EXPERIMENT NO. -01

HEAT TRANSFER IN NATURAL CONVECTION

OBJECT: To determine the surface heat transfer coefficient for heated vertical cylinder in Natural Convection.

THEORY: When a hot body is kept in still air, it looses heat to the surroundings by the process of natural convection. The layer of fluid adjacent to the hot body gets heated up, as a result of which its density decreases. Due to the density difference between the heated fluid and the surrounded cooler fluid, a convective motion is initiated with a continuous motion of hot fluid flowing upwards along the plate and replacement of this fluid by the cooler fluid.

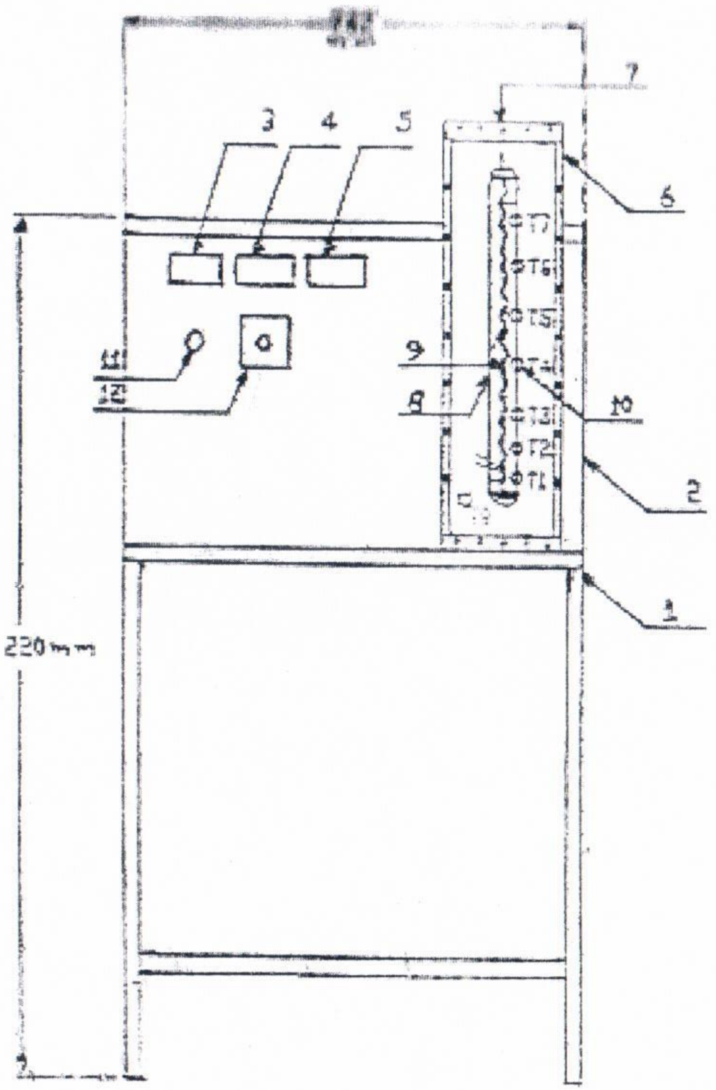
DESCRIPTION OF APPARATUS:-

The experimental apparatus consists of a vertical tube enclosed in a rectangular duct open at both top & bottom. One side of the duct is made of transparent section to facilitate visual observation. An electrical heating .element is embedded in the cooper tube along the length of tube. The temperatures are measured at different heights of tube using thermocouple. The surface of the tube is polished to minimum radiation losses. A voltmeter and an ammeter enable the determination of wattage dissipated by the heater and hence the heat input to the system.

