

Q = Heat transfer rate

$\frac{dT}{dX}$ = gradient temp

Heat conducted through the rod in axial direction :

$$Q = -kA\frac{dT}{dX}$$

Fourier Law

at steady state $Q = -kA\frac{dT}{dX} = M.C_p\Delta T$

VI

$$k = \frac{mC_p\,\Delta T\,(T_{12}-T_{11})}{A.\frac{dT}{dx}}$$

(1-2), (3-4), 4 e.

OBSERVATION TABLE :

Diameter of the copper rod = D =2.54Cm

Test length of the copper rod = 235mm

Temp. Sensor No. →	1	2	3	4	5	6	7	8	9	10	11	12
Temperature °C ↓												
Steady state temp →												

Temp Sensor No. along the axis	Distance from leading edge (hot end) of the rod , X, mm
T1	35
T2	75
T3	115
T4	155
T5	195
T6	235

T7, T8 ,T9, T10 are the Temperature sensor fixed alog radial direction in the insulating material.

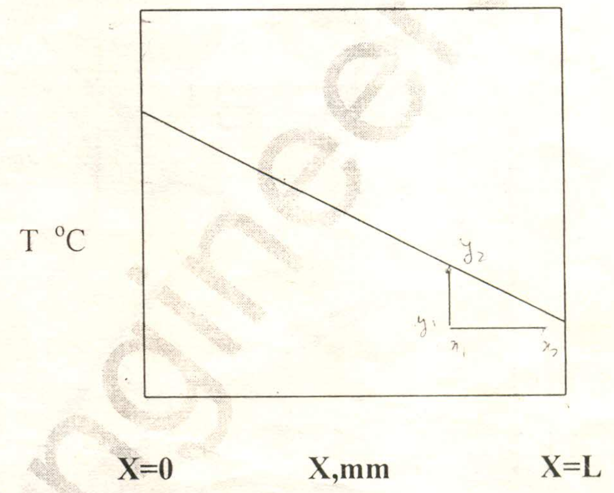
T11 is the inlet temp. of cold water

T12 is the outlet temp. of cold water

$k = M.C_p \Delta T \; / \; [\; -A \, \{dT/dX\} \,]$

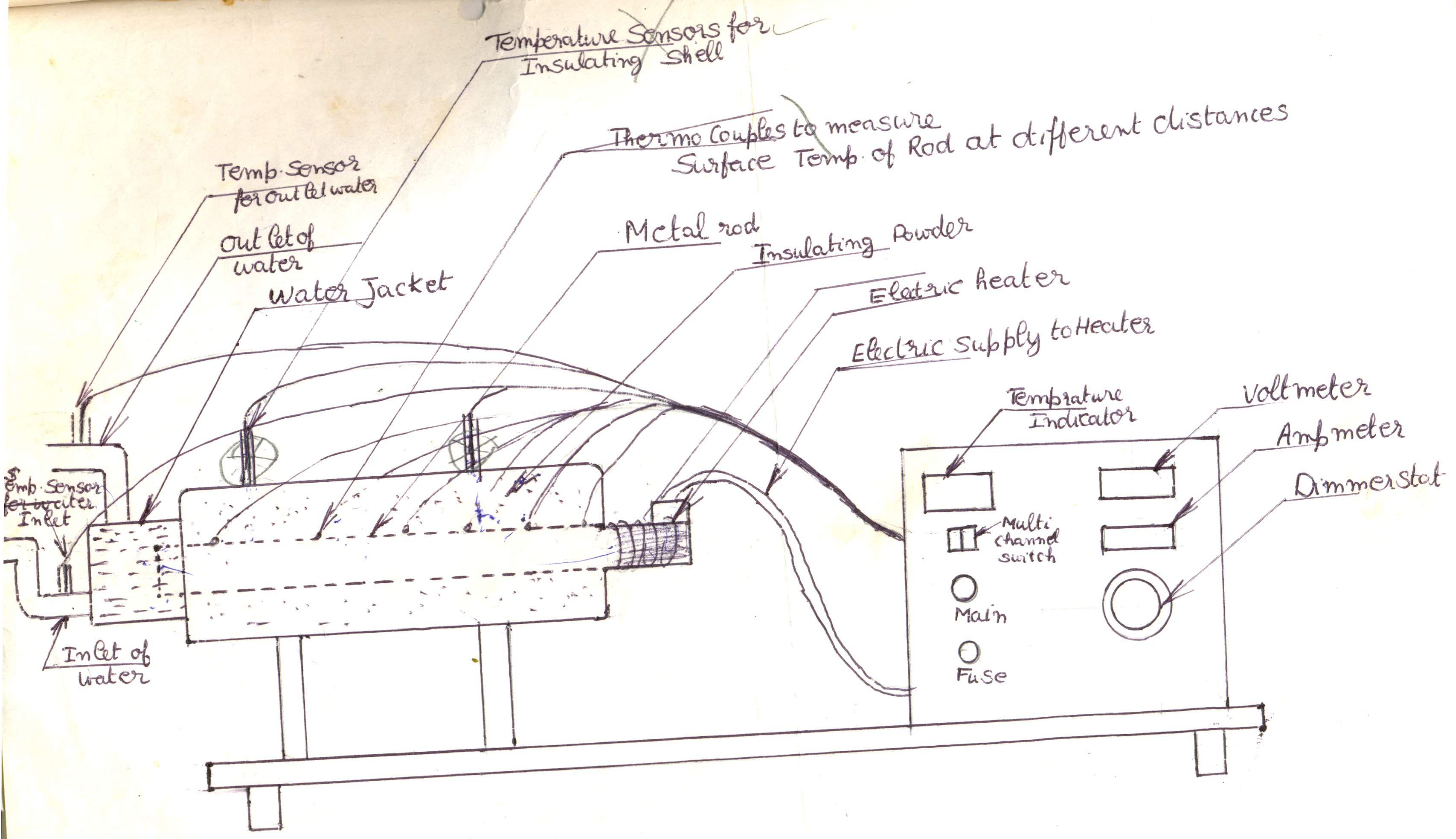
The assumption that at steady state , the heat flow is mainly due to axial conduction can be verifed by the readings of temperature sensors fixed in the insulation material around the rod in radial direction. Less variation in these readings shall confirm the assumption.

The value of $\left. dT/dX \right|_{X=L}$ is obtained as the slope of the graph between T vs X



PROCEDURE :

1. Start the cold water supply at a low rate (< 2 LPM)
2. Start the electric supply.
3. Give input to the heater by slowly rotating the dimmerstat and adjust it to valtage equal to 50V, 100V, 120V etc.
4. Check the temperatures at some specified time intervals till a satisfactory steady state conditions is reached. Record the temperature sensors readings along the axis of the copper rod.
5. Note the mass flow rate of water in kg per minute and the inlet and outlet temperature and thus the temperature rise in it.



THERMAL CONDUCTIVITY OF METAL BAR

Thermal Conductivity of Metal Rod

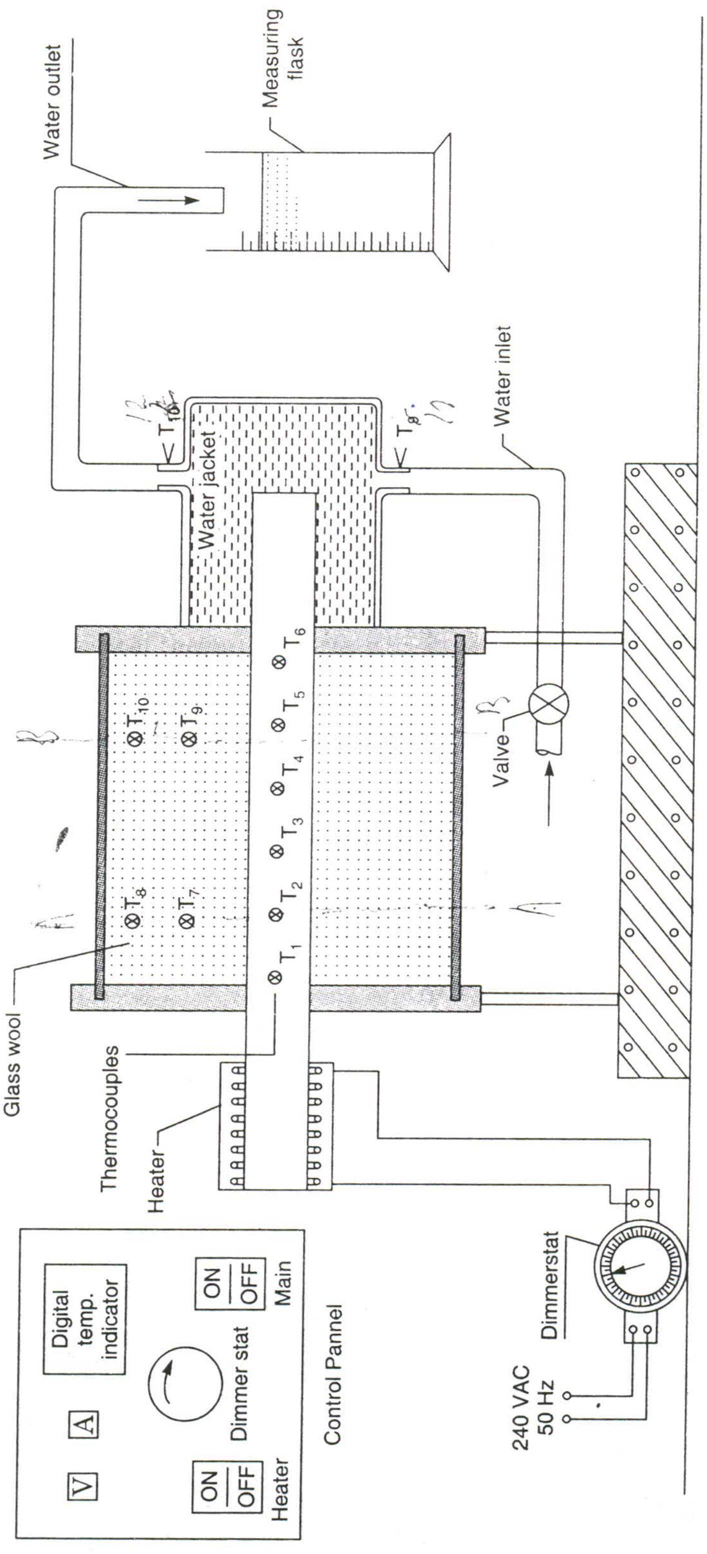


Fig.16.1. Experimental setup for determination of thermal conductivity of metal bar

Experiment No. 5
POOL BOILING IN A SATURATED LIQUID

Nomenclature

Bi	Biot number, -
C	constant in Eq. (1), W/(m^2 K^m)
c_p	specific heat, J/(kg K)
D	diameter, m
g	gravitational constant, m/sec^2
$\bar{h}$	overall heat transfer coefficient, W/(m^2 K)
h_{fg}	latent heat of vaporization, kJ/kg
k	thermal conductivity, W/(m K)
q''_{min}	minimum heat flux, W/m^2
q''_{max}	critical heat flux for nucleate pool boiling, W/m^2
q_s	boiling heat flux, W/m^2
t	time, sec
T	temperature, K
T_{bp}	boiling point, K
T_i	initial temperature, K
T_s	surface temperature, K
ΔT_e	excess temperature, K
σ	surface tension, N/m
ρ_l	liquid density, kg/m^3
ρ_v	vapor density, kg/m^3

Objective

The objective of this experiment is to observe the regimes of nucleate, transition, and film boiling in a pool of saturated liquid, to determine the rate of boiling, and to construct the boiling curve.