PROCEDURE:-

1. Switch on the mains.
2. Keep the power to a lowest range at this position band switch should be in zero position.
3. Allow the unit to stabilize.
4. Switch on the band switch No.1 and see that readings should not change.
5. Note down the readings by operating the band switch . t_1,t_2, t_3, . t_4,t_5, t_6 are temperatures of the surface and t_8 is ambient temperature.
6. Repeat the experiment for different inputs and tabulates the readings for calculations.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001



1) Tube Frame
2) Panel Board
3) Digital Voltmeter, 0-300 V
4) Digital Temp. Indicator, 0-400°C
5) Digital Ammeter, 0-15 A
6) Wooden Chamber
7) Top & Bottom End Caps
8) S.S. Pipe, I.D. 39mm, O.D. 40mm, Length 450mm
9) Heater, 250 W
10) Thermocouples
11) Dimmer, 15 KW
12) Temp. Selector Switch

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

OBSERVATION:

1. Diameter of tube (d) = 0.045m
2. Length of tube (l) = 0.45m

Voltage V volts	Current I Amps	Heat Input (q) Watt.	Surface Temperature $t_1, t_2, t_3, t_4, t_5, t_6, t_7$ ^0C	Avg. surface temp. t_s	Ambient temperature. t_a	Heat transfer coefficient	Avg. heat transfer coefficient

CALCULATION:

Heat transfer coefficient is given by $h = \frac{q}{As(t_s - t_a)}$

Where

Q= Rate of heat transfer (Watt.) = V.A.

H= Heat transfer coefficient W/m^2 ^{0}C

RESULT:-

The average value of heat transfer is ________________ W/m^2 ^{0}C.

PRECAUTION:

1. Keep dimmerstate to zero position before start.
2. Increase voltage slowly.
3. Keep the assembly undisturbed while testing.
4. Do not increase voltage above 150 Volts.
5. Operate Selector switch of temperature indicator gently.
6. Take reading after the system is stabilized.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

SHORT QUESTIONS:

1. Discuss the different modes by which heat is transferred.
2. What is natural convection?
3. What is the unit of heat transfer coefficient and on what factors it depends?
4. Name the dimensionless numbers which are applied for natural convection.
5. What is the difference between natural and forced convection?

Dr. M[illegible]
Professor & [illegible]
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

EXPERIMENT NO. -02

TEST OF EMMISSIVITY MEASUREMENT APPARATUS

OBJECT: To measure the emmissivity of the test plate surface..

THEORY: An ideally black surface is one which absorbs all the radiation falling on it. It's reflectivity and transmissivity is zero. The radiation emitted per unit time per unit area from the surface of the body is called emissive power. Emissivtiy is defined as the ratio of the emissive power of the surface to the emissive power of a hypothetical black body at the same temperature. For a black body absorptive is 1 and by kirchoff's law its emissivity is 1 emissivity depends on the surface temperature and the nature of the surfaces.