Concepts Emphasized

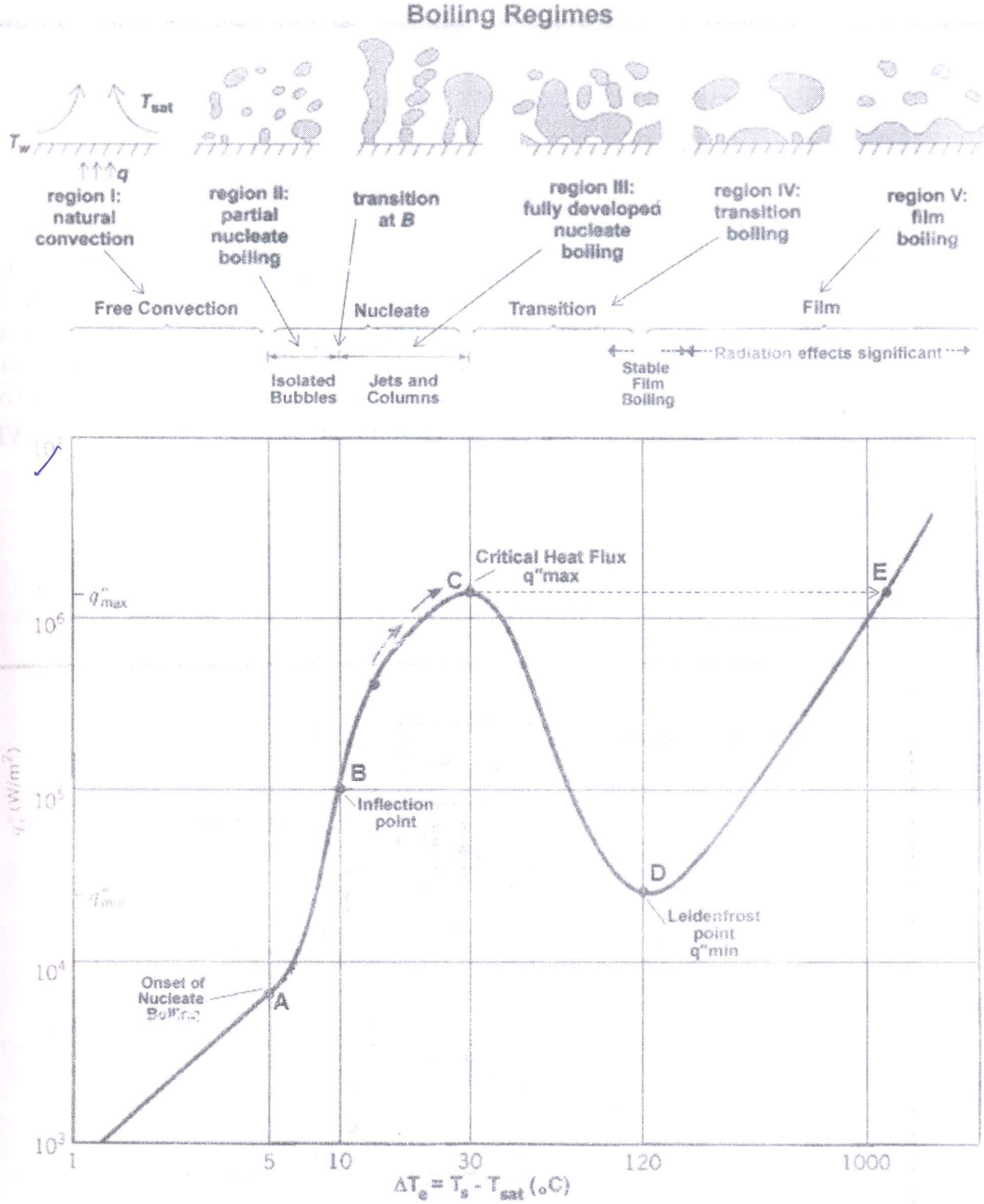
1. Energy balance and conditions justifying the lumped capacitance method;
2. variation of the boiling heat flux with excess temperature - peculiar features of the boiling curve;
3. magnitude of the overall heat transfer coefficient;
4. definition and physical significance of the critical heat flux and Leidenfrost point; and
5. transient nature of the problem and time variation of the surface temperature.

Pre-Lab Section: Theoretical Analysis

The experiment is designed to illustrate the characteristics of the boiling *phase-change* phenomenon. It involves observing the rate of boiling of a saturated liquid on the surface of a submerged hot object and measuring the variation of the object temperature with time. The object is initially at a temperature ($T_{i,} \approx$ 273K) far above the boiling point of the liquid (in this case, liquid nitrogen: $T_{bp} \approx 77$K). By measuring the time variation of the object's temperature, the rate of boiling, and the boiling curve can be constructed based upon the application of the lumped capacitance method. A sample boiling curve is given in Figure 1. To prepare for the experiment, which could be performed prior to when the topic has been discussed in the Heat Transfer course, the student should complete the following items:

1. Review sections 10.2, 10.3, and 10.4 of the text by Incropera et al., 4th ed., 5th ed., or 6th edition.

2. Consider a hot metal sphere, initially at a temperature of T_i, that is suddenly quenched in a large pool of saturated liquid at $T_{bp} < T_i$ (see Fig. 2). If the excess temperature, $(T_s - T_{bp})$ is between about 5 and 30°C, what is this boiling regime called? Describe the boiling phenomena in this regime.



Boiling Curve for water at 1 atm.
Surface heat flux q'' as a function of excess temperature $\Delta T_e = T_s - T_{sat}$

Figure 1. Boiling curve for water including regime illustrations and labeling of key points.

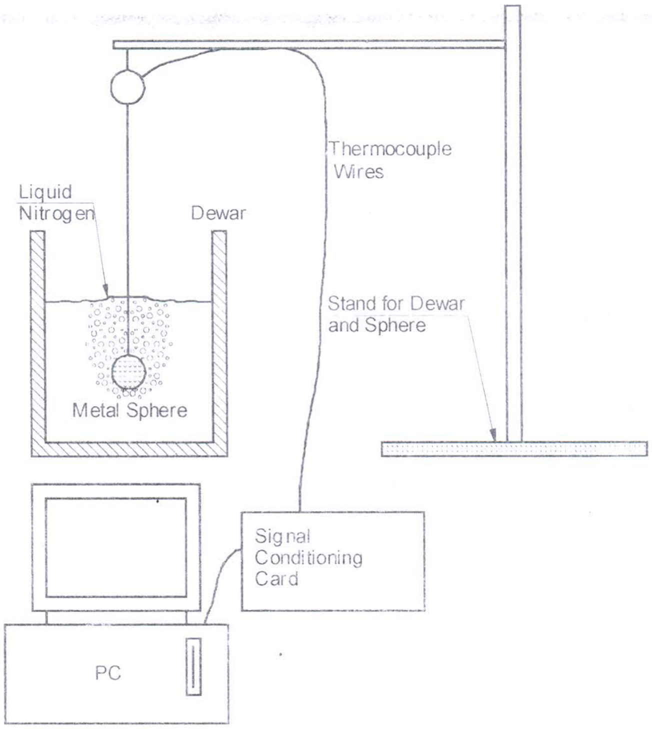


Figure 2. Experimental setup for measuring transient temperature of a metal sphere cooled in liquid nitrogen (not to scale).

3. If the excess temperature, $(T_i - T_{bp})$ is beyond the Leidenfrost point, will there be direct contact between the liquid phase and the surface of the sphere? What do we call this regime of pool boiling?

4. Using the lumped capacitance method, derive a differential equation for the transient temperature response of the sphere. The boiling heat flux takes an unusual form, so leave the heat flux as a variable for now.

5. If the metal sphere in item 2 above is copper, has a diameter of 2.54×10^{-2} m, an initial temperature of T_i = 773K, and the *liquid is saturated* ***water*** **at 373K and 1 atm**, estimate the time for the sphere to become partially wetted by the liquid phase (i.e., the time for the sphere to reach the Leidenfrost point at 493K). Hint: Approximate the appropriate segment of the boiling curve shown in Fig. 10.4 of the text (p. 540 in 4th ed., or p. 598 in 5th ed., or p. 624 in 6th ed.) by the following expression,

$$q''_s = C \Delta T_e^m \quad (1)$$

and integrate the differential equation derived in item 4.

6. Beyond this time, what will be the regime of pool boiling?

7. Although the physical size of the sphere is small and its thermal conductivity is high, it is possible that the Biot number significantly exceeds 0.1. If this is the case, possibly in the nucleate and transition regimes, then the lumped analysis is not a good approach. That is, we would have to consider the radial variation of the temperature. To estimate the heat transfer coefficient, you may use the Heisler charts shown below. If the sphere properties and the center, surface and initial temperatures are known from measurements, describe in words how you would use Figs. D.7, D.8, D.9 shown below (in Appendix D of textbook, 4th and 5th ed. only) to deduce the heat transfer coefficient h and the heat flux q''_s.

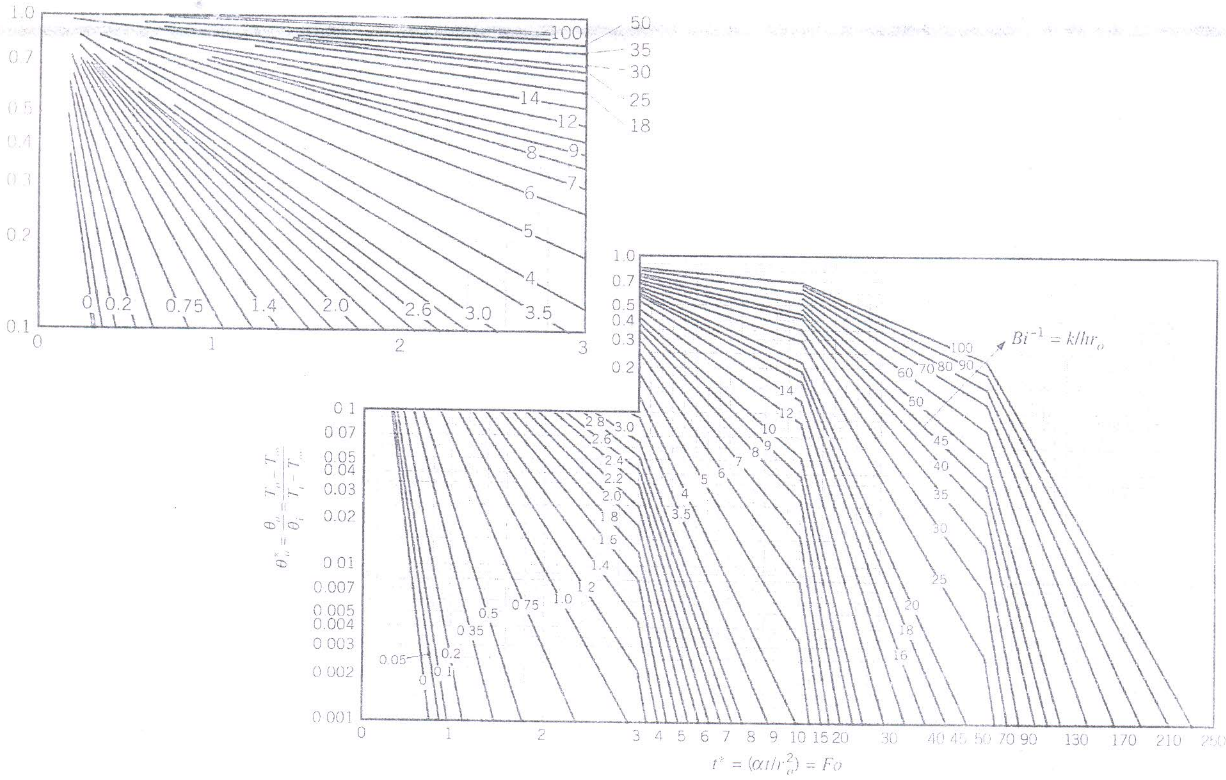


FIGURE D.7 Center temperature as a function of time in a sphere of radius r_o [1]. Used with permission.

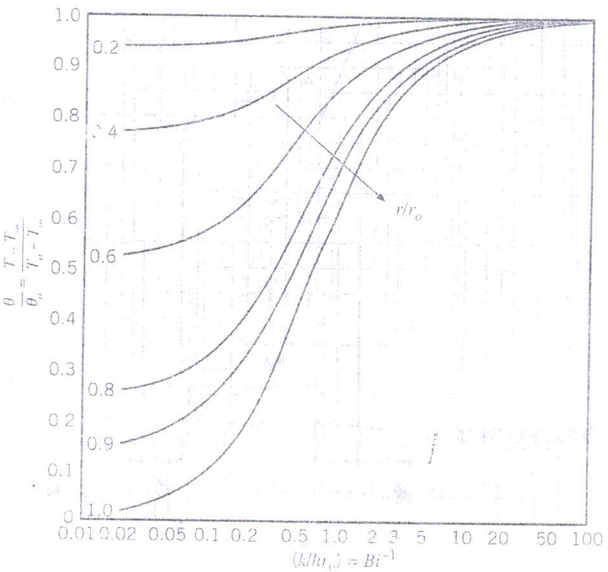


FIGURE D.8 Temperature distribution in a sphere of radius r_o [1]. Used with permission.

8. Estimate the value of the critical heat flux using equation 7 of this lab manual. Explain the physical significance associated with this value.

9. Estimate the total amount of water that boils away when the sphere cools from 773 to 378 K.

10. Get familiar with the experimental setup and read the experimental procedures carefully, so that you can effectively perform the experiment in the next meeting. More importantly, also review once again the section on the Laboratory Safety Instructions for handling liquid nitrogen - it may cause severe burns if

handled inappropriately! Please note that the supplied safety goggles must be worn when conducting the experiment.

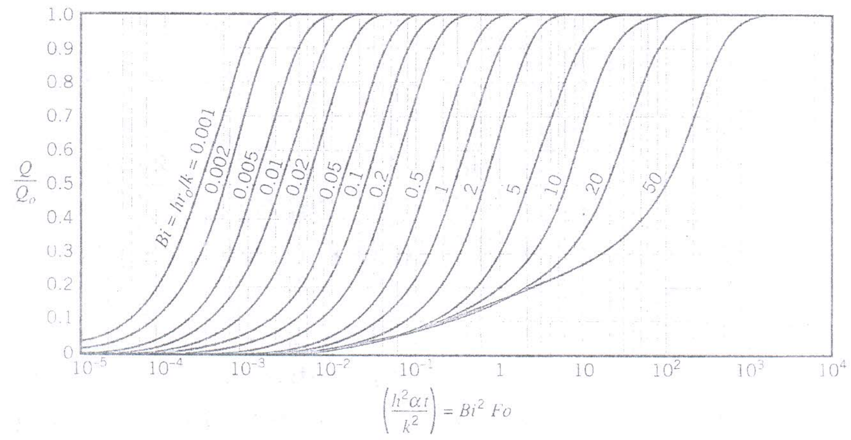


FIGURE D.9 Internal energy change as a function of time for a sphere of radius r_o [2]. Adapted with permission.

DAQView Setup Parameters

Thermocouple Type:	**T**
Units:	**K**
Number of Thermocouples:	**2 (+CJC)**
Start Condition:	**Manual Start**
Stop Condition:	**Manual Stop**
Scan Rate:	**4 scans/secs**
Averaging:	**Enabled: 100**
Suggested Monitoring Method:	**Digital Meters**

Experimental Procedures

1. The teaching assistant will give a brief discussion of the experimental procedure. The experiment is of a relatively short time duration, and could be repeated if necessary. The data acquisition system will acquire the transient temperature data, and curve fits of the temperature will once again be determined using Excel.

2. The experimental apparatus consists of a dewar filled with liquid nitrogen and a metal sphere with two thermocouples attached to it in order to determine the transient sphere temperature. The sphere, initially at room temperature, is to be quenched in a bath of *liquid nitrogen* to induce rapid boiling of the liquid phase in the region around the sphere. You should choose one of the two metal spheres and record its size in Table 1.

3. Setup the data acquisition program.

4. To prepare for the run, fill the dewar with liquid nitrogen and connect the thermocouples that have been welded onto the sphere to the data acquisition system.

5. Properly position the sphere and quench it in the bath of liquid nitrogen. Simultaneously, click the **Manual Trigger** button in the DAQView popup window to start the data acquisition. Also, click the **Start** button in the digital meters window so that you can monitor the temperature of the sphere.

6. Owing to very large magnitudes of the boiling heat transfer coefficient, the sphere temperature will drop rapidly with time. In most cases, it will take less than five minutes to cool the sphere to a sufficiently low temperature (say, no more than 5 to 10K above the boiling point of liquid nitrogen, which has a

value of 77 K at 1 atm]. Observe closely the boiling phenomena occurring in this fast transient period. Once the temperature has reached a minimum steady value, stop the data acquisition and the chart by clicking the **Stop** button in both the DAQView popup window and the charts window. Then, carefully remove the sphere from the dewar and place it in a dewar filled with water. Such placement of the extremely cold sphere in the ("hot") water will produce an interesting freezing problem, which you should observe!

7. Once the data acquisition has been stopped, the data will automatically be imported into Excel. Column A corresponds to the cold-junction circuit temperature (which can be deleted), while Columns B and C correspond to the temperatures of the two thermocouples in the sphere. The rows correspond with time; knowing that the scan rate is 4 scans per second, insert a column on the far left and enter the time.

8. Since the experiment is of short duration, you may run it multiple times to ensure your results are consistent and accurate. Also, be sure each student visually observes the boiling process during an experiment or separately without data acquisition. Record your observations and use them to answer the discussion points at the end of this lab report.

9. Repeat the experiment for the other sphere. Be sure to measure and record the sphere size.

10. Utilizing the output from the data acquisition system, each student should process and analyze each set of data. Use the average of the two measured temperatures as the data for T. Since you should have started the data acquisition before the sphere was immersed in the liquid nitrogen, there will be some data points in the initial part of the data file that report a steady, room temperature. You should discard these data points from the curve fit procedure. We are interested in the portions of the data wherein the temperature is changing.

Data Reduction

1. Begin by constructing a table similar to Table 1. Calculate T_s for both spheres by averaging the temperatures of the two thermocouples. For each sphere, plot the center, surface and average temperature vs. time. What is the substantial difference between the spheres? Describe the difference in terms of a theoretical assumption discussed in the pre-lab. Present both temperature plots in your final report, but only perform the rest of this analysis on the sphere that conforms to the initial assumptions used during the pre-lab and explain why you choose that sphere. (If you are unsure of which to use, ask the TA.)