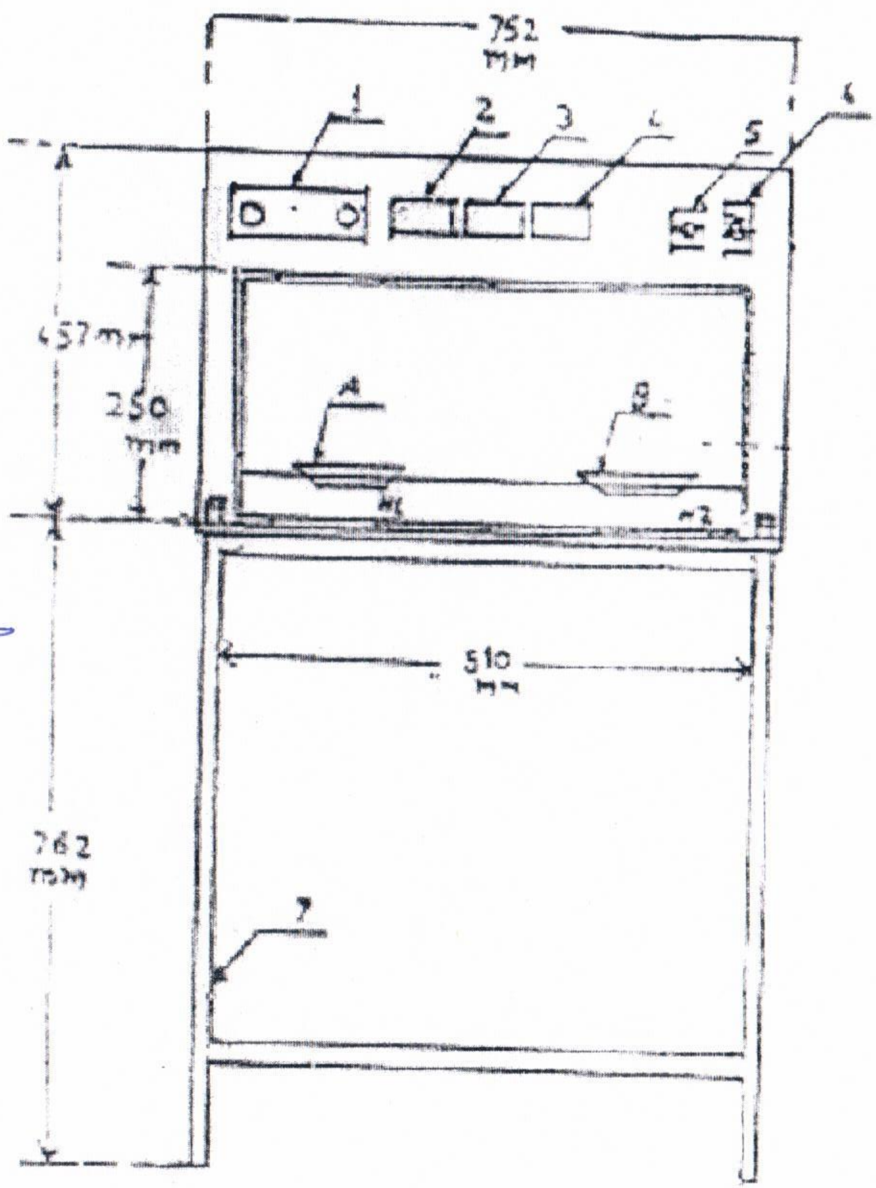
DESCRIPTION OF APPARATUS:-

The experimental set up consist of two circular lrass plate, identical is size and are provided with heating coils at the bottom. The plates are mounted on asbestos cement sheet and kept in an enclosure so as to provide undisturbed natural convection surroundings. The heat input to the heater is varied by dimmerstate and is measured by an ammeter and voltmeter. The temperature of the plates are measured by thermocouples, hence an average temperature may by taken. One thermocouple is kept in the enclosure to read the ambient (chamber) temperature. On e plate is blackened by a thick layer of lamp black to form the idealized black surface.

PROCEDURE:-

1. Switch on the power supply to the apparatus.
2. Operate the dimmers and give the power input to the black body and test surface. Adjust it to the same input conditions.
3. When steady state is reached, measure the temperatures by operating the temperature selector switch.
4. Take the temperature of black surface i.e. t_1,t_2, t_3, and also take the temperatures of the test i.e. t_3,t_5, t_6,
5. Measure the chamber temperature.
6. Repeat the experiment for different small inputs.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001



1) Heater Controller
2) Digital Voltmeter, 0-300 V
3) Temperature Indicator, 0-400°C
4) Digital Ammeter
5) Ammeter & Voltmeter Selector Switch
6) Band Switch For Thermocouples
7) Tube Frame
A) Black Surface
B) Test Surface
H1 H2. Heaters, 250 W Each

OBSERVATION:

S.No.	Black Surface V I t_1 t_2 t_3 $t_b = (t_1 + t_2 + t_3)/3$	Test Surface V I t_1 t_2 t_3 $t_s = (t_4 + t_5 + t_6)/3$	Tem. of chamber t_a	Emissivity ε

CALCULATION :

Following expression is used to find emmisivity of test surface.

Power input to the black body =P_b= $\varepsilon_b A_b \left(T_b^4 - T_a^4 \right)$ --------- (1)

Power input to the test surface =P_s= $\varepsilon \ A_s \left(T_b^4 - T_a^4 \right)$ ---------- (2)

Since power input to the black body and test surface is same, therefore equating eq" (1) & (2)

$$\varepsilon As \left(T_s^4 - T_a^4 \right) = \varepsilon_b A_b \left(T_b^4 - T_a^4 \right)$$

Since surface areas of test surface and black body are same & ε_b= 1, therefore

$$\text{Emissivity} = \varepsilon = \frac{\left(T_b^4 - T_a^4 \right)}{\left(T_s^4 - T_a^4 \right)} \quad Where \quad \varepsilon_b = 1$$

RESULTS:

1. The Emissivity of test surface at temperature______________ is ____________
2. The Emissivity of test surface at temperature______________ is ____________

PRECAUTION:

1. Keep dimmerstate to zero position before start.
2. Increase voltage slowly.
3. Keep the assembly undisturbed while testing.
4. Do not increase voltage above 150 Volts.
5. Operate selector switch of temperature indicator gently.