2. There are several ways one can evaluate the time derivative of the transient temperature. One *approximate* way, which also may be subject to significant errors, is to express the derivative in terms of finite differences. The finite difference method is quite tedious to apply, and it will not be used in this experiment. Instead, Excel will be employed. This package contains a curve-fitting program, which takes the temperature vs. time data and expresses it in the form

$$T(t) = \sum_{i=0}^{I} a_i t^i \tag{2a}$$

Once the coefficients $a_i, i = 0,\ldots,I$, are known, it is a simple matter to differentiate Eq. (2a) with respect to time to obtain

$$\frac{dT}{dt} = \sum_{i=1}^{I} a_i i t^{i-1} \tag{2b}$$

The use of a polynomial fit, such as Eq. (2), may not yield good results in some situations. This is the case for the boiling experiment and most easily explained by examining Fig. 3. Near times t^* and t^{**}, the rate of change of temperature changes very rapidly. That is, the slope changes significantly over a very small time interval. Any curve fitting technique will have problems representing this change in the slope. To circumvent this problem, the data will be split into three parts. Use a fourth order polynomial fit for the portion of the curve given by $t < t^*$ and a third order polynomial fit for the portions of the

HEAT TRANSFER IN NATURAL CONVECTION

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

INTRODUCTION:
Natural convection phenomenon is due to the temp. Difference between the surface and the fluid and is not created by any 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.

APPARATUS:
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 serves the purpose of undisturbed surrounding. One side of it is made up of glass/Acrylic for visualization.
An heating element is kept in the vertical tube which heats the tube surface. The heat is lost from the tube to the surrounding air by natural convection. The temperature is measured by seven temperature sensors. The heat input to the heater is measured by Digital Ammeter and Digital voltmeter and can be varied by a dimmerstat.

SPECIFICATIONS :

- Dia of the tube : 38mm.
- Length of the tube : 525 mm.
- Size of duct : 25 X 25 X 90 cm.
- Temperature Sensors : RTD PT-100 type.
- No. of Temperature Sensors : 8 Nos.
- Digital Voltmeter : 0 to 250 V.
- Digital Ammeter : 0 to 2.5 Amps.
- Dimmerstat : 2 Amps/220 V.
- Temperature Indicator : Digital Temperature Indicator 0 to 199.9°C with least count 0 to 1°C with multi channel switch.

OBSERVATIONS:

Outer diameter of Cylinder : 38mm.

Length of Cylinder : 525mm.

Input to heater : V.I. Watts.

Where V = Volts.

I = Amps.

Temperature Sensor No	1	2	3	4	5	6	7	8
Set No.I								
Set No.II								
Set No.III								

PROCEDURE:

1. Switch on the supply and adjust the dimmerstat to obtain the required heat input.
2. Wait till the fairly steady state is reached.
3. Note down the temperature readings.
4. Repeat the experiment at different heat inputs.

CALCULATIONS :

The heat transfer coefficient is given by.

$$h = \frac{q}{A_S\,(T_S - T_a)} \quad \text{Kcal/Hr. m}^2\,{}^\circ\text{C}$$

Where q = heat transfer rate = V.I. (KCal/Hr.)

A_S = Area of the heat transferring surface.

$= \pi d l \ m^2$

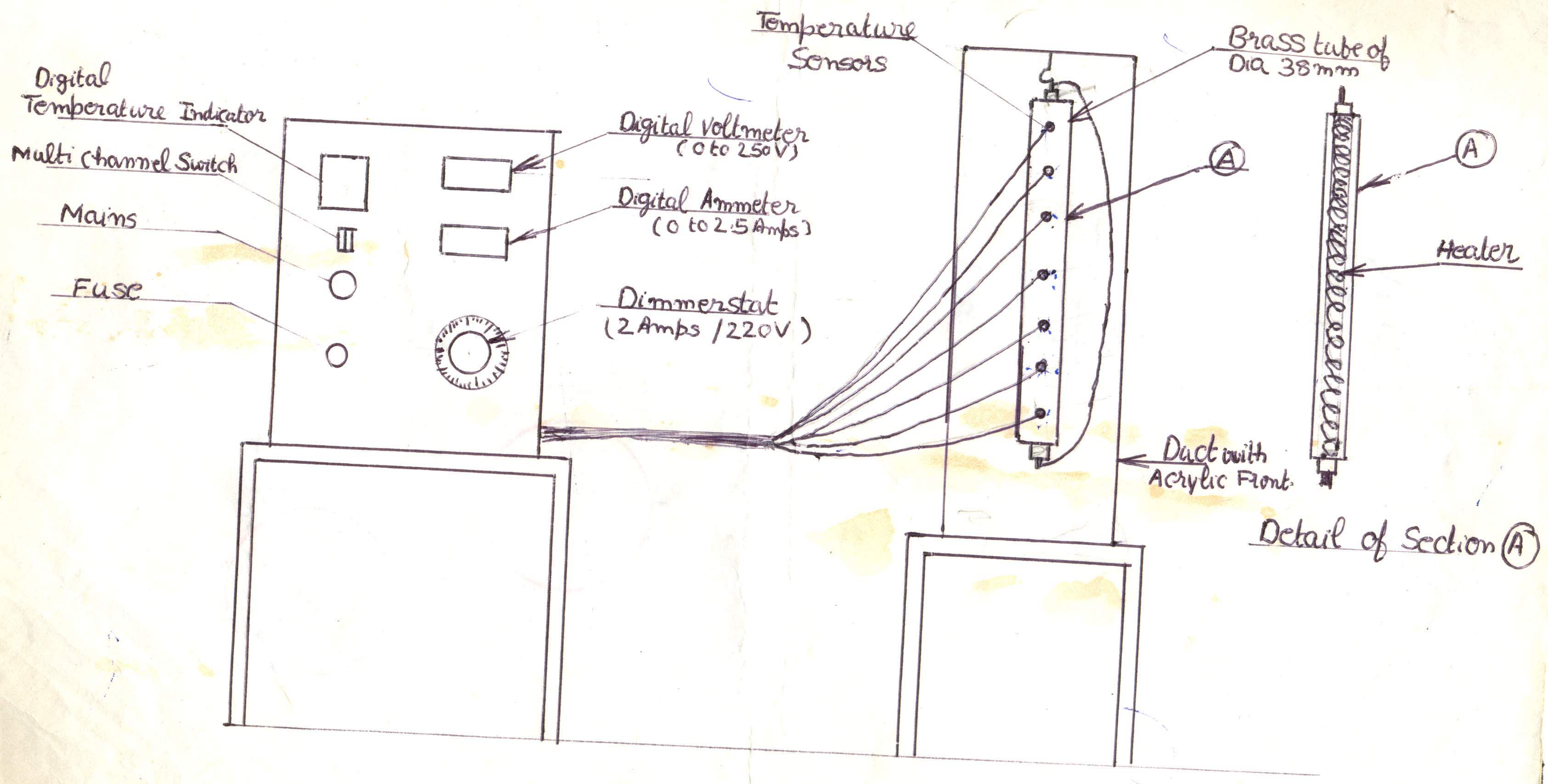
T_S = Average Temperature

$$= \frac{T_1+T_2+T_3+T_4+T_5+T_6+T_7}{7}$$

T_a = ambient temperature in duct °C = T_8

PRECAUTIONS:

1. Keep dimmerstat to zero volt and increase it slowly.
2. Operate the channel switch of temperature indicator gently.



HEAT TRANSFER IN NATURAL CONVECTION

HEAT TRANSFER IN FORCED CONVECTION

AIM :

To find surface heat transfer coefficient for a pipe flowing heat by force convection to air flowing through it, for different air flow rate and heat flow rate.

APPARATUS :

The apparatus consists of blower unit fitted with the test pipe. The test section is surrounding by nichrome heater. Four Temperature Sensors are embedded on the test section and two temperature sensors are placed in the air stream at the entrance and exit of the test section to measure the air temperature.

Test Pipe is connected to the delivery side of the blower alongwith the Orifice to measure flow of air through the pipe. Input to the heater is given through a dimmerstat and measured by meters. It is to be noted that only a part of the total heat supplied is utilised in heating the air.

A temperature indicator is provided to measure temperature of pipe wall in the test section. Air flow is measured with the help of Orifice meter and the water manometer fitted on the board.

SPECIFICATIONS :

- Length : 40cm
- I.D. of Test section : 28 mm
- O.D. of Test Section : 32 mm
- No. of Temperature sensors : 6 Nos.
- Blower : 1 H.P.
- Orifice Diameter : 14mm
- Dimmerstat : 2 Amps.,220 V.
- Digital temperature indicator with multichannel switch Digital voltmeter & Digital Ammeter are also provided.

Newton Richmann's Method

PROCEDURE :

1. Start the blower and adjust the flow of air by means of valve to some desired difference in manometer level.
2. Start the heating of the test section with the help of dimmerstat and adjust desired heat input with the help of Digital voltmeter and Digital Ammeter.(Don`t exceed 90 volts)
3. Note the reading of all the temperature sensors until the steady state is reached.(Wait atleast 45 min. for first set of readings & then 15 minutes for consecutive readings)
4. Note down the heat input.

OBSERVATIONS :

Inner dia of test section , D_i : 28mm

Outer dia of test section, D_o : 32mm

length of test section, L : 40cm

Diameter of orifice, : 14mm

Temperature sensors readings : T_1 = ... °C.

T_2 = ... °C.

T_3 = ... °C.

T_4 = ... °C.

T_5 = ... °C.

T_6 = ... °C.

Manometer reading : H = ... Meters.

CALCULATIONS: Formula used

$$\text{HEAT TRANSFER COEFFICIENT } \bar{U} = \frac{Q_a}{A\,(T_S - T_a)}$$

Q_a the rate at which air is getting heating is calculated as follows :

$Q_a = mc_p\,\Delta T$ K cal/Hr.

where m = mass flow rate of air Kg/Hr.

c_p = Specific heat of air Kcal/°C Kg.

ΔT = Temp. rise in air °C.($T_6 - T_1$)

m = Q f a

7

where ρ_a = Density of air

Q = Vol. flow rate

$Q = C_d \times \pi/4\, d^2 \sqrt{2gH \times \rho_w/\rho_a}\ (m^3/Hr)$

$$U = \frac{Q_a}{A\,(T_S - T_a)}\ \text{kCal/m}^2\ {}^\circ\text{C hr}$$

C_d = Coefficient of discharge = 0.64

H = Difference of water level in manometer in meters.

ρ_w = Density of water

= $1000 kg/m^3$

ρ_a = Density of air

= ~~$1.03 kg/m^3$~~

d = Diameter of Orifice

= 0.014

A = Test section area.

= $\pi D_i L\, m^2$

T_a = Average temperature of air.

$$= \frac{(T_1 + T_6)}{2}\ {}^\circ C$$

T_s = Average surface temperature.

$$= \frac{T_2+T_3+T_4+T_5}{4}\ {}^\circ C$$

using this procedure obtain the values of Ha for different air flow rates.