Dr. Munish Chha[illegible]
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

SHORT QUESTION:

1. What is thermal radiation and how it is different from conduction & convection?
2. What is the difference between black body and grey body as applied to radiation>
3. What is the range of wavelength responsible for thermal radiation?
4. State Kirchoff's law of radiation.
5. Name the factors on which the emmisivity of material depends.
6. Define monochromatic emmisivity & total emmisivity.
7. Define emmisive power & emmisivity.

Dr. Munish Chh[illegible]a
Professor & [illegible]
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

EXPERIMENT NO. -03

TEST ON PARALLEL FLOW HEAT EXCHANGER

OBJECT: To determine effectiveness, heat transfer rate and over all heat transfer coefficient in counter flow heat exchanger.

THEORY: Heat exchangers are devices in which heat is transferred from on e fluid to another. Common examples of heat exchangers are the radiator of a car, condenser at the back of domestic refrigerator etc. Heat exchangers are mainly classified into three categories: -

(I) Transfer type (II) Storage type (III) Direct contact type.

Transfer types of heat exchangers are most widely used.

Transfer type of heat exchanger is one in which both fluids pass simultaneously through the device and heat is transferred through separating walls. Transfer type of heat exchangers are further classified as:-

(a) Parallel flows type-in which fluids flow in the same direction.

(b) Counter flow type-in which fluid flow in the opposite direction.

(c) Cross flow type-in which fluid flow at any angle to each other.

Simple heat exchanger of transfer type can be in the form of a tube 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.

DESCRIPTION OF APPARATUS:-

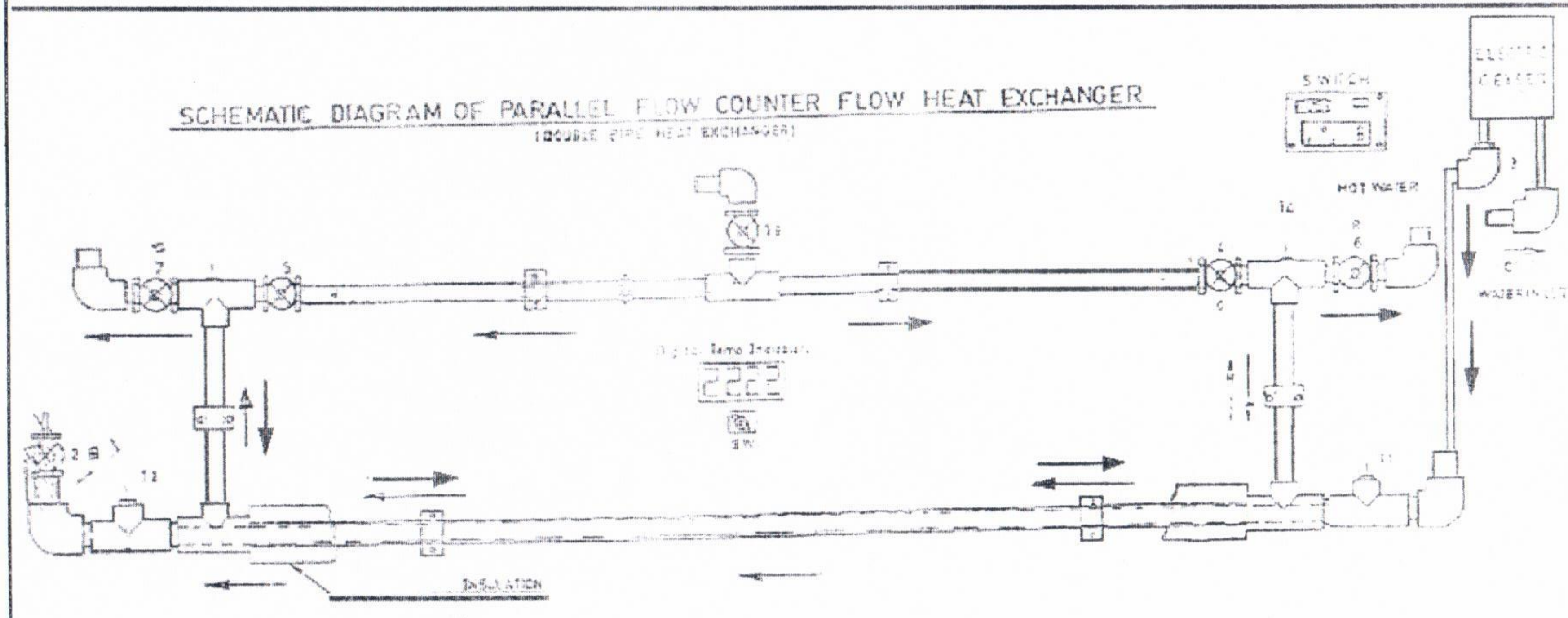
The apparatus consist of a concentric tube heat exchanger. The hot fluid i.e. hot water is obtained from an electrical geyser and it flows through the inner tube. The cold fulid i.e. cold water can be admitted at any one of the ends enabling the heat exchanger to run as a counter flow or parallel apparatus. This can be done by operating the different valves provided. Flow rate can be measured using stop clock and measuring flask. The outer tube is provided with adequate asbestos rope insulation to minimize the heat losses to the surroundings.