PRECAUTIONS:

1. Keep the dimmerstat at zero position before giving the supply.
2. Start the blower unit first.
3. Increase the voltage gradually.
4. Don't stop the blower in between the testing period.
5. Operate selector switch of temperature indicator gently.
6. Don't exceed 90 Volts.

FORCED CONVECTION

SAMPLE CALCULATIONS :

RECORD:

PIPE OUT-SIDE DIAMETER :	D_o = 32 mm
PIPE INSIDE DIAMETER :	D_I = 28 mm
LENGTH OF TEST SECTION:	L = 40 cm
ORFICE DIAMETER :	d_o = 14 mm
ORFICE PIPE INSIDE DIAMETER	d_p = 28 mm
ORFICE COEFF.	C_o = 0.6
MANOMETER FLUID	WATER
PROCESS FLUID	AIR

OBSERVATIONS :

AT STEADY STATE

RUN. NO	MANOMETER READING , R , cm OF WATER	V VOLT	I AMPS	T_1 °C	T_2 °C	T_3 °C	T_4 °C	T_5 °C	T_6 °C
1	10	100	0.95	48	118	137	151	157	69

CALCULATIONS
RUN NO. 1

1. MASS FLOW RATE OF AIR , M_{air}

DENSITY OF AIR AT AMBIENT INLET CONDITION : $\rho_f = 1.128 \text{ kg / m}^3$
DENSITY OF WATER (MANOMETER FLUID) : $\rho_m = 1000 \text{ kg / m}^3$

$$\Delta H = R\left(\frac{\rho_m}{\rho_f} - 1\right) = 10x10^{-2}\left(\frac{1000}{1.128} - 1\right) = 88.55 \text{ m}$$

VELOCITY OF AIR ACROSS THE ORFICE = V_o

$$V_o = Co\sqrt{\frac{2g\ \Delta H}{1-\beta^4}} = 0.6\sqrt{\frac{2\ x\ 9.81\ x\ 88.55}{1-0.5^4}} = 25.83 \text{ m / s}$$

MASS FLOW RATE OF AIR = M_{air} = $Vo \dfrac{\pi d_o^2}{4} \rho_f \, 3600$

$M_{air} = 25.83 \dfrac{\pi \times 0.014^2}{4} 1.128 \times 3600 = 16.146 \text{ kg / h}$

2. RATE OF HEAT TRANSFER

INLET AIR TEMP. = $T_1 = 48^{o}C$
OUT LET AIR TEMP. = $T_6 = 69^{o}C$

SPECIFIC HEAT OF AIR AT ITS MEAN TEMP. OF 58.5°C = Cp = 0.240 kcal / kg.°C
Or Cp = 1.005 kJ/kg K
RATE OF HEAT TRANSFER TO AIR = $Q_a = M_{air}\, Cp\, (T_6 - T_1)$

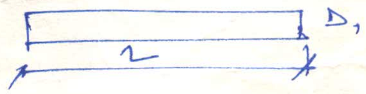
Q_a = 16.146 x 0.24 x (69 – 48) = **81.37 kcal/h = 94.65 W**

AMOUNT OF HEAT INPUT TO THE SYSTEM = V x I = 100 x 0.95 = 95 W
HEAT LOSS FROM THE HEAT EXCHANGER = 100 (95 – 94.65)/ 95 = 0.36 %

3. OBSERVED CONVECTIVE HEAT TRANSFER COEFF.

HEAT TRANSFER AREA OF THE TEST SECTION = $A = \pi D_I L = \pi \times 0.028 \times 0.40$ = A = 0.03518 m^2

CONVECTIVE HEAT TRANSFER COEFFICIENT = h



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

WHERE

Q_a = RATE OF HEAT TRANSFER TO AIR , kcal / h OR W

T_s = AVERAGE TEMPERATURE OF HEAT TRANSFER SURFACE = = $\dfrac{T_2 + T_3 + T_4 + T_5}{4}$ = (118 + 137 + 151 + 157) /4 = 140.75°C

T_a = AVERAGE AIR TEMPERATURE = $(T_1 + T_6) /2$ = 58.5°C

HEAT TRANSFER COEFF. = 81.37 / [0.03518 x (140.75 – 58.5)]

EXPERIMENTAL HEAT TRANSFER COEFFICIENT IS

h = 28.12 kcal / h – m² - °C

EXPERIMENTALLY OBSERVED NUSSELT NUMBER IS :

$Nu = h\,D_I / k_f$ = 28.12 x 0.028 / 0.0249 = 31.62

REYNOLD'S NO. = Re = D_I x V x ρ_f / μ_f

PROPERTIES OF AIR AT ITS MEAN TEMP. OF (T_1+T_6)/2 = 58.5°C
$\rho_f = 1.06\ kg/m^3$
$\mu_f = 20.10\times10^{-6}\ kg/m\text{-}s$
$\nu = 18.97\times10^{-6}\ m^2/s$
Pr = 0.696
THERMAL CONDUCTIVITY OF AIR = k_f = 0.0249 kcal/h-m-°C

VELOCITY OF AIR IN THE PIPE = V = $M_{air} / (\rho_f \times 3600 \times (\pi/4) \times D_i^2)$, m/s