PROCEDURE:-

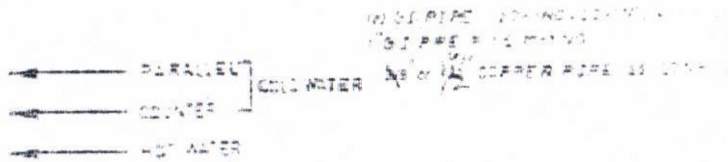
1. Keep the thermometers in position.
2. Start the flow on hot water side.
3. Start the flow on cold water side.
4. Put on the electric geyser.
5. Keep the flow rate same till the steady condition is reached.
6. Note the temperatures and measure the flow rates.
7. The experiment can be repeated for different flow rates.

SCHEMATIC DIAGRAM OF PARALLEL FLOW COUNTER FLOW HEAT EXCHANGER

(DOUBLE PIPE HEAT EXCHANGER)



VALVE NO.		PARALLEL FLOW	COUNTER FLOW
1	MAIN CONNECTION	OPEN	OPEN
2	HOT WATER	OPEN	OPEN
3	COLD WATER	OPEN	OPEN
4	VALVE ON COLD WATER SIDE	OPEN	CLOSE
5		CLOSE	OPEN
6		CLOSE	OPEN
7		OPEN	CLOSE



Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

OBSERVATION:

1. Length of heat exchanger = 1.2m
2. Surface area of heat exchanger (A) = 0.065 m^2

Hot Water			Cold Water			LMTD	Average rate heat transfer (W) $Q_{av}=(q_h+q_c)/2$	Overall heat transfer coeff. (U) $W/m^2\,^0C$	Effectiveness ε
Mass Flow (m_h) Kg/s	Inlet Temp. t_{hi}	Outlet Temp. Kg/s	Mass Flow (m_c) Kg/s	Inlet Temp. t_{ci}	Outlet Temp. t_{co}				

CALCULATION:

$$LMTD = \frac{(t_{hi} - t_{co}) - (t_{ho} - t_{ci})}{In \frac{[t_{hi} - t_{co}]}{[t_{ho} - t_{ci}]}}$$

Heat transfer from hot water (q_h) = $m_h C_h (t_{hi} - t_{ho})$

Heat transfer from cold water (q_c) = $m_c C_c (t_{co} - t_{cj})$

Where $C_h = C_c$ specific heat of water = 4.18 Kj/Kg-K

Overall heat transfer coefficient $(U) = \frac{q_{av}}{A(LMTD)}$

Effectiveness $\varepsilon = \frac{m_c C_c (t_{\infty} - t_{ci})}{C_{mm} (t_{hi} - t_{ci})}$

Where C_{min} = m C or m C (Whichever is less)

RESULTS:

1. Heat transfer rate (q_{av})= ____________________W
2. Overall heat transfer coeff. = ________________$W/m^2\,^0C$
3. Effectiveness =____________________

PRECAUTION:

1. Keep dimmer state to zero position before start.
2. Keep the assembly undisturbed while testing.
3. Do not increase voltage above 150 volts.
4. Operate selector switch of temp. indicator gently.
5. Put on geyser after water flow is started.
6. Increase voltage slowly.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

SHORT QUESTION:

1. Classify the heat exchanger and explain them in brief.
2. Give some applications of heat exchanger.
3. Show the temperature variation along the length of heat exchanger for parallel and counter flow arrangement.
4. What is meant by fouling factor? How does it affect the performance of heat exchanger?
5. Show the temperature variation along the length of heat exchanger for condensation and evaporation process.
6. Define heat exchanger effectiveness.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

EXPERIMENT No. -04

FORCED CONVECTION APPARATUS

OBJECT: To determine the heat transfer coefficient for heated tube in forced convection.

THEORY: Convection is a process involving mass movement of fluids. Thus the mechanism of convection is simply the transfer of energy by actual physical movement from one molecule to another of a fluid in which the energy is stored. When the temperature difference produces density difference which results in the mass movement, the process is called free or natural convection. When an external source such as pump or fan causes mass motion to take place, the process is called forced convection.