$$V = \frac{16.146}{1.06\ x\ 3600\ x\ \frac{\pi}{4} 0.028^2} = 6.871\ m/s$$

$$Re = \frac{0.028 x\ 6.871}{18.97 x 10^{-6}} = \mathbf{10142.41}$$

Pr = **0.696**

OBSERVED $\frac{Nu}{Pr^{0.4}}$ = 31.62 / $0.696^{0.4}$ = **36.55**

4. CALCULATION OF THEORETICAL HEAT TRANSFER COEFFICIENT USING DITTUS BOELTER EQUATION:

$Nu = 0.023\ Re^{0.8}\ Pr^{0.4}$

Nu = 0.023 x $10142.41^{0.8}$ x $0.696^{0.4}$ = **31.892**

THEORETICAL Nu / $Pr^{0.4}$ = 31.892 / $0.696^{0.4}$ = **36.867**

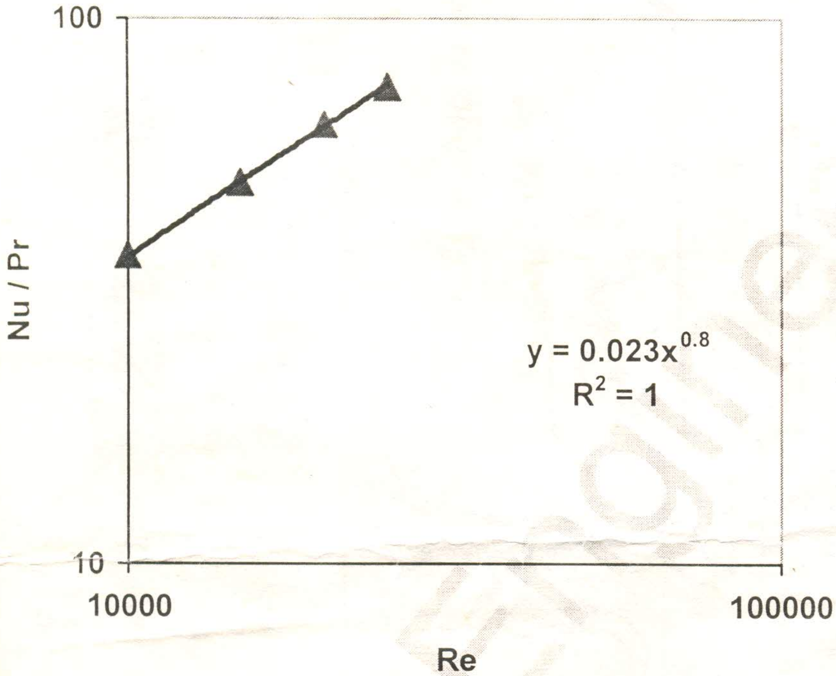
$Nu = h\,D_I / k_f$

OR h = Nu x k_f / D_I = 31.892 x 0.0249 / 0.028 = **28.36 kcal / h-m²-°C**

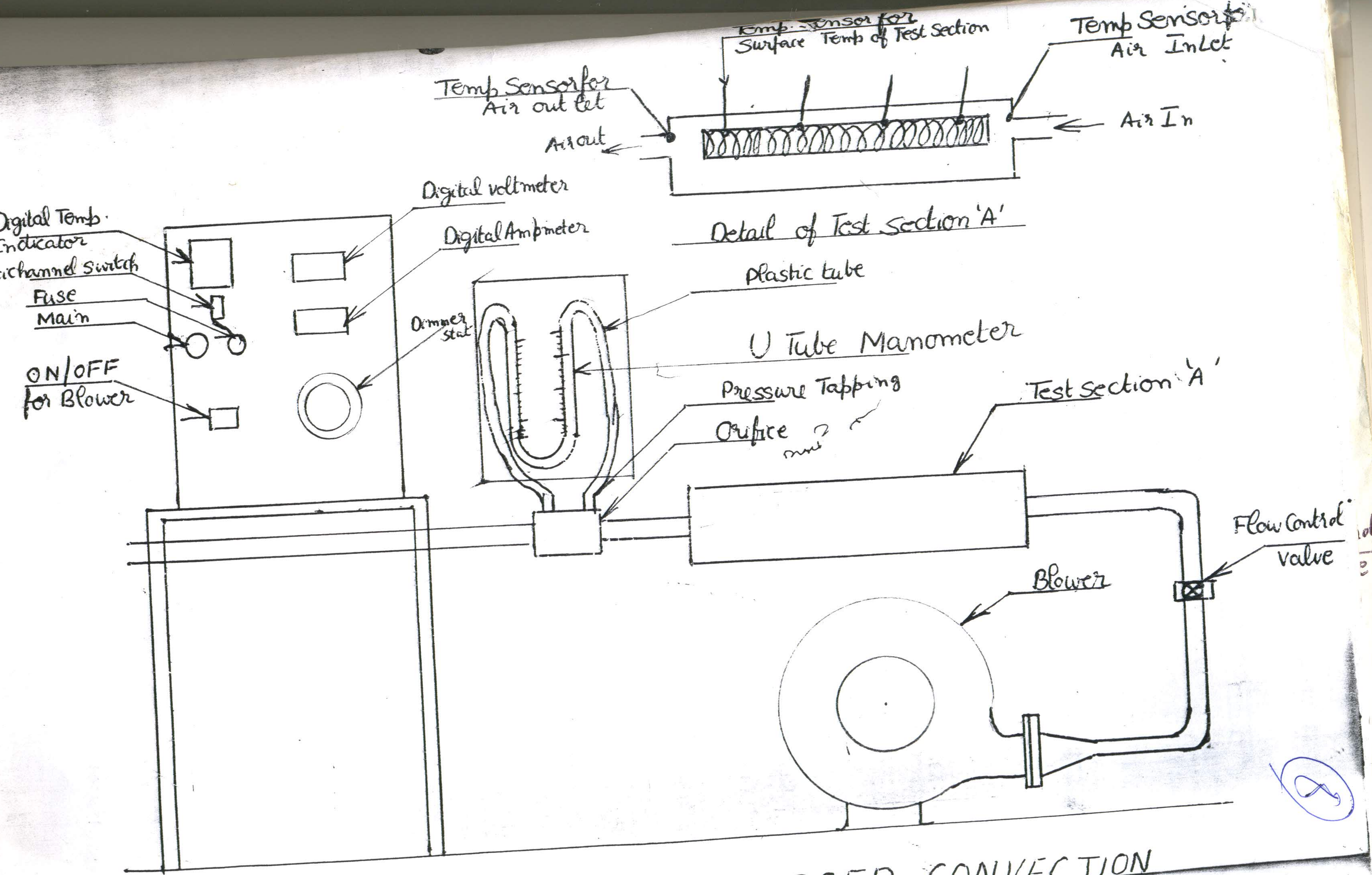
EXPERIMENTALLY OBSERVED HEAT TRANSFER COEFF. IS

h = 28.12 kcal / h – m² - °C

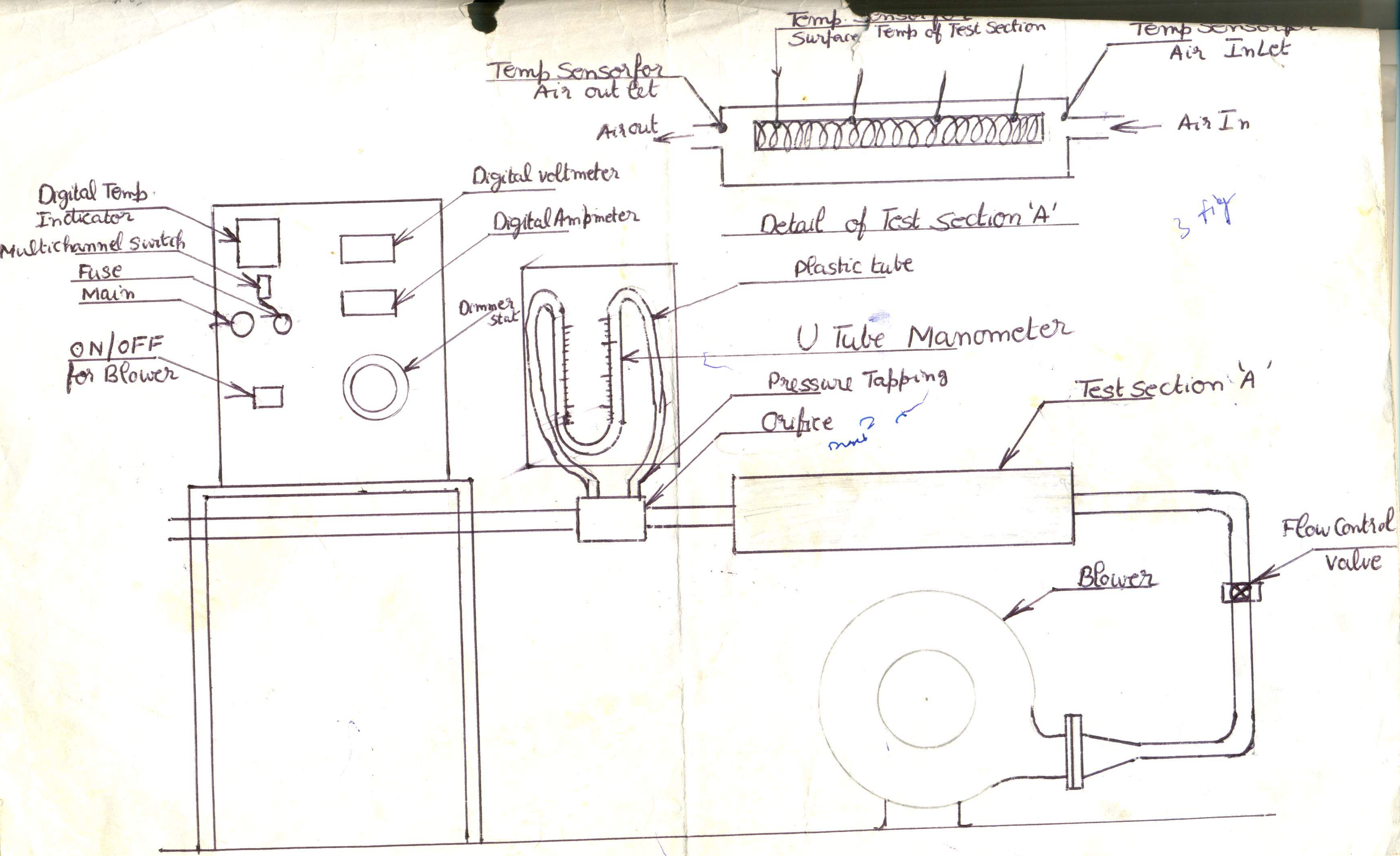
WHICH IS VERY CLOSE TO THE HEAT TRANSFER COEFFICIENT CALCULATED FROM DITTUS BOELTER EQUATION



PLOT EXPERIMENTALLY OBSERVED $\frac{Nu}{Pr^{0.4}}$ VS Re ON A LOG-LOG PLOT AND COMPARE IT WITH THE VALUES OBTAINED FROM DITTUS BOELTER EQUATION.



HEAT TRANSFER IN FORCED CONVECTION



HEAT TRANSFER IN FORCED CONVECTION.

DROPWISE AND FILMWISE CONDENSATION UNIT

Aim . Study of Dropwise and Filmwise condensation
- Find the Condensation heat Transfer Coffricient for Dropwise and Filmwise Condensation

INTRODUCTION :

In all applications, the steam must be condensed as it transfer heat to a cooling medium, e.g. cold water in the condenser of a generating station, hot water in a heating calorifier, sugar refinery, etc. During condensation very high heat fluxes are possible & provided the heat can be quickly transferred from the condensing surface to the cooling medium, heat exchangers using steam can be compact & effective.

Steam may condense on to a surface in two distinct modes, known as "filmwise" & "Dropwise". For the same temperature difference between the steam & the surface, dropwise condensation is much more effective than filmwise & for this reason the former is desirable although in practical plants it rarely occurs for prolonged periods.

FILMWISE CONDENSATION :

Unless specially treated, most materials are wettable & as condensation occurs a film condensate spreads over the surface. The thickness of the film depends upon a numbers of factors, e.g. the rate of condensation, the viscosity of the condensate and whether the surface is vertical or horizontal, etc.

Fresh vapour condenses on to the outside of the film & heat is transferred by conduction through the film to the metal surface beneath. As the film thickness it flows downward & drips from the low points leaving the film intact & at an equilibrium thickness.
The film of liquid is a barrier to the transfer of heat and its resistance accounts for most of the difference between the effectiveness of filmwise and dropwise condensation.

DROPWLISE CONDENSATION :

By specially treating the condensing surface the contact angle can be changed and the surface becomes 'non - wettable'. As the steam condenses, a large number of generally spherical beads cover the surface. As condensation proceeds, the beads become larger, coalesce, and then strike downwards over the surface. The moving bead gathers all the static beads along its downward in its trail. The 'bare' surface offers very little resistance to the transfer of heat and very high heat fluxes are therefore possible.

Unfortunately, due to the nature of the material used in the construction of condensing heat exchangers, filmwise condensation is normal. (Although many bare metal surface are 'non- wetable' this is not true of the oxide film which quickly covers the bare material)

DESCRIPTION :

The equipment consists of a metallic container in which steam generation takes place.

The lower portion houses suitable electric heater for steam generation. A special arrangement is provided for the container for filling the water. The glass cylinder houses two water cooled copper condensers, one of which is chromium plated to promote dropwise condensation and the other is in its natural state to give filmwise condensation. A connection for pressure gauge is provided. Separate connections of two condensers for passing water are provided. One rotameter with appropriate piping can be used for measuring water flow rate in one of the condensers under test.

A digital temperature indicator provided has multipoint connections which measures temperatures of steam, two condensers, water inlet & outlet temperature of condenser water flows.

SPECIFICATIONS :

Condensers : One chromium plated for dropwise condensation & one natural finish for filmwise condensation other wise identical in construction.

Dimensions : 20 mm outer dia. 160 mm length ,

Fabricated from copper with reverse flow in concentric tubes.

Fitted with Temperature Sensor for surface temp. measurement.

Main Unit : M.S. Fabricated construction comprising test section & steam generation section. Test section provided with glass cylinder for visualisation of the process.

Heating Elements : Suitable water heater.

Instrumentation : 1 *Temperature Indicator : Digital 0-199.9°C & least count 0.1°C with multichannel switch.*

2. *Temperature Sensors* : RTD PT-100 Type.

3 *Rotameter* : Standard Make 100 LPH capacity for measuring water flow rate.

4. *Pressure Gauge* : Dial type 0 - 2 Kg/cm^2

OPERATION :

1. Fill water in steam generator by opening the valve.
2. Start water flow through one of the condensers which is to be tested and note down water flow rate in rotameter. Ensure that during measurement, water is flowing only through the condenser under test and and second valve is closed.
3. Connect supply socket to mains and switch ON the heater switch.
4. Slowly steam generation will start in the steam generator of the unit and the steam rises to test section., gets condensed on the tubes and falls down in the cylinder.
5. Depending upon type of condenser under test dropwise or filmwise can be visualised.

6. If the water flow rate is low then steam pressure in the chamber will rise and pressure gauge will read the pressure. If the water flow rate is matched then condensation will occur at more or less atmospheric pressure or upto 1 kg pressure.
7. Observations like temperatures, water flow rates, pressure are noted down in the observations table at the end of each set.

CALCULATION :

Normally steam will not be pressurised. But if pressure gauge reads some pressure then properties of steam should be taken at that pressure or other wise atmospheric pressure will be taken.

We will first calculate the heat transfer coefficient inside the condenser under test. For this properties of water are taken at bulk mean temperature of water i.e. $(T_{wi} + T_{wo})/2$

Where T_{wi} and Two are water inlet & outlet temperatures.

Following properties are required. :

ρ_l	=	Density of water Kgm/m^3
ν_l	=	Kinematics Viscosity m^2/sec.
K_l	=	Thermal conductivity kcal/hr -m °C. (W /m - °C)
P_r	=	Prandtl number.

Now calculate Reynold's number.

$$R_{ed} = \frac{4m_w}{\pi D_i \rho_l \nu_l}$$

Where D_i = Inner Dia of condenser.

= 1.7 cms.

If this value of Re ≥ 2100 then flow is turbulent and below this value flow is laminar.

Normally flow will be turbulent in the tube.

Now Nusselt Number.

$$N_{ul} = 0.023 . (R_{ed})^{0.8} . (P_r)^{0.4}$$

$$\text{and} \quad hi = \frac{N_{ul} . K}{L} \quad \frac{Kcal}{hr. m^2 °C} \quad \frac{W}{m^2 °C}$$

Where, hi = Inside Heat Transfer Coefficient.

Now calculate heat transfer coefficient on outer surface of the condenser (h_o),. For this properties of water are taken at bulk mean temperature of condensate i.e.

$$\frac{(T_S + T_W)\ °C}{2} = T_2\ °C$$

Where T_S = Temperature of steam °C.

T_W = Temperature of condenser wall °C.

Properties needed are

i) ρ_2 = Density of water Kgm/m^3

ii) K_2 = Thermal Conductivity Kcal/ hr - m°C (W/ m - °C)

iii) μ = Viscosity of condensate Kgf - sec/m^2. (Kg/m.s)

iv) λ = Heat of evaporation Kcal/Kg. (540 Kcal/kg)

$$h_o = 0.943 \left[\frac{\lambda \rho_2^2 . g . k_2^3}{(T_S - T_W)\ \mu\ L} \right]^{0.25}$$

where g = Acc. due to gravity = 9.8 m/sec^2. = 1.27×10^8 m/hr^2

L = Length of condenser = 160mm.

From these values overall Heat Transfer coefficient (U) can be calculated.

$$\frac{1}{U} = \frac{1}{h_i} + \frac{D_i}{D_o} \times \frac{1}{h_o} \quad \text{Kcal/hr - m}^2\text{ - °C}$$

Same procedure can be repeated for other condenser.

Except for some exceptional cases overall heat transfer coefficient for Dropwise Condensation will be higher than that of filmwise condensation.

Results may vary from theory in some degree due to unavoidable heat losses.

PRECAUTIONS :

1. Do not start heater supply unless water is filled in the test unit.
2. Operate gently the selector switch of temperature indicator to read various temperature.
3. Take care of water level in steam generator.

OBSERVATION - TABLE

Sr. No.	
Steam Pressure Kg/cm^2	
Condenser Under Test	
Water Flow Rate LPH	

TEMPERATURE

Plated Condenser Outer Surface	T1			
Plain Condenser Outer Surface	T2			
Steam	T3			
Water Inlet To Condenser	T4			
Water Outlet Plain Condenser	T5			
Water Outlet Plated Condenser	T6			
Ambient	T7			

SAMPLE OBSERVATIONS & CALCULATIONS *

OBSERVATION - TABLE

Sr. No.	1.	2.
Steam Pressure Kg/cm²		
Condenser Under Test		
Water Flow Rate LPH		

TEMPERATURE

Plated Condenser Outer Surface	T_1		
Plain Condenser Outer Surface	T_2		
Steam	T_3		
Water Inlet To Condenser	T_4		
Water Outlet Plain Condenser	T_5		
Water Outlet Plated Condenser	T_6		

For plain condenser

$$R_{ed} = \frac{4 m_w}{\pi D_i \rho_1 v_1}$$

$$= \text{------------------------------}$$

$$N_{ul} = 0.023 \cdot (R_{ed})^{0.8} \cdot (P_r)^{0.4}$$

$$= \text{------------------------------}$$

$$\text{and } h_i = \text{---------} \quad \frac{N_{ul} \cdot K}{L} \quad \frac{Kcal}{hr.\, m^2\, °C} \quad \frac{W}{m^2\, °C}$$

$=$ ------------------------------

$$h_o = 0.943 \left[\frac{\lambda \rho_2^2 . g . k_2^3}{(T_S - T_W)\, \mu\, L} \right]^{0.25}$$

$=$ ------------------------------

where g = Acc. due to gravity = 9.8 m/sec. = 9.8 x 3600 m/hr

L = Length of condenser = 160mm.

From these values overall Heat Transfer coefficient (U) can be calculated.

$$\frac{1}{U} = \frac{1}{h_i} + \left(\frac{D_i}{D_o} \times \frac{1}{h_o} \right) \text{Kcal/hr - m}^2 \text{ - °C}$$

$=$ ------------------------------

For plated condenser

$$R_{ed} = \frac{4m_w}{\pi D_i \rho_1 \nu_1}$$

$=$ ------------------------------

$$N_{ul} = 0.023 . (R_{ed})^{0.8} . (P_r)^{0.4}$$

$=$ ------------------------------

and $hi = \frac{N_{ul} . K}{L}$ --------- $\frac{\text{Kcal}}{\text{hr. m}^2 \text{°C}}$ $\frac{\text{W}}{\text{m}^2 \text{°C}}$

$$= \text{-----------------------------}$$

$$h_o = 0.943 \left[\frac{\lambda \rho_2^2 . g . k_2^3}{(T_S - T_W)\, \mu\, L} \right]^{0.25}$$

$$= \text{-----------------------------}$$

- where g = Acc. due to gravity = 9.8 m/sec². = 1.27×10^8 m/hr□3

  L = Length of condenser = 160mm.

From these values overall Heat Transfer coefficient (U) can be calculated.

$$\frac{1}{U} = \frac{1}{h_i} + \left(\frac{D_i}{D_o} \times \frac{1}{h_o} \right) \text{ Kcal/hr - m}^2 \text{ - °C}$$

$$= \left[\frac{1}{h_i} + \left(\frac{D_i}{D_o} \times \frac{1}{h_o} \right) \right] \frac{4.1868}{3600} \text{ Kw/hr - m}^2 \text{ - °C}$$

$$= \text{-----------------------------}$$

STEFAN BOLTZMANN APPARATUS

Aim :- To find the stefan Boltzmann Constant. (σ)

INTRODUCTION :

The most commonly used law of thermal radiation is the Steffan Boltzmann law which states that thermal radiation heat flux or emmissive power of a black surface is proportional to the fourth power of absolute temperature of the surface and is given by

$$\frac{Q}{A} = e\,b = \sigma T^4 \qquad (\text{K Cal/hr.m}^2\,\text{K}^4)$$

The constant of proportionally is called the Stefan Boltzman constant and has the value of 4.88×10^{-8} Kcal/Hr. m² K⁴

The Stefan Boltzmann law can be derived by integrating the Planck's law over the entire spectrum of wave length from 0 to ∞. The objective of this experimental set up is to measure the value of this constant fairly closely, by an easy arrangement.

APPARATUS:-

The apparatus is centered on a flanged copper hemisphere B fixed on a flat non-conducting plate A. The outer surface of B is enclosed in a metal water jacket used to heat B to some suitable constant temperature.

One RTD PT-100 type Temperature Sensor is attached to the inner wall of hemisphere B to measure its temperature and to be read by a temperature indicator.

The disc D, which is mounted in an insulating bakelite sleeve S is fitted in a hole drilled in the centre of the base plate A. A chromel Alumel Temperature Sensor is used to measure the temperature of D i.e. T_D. The Temperature Sensor is mounted on the disc to study the rise of its temperature.

When the disc is inserted at the temperature T_D ($T_D < T$)

(i.e. the temperature of the enclose) the response of temperature change of disc. with time is used to calculate the stefan Boltzmann constant.

SPECIFICATIONS :

1. Hemispherical enclosure dia	200 mm
2. Suitable sized Water jacket for hemisphere.	
3. Base plate, Bakelite diameter	250 mm.
4. Test disc dia	20 mm
5. Mass of test disc	5.1 gms
6. Specific heat, S of the test disc.	0.1 Kcal/kg -°C
7. No. of Temperature Sensor mounted on B	1
8. No. of Temperature Sensor mounted on D	1
9. Temperature indicator digital	0-199.9°C RTD PT-100 type
10. Immersion water heater of suitable capacity and tank for hot water.	

The surface of B and A forming the enclosure are blacked by using lamp black to make their absorptivities to be approximately unity. The copper surface of the disc D is also blackened.

EXPERIMENTAL PROCEDURE :

1. Heat the water in the tank by the immersion heater upto a temperature of about 90 °C.
2. The disc D is removed before pouring the hot water in the jacket.
3. The hot water is poured in the water jacket.
4. The hemispherical enclosure B and A will come to some Uniform temperature in a short time after filling the hot water in the jacket. The thermal inertia of hot water is quite adequate to prevent significant cooling in the time required to conduct the experiment.
5. The enclosure will soon come to thermal equilibrium conditions.

6. The disc. D is now inserted in A at a time when its temperature is T_D.

The radiation energy falling on D from the enclosure is given by :

$$E = \sigma A_D (T)^4 \quad \text{--------(i)}$$

Where A_D = Area of disc D.

T = Temp. of enclosure.

The emmissivity of the disc D is assumed to be unity, (Black disc). The radiant energy disc D is emitting into enclosure will be

$$E_1 = A_D \cdot T_D^4 \sigma \quad \text{--------(ii)}$$

Net heat input to disc. D per unit time is given by (i) -(ii)

$$E - E_1 = A_D (T^4 - T_D^4) \sigma \quad \text{-------(iii)}$$

if the disc D has a mass m and specific heat s then a short time after D is inserted in A.

$$m \cdot s \, (dT/dt)_{t=0} = \sigma A_D (T^4 - T_D^4)$$

OR

$$\sigma = \frac{m \cdot s \, (dT/dt)_{t=0}}{A_D (T^4 - T_D^4)}$$

In this equation $(dT/dt)_{t=0}$ denotes the rate of rise of temperature of the disc D at the instant when its temperature is T_D and will vary with T_D. It is clearly measured at time $t = 0$ before heat conducted from A to D begins to have any significant effect. This is obtained from plot of temperature rise of D w.r.t. time and obtaining its slope at $t=0$ when temperature is T_D. This will be the required value of dT/dt at $t = 0$. The Temperature Sensor mounted on disc is to be used for this purpose.

➡ Note that the disc D with its sleeve is placed quickly in position and start recording the temperature at fixed time intervals. The whole process must be completed in 30 seconds of time. Longer disc D is left in position the greater is the probability of errors due to heat conduction form A to D.

1. Mass of test disc (m) = 5.1 gms
2. Specific heat of disc material = 0.1 K Cal/Kgm - °C (Copper disc)

   = 0.418KJ/Kg - °C
3. T temperature of enclosure in °C = ------

   T temperature of enclosure in °K = ------
4. Temp. of disc D at the instant when it is inserted (T_D) in °K = -------
5. Temperature time response of the disc. Note down the temperature T_D at the time interval of 5 second. Plot the graph of T against as shown in figure.
6. Obtain from the graph

   (dT/dt) at t = 0 = ------ °C/Sec.

   = ------ °C/hr.
7. Value of σ can be obtained by using (3)

$$\sigma = \frac{m \cdot s\,(dT/dt)_{t=0}}{A_D\,(T^4 - T_D^4)}$$

SHELL & TUBE HEAT EXCHANGER

Aim :- Study of Shell and Tube Heat Exchanger Also Find Heat Transfer rate, L.M.T.D and overall Heat Transfer Coff.

INTRODUCTION :

Heat Exchanger 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 heat exchangers are the radiator of a car, the condenser at the back of a domestic refrigerator and the steam boiler of a thermal power plant.

Heat Exchangers are classified in three categories :

1) Transfer Type.
2) Storage Type.
3) Direct Contact Type.

A transfer type of heat exchanger is one on which both fluids pass simultaneously through the device and heat is transferred through separating walls. In practice most of the heat exchangers used are transfer type ones.

The transfer type exchangers are further classified according to flow arrangement as -

i) Single-Single Pass.
ii) 1 - 2 Parallel-Counter Flow Exchanger.
iii) 2 - 2 Pass.

A simple example of transfer type of heat exchanger can be in the form of a tube type arrangement in which one of the fluids is flowing through the inner tube and the other through the annulus surroundings it. The heat transfer takes place across the walls of the inner tube.

APPARATUS :

The apparatus consists of 1 - 2 ParallelFlow-Counter Flow heat exchangers. The hot fluid is hot water which is attained from an insulating water bath using a magnetic drive pump. and it flow through the inner tube while the cold water flowing through the annuals. The cold water passes through the heat exchanger once and hot water passes twice. 25% cut four baffles are provided at equidistance in the heat exchanger. For flow measurement Rotameters are provided at inlet of cold water and outlet of hot water line. The Hot water bath is of recycled type with Digital Temperature Controller 0 to 200°C .

SPECIFICATIONS :

1. Shell.
   - Material -M.S.
   - Inner dia. -208mm
   - Length -500mm
   - 25% cut baffles at 100 mm distance 4 Nos.

2. Tube
   - Material -Copper.
   - ID -13mm
   - OD 16mm
   - Length of tubes -500mm
   - Nos. of tubes -32

3. Temperature Controller : Digital 0 - 200°C

4. Temperature Sensors : RTD PT-100 type (4 nos.)

5. Temperature Indicator : Digital 0 to 199.9°C & 0 to 1°C Least Count with multichannel switch.

6. Electric Heater : 230 V AC 2.5 kw (2 Nos.)

7. Flow measurement : Rotameter (2 No.)

8. Water Bath : MOC SS-304 insulated with ceramic wool and powder coated MS outer Shell fitted with heating elements.

9. Pump : FHP magnetic drive pump (Max operating temp 85°C).

EXPERIMENTAL PROCEDURE :

1) Put water in bath and switch on the heaters.
2) Adjust the required temperature of hot water using DTC. (Digital. Temp. Controller)
3) Adjust the valve. Allow hot water to recycle in bath through by-pass by switching on the magnetic pump.
4) Adjust the flow rate on cold water side between range of 3 to 8 L/Min.
5) Adjust the flow rate on hot water side, between the rate of 1.5 to 4 L/min.
6) Keeping the flow rates same, wait till the steady state conditions are reached.
7) Record the temperatures on hot water and cold water side and also the flow rates accurately.
8) Repeat the experiment with a counter flow under identical flow conditions.

OBSERVATION TABLE :

S. No.	HOT WATER SIDE			COLD WATER SIDE		
	Flow rate m_h kg/hr.	T_{hi} °C	T_{ho} °C	Flow rate m_c kg/hr	T_{ci} °C	T_{co} °C
1.	24	34	36	1	37	39
2.						

Where

T_{hi} • Temperature of Hot water Input

T_{ho} • Temperature of Hot Water Output

T_{ci} • Temperature of Cold Water Input

T_{co} • Temperature of Cold Water Output

CALCULATIONS:

i) Heat Transfer rate, is calculated as

q_h = Heat Transfer rate from hot water.

= $m_h \quad C_{ph} (T_{hi} - T_{ho})$ K cal/hr.

q_c = Heat Transfer rate to the cold water.

= $m_c \, C_{pc} \; (T_{co} - T_{ci})$ K cal/hr.

$$q = \frac{(q_h + q_c)}{2} \text{ K cal/hr.}$$

(Asume $C_{ph} = C_{pc} = 1$ K cal/kg- °C)

ii) L M T D - logarithmic mean temperature difference which can be calculated as per the following formula :

$$\text{L M T D} = \Delta T_m = \frac{\Delta T_i - \Delta T_o}{\ln \; (\Delta T_i / \Delta T_o)}$$

Where ΔT_i = $T_{hi} - T_{ci}$ (for parallel flow)

= $T_{hi} - T_{co}$ (for counter flow)

and ΔT_o = $T_{ho} - T_{co}$ (for parallel flow)

= $T_{ho} - T_{ci}$ (for counter flow)

☞ Note that in a special case of Counter Flow Exchanger exists when the heat capacity rates C_c & C_h are equal, then $T_{hi} - T_{co} = T_{ho} - T_{ci}$ thereby making $\Delta T_i = \Delta T_o$. In this case LMTD is of the form 0/0 and so undefined. But it is obvious that since ΔT is constant throughout the exchanger, hence

$$\Delta T_m = \Delta T_i = \Delta T_o$$

(acc. to ref. Fundamental of Engineering Heat & Mass Transfer by R.C.Sachdeva, Pg. 499)

iii) Overall heat transfer coefficient can be calculated by using.

$$q = UA \ \Delta T_m$$

$$\therefore \quad U = q/A \ \Delta T_m \ \text{K cal / hr.-m}^2\text{-°C}$$

Calculated U_{ri} based on Ai = $\pi d_i L$

U_{ro} based on Ao = $\pi d_o L$

PRECAUTION:

1) During the complete EXPERIMENTATION open the valves of geyser before starting it.
2) Take the readings after the steady stage is reached.

$A = \pi d_o l \times M$

HEAT PIPE DEMONSTRATOR.

Aim :- Study of Heat Pipe Demonstrator and Also Compare its heat transfer rate with stainless steel pipe and Copper pipe

INTRODUCTION :

The Heat Pipe is a device which transfers heat by boiling a fluid at one end and condensing it on other end of a pipe. The evaporation and condensation processes are responsible for the nearly isothermal working of the heat pip. The condensed liquid is transferred back to boiling area by the capillary action through a wick structure in the heat pipe. This use of capillary action for pumping the liquid back, is the unique characteristic of the heat pipe.

DESCRIPTION:

The demonstrator consists of a heat pipe, a stainless steel tube and a copper pipe of identical physical properties such as diameters, and lengths.

Heat pipe is made up of stainless steel pipe. A stainless steel wire mesh of suitable mesh size is inserted in this pipe. Circumferential layers of this mesh have been used. Calculated quantity of distilled water as working fluid is introduced in the heat pipe after cleaning the pipe and mesh with hydrochloric acid, acetone and distilled water, making perfect vacuum as far as possible. The pipe is sealed after filling distilled water.

A stainless steel pipe and copper pipe are taken for comparison.

The lengths of the three members are kept equal. Band type heaters are used and mounted on the heating sections. The surface temperatures along the lengths of pipe are measured by temperature sensors while temperature of water in the condenser tank is measured by thermometers.

PROCEDURE:

1. Before using the demonstrator evacuate the heat pipe if necessary and fill about 50cc of distilled water. Fill equal amount of water in three condenser tanks so that the pipe is submerged completely in water.
2. Start the supply.
3. Give known steady input to all the three heaters with the help ~~of a~~ dimmerstat.
4. Check the input to three heaters with help of selector switch and voltmeter and ammeter.
5. Allow an initial heating period of about 15 minutes for starting up of the demonstrator.
6. Note down all the temperature along lengths of the pipes and also of the water in the tanks at the time interval of 10 minutes.
7. This procedure is to be followed for about 60 minutes to study the heat pipe demonstrator working.

LIMITS & PRECAUTIONS :

1. Operate the selector switch of the temperature indicator from 1 to 15 gently.
2. Stir the water with the stirrer before taking readings with thermometer.
3. Do not exceed 120 watts.
4. Vacuum valve should not be disturb to avoid breakage of vacuum otherwise readings will not be satisfactory.

EXPERIMENTS TO BE CARRIED OUT:

1. To demonstrate the super thermal conducting heat pipe and to compare its working with that of the best conductor i.e. Cu pipe.
2. To find and plot temperature V/s. time response of three pipes.
3. Temperature distribution along the length of three members at different time intervals can be plotted and nearly isothermal temperature distribution in case of heat pipe can be seen.

CONCLUSIONS :

Nearly isothermal nature of the temperature distribution clearly shows the very high values of effective thermal conductivity of the heat pipe over the conventional conductors viz. copper and stainless steel. This can also be observed in terms of the fast temperature rise in condenser tank and the temperature gradients present on the three members.