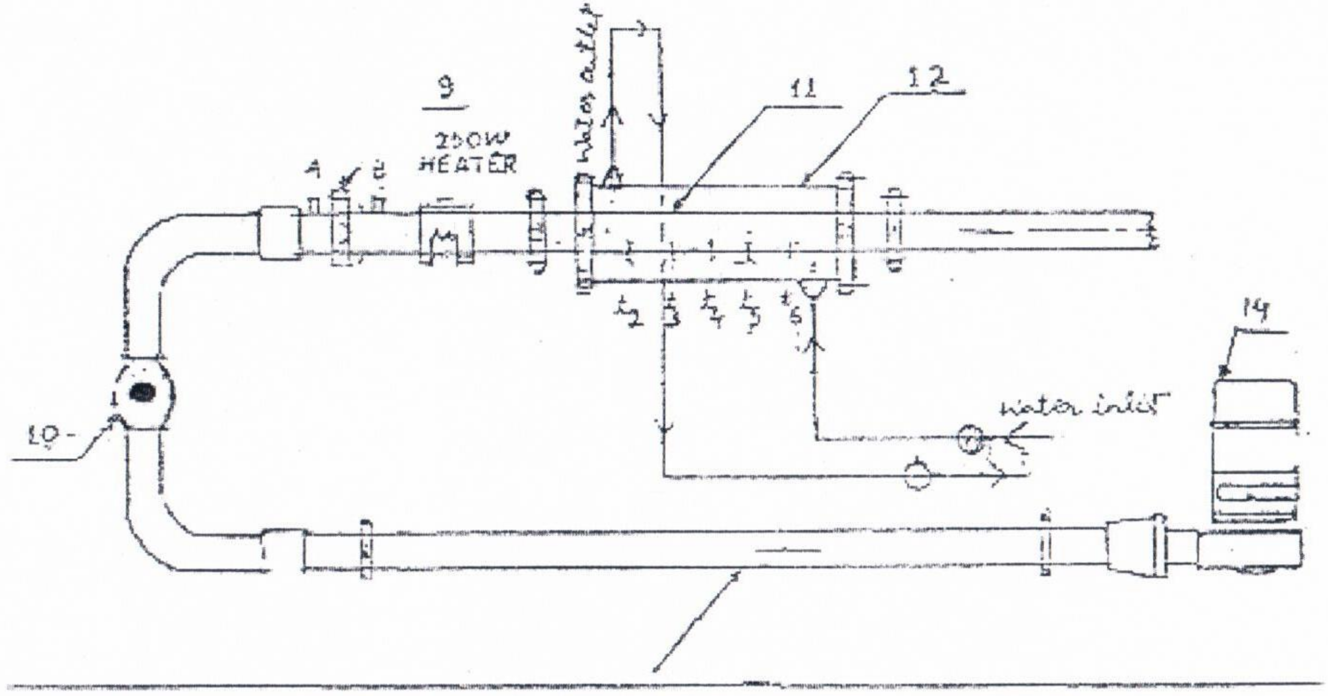
DESCRIPTION OF APPARATUS:-

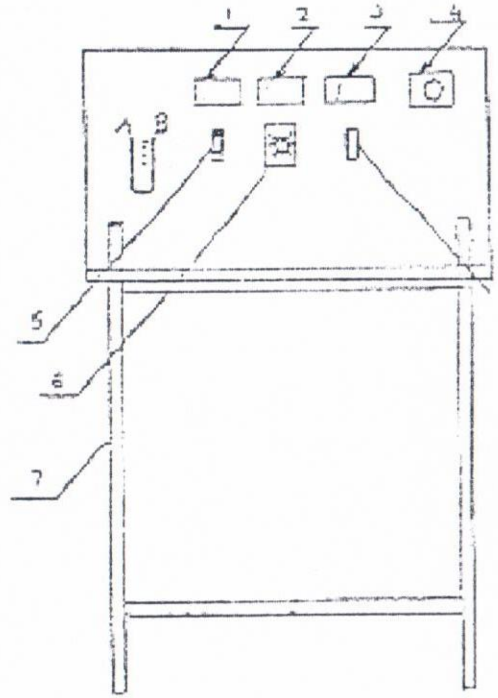
The apparatus consist of a blower for supply so air from blower passes through a flow passage and an air heater and then to the test section. Air flow is measured by an orifice meter placed near the test section. Heating of air is done by heater placed around the tube, the wattage to the heater being controlled by an electrical dimmer state. Temperature of the air at the inlet and outlet form the test sections are measured using Cr-A1 thermocouples located in the air stream. Test section was surface temperatures are measured using thermocouples embedded in the walls at different axial distance from the entrance. The test section is enclosed in a water-jacket where the circulating water removes heat from air.

PROCEDURE:-

1. The water flow rate should be enough to cause a minimum temperature rise.
2. The blower is started by keeping the valve fully open.
3. Put on heater power.
4. Water circulation is started and system is allowed to stabilize for 30. Minutes.
5. Water flow rate, heater wattage input and orifice pressure drops are recorded.
6. Air temp. at inlet(t_1) and at outlet (t_7) of test specimen are recorded.
7. Temperature at the surface of test specimen ($\mathbf{t_1, t_2, t_3, t_4, t_5, t_6}$) are taken and then average surface temp. of test specimen is determined.
8. Experiments are repeated for different heat input and air flow rate.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001





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1) Digital Voltmeter, 0-300 V
2) Temperature Indicator, 0-400°C
3) Digital Ammeter, 0-5 A
4) Dimmer, 2000W
5) 5 Amps, 2 Pin Socket
6) Selector Switch For Thermocouples
7) M. S. Frame
8) 5 Amps, 230 V Switch
9) Orifice, 20 mm Ø
10) Gate Valve
11) Test Specimen, Cu pipe, 25mm I.D., 400mm long
12) Test Specimen Jacket
13) 40mm I.D., 1m Long, G.I. Pipe
14) Blower

OBSERVATION

1. Coeff. Of discharge of orifice. (C_d) = 0.62
2. Tube diameter (d_1) = 0.04 m
3. Orifice diameter (d_2) = 0.02 m
4. Density of water (ρ_w) = 1000 Kg/m^3
5. Diameter of test specimen (d) = 0.025 m
6. Length of test specimen (1) = 0.4 m

Run NO.	Heater Wattage		Air Temp.		Reading of water manometer h_w (m)	Tube surface temperature					Avg. surface temp. of specimen t_s	Average air temp. $t_{av} = (t_1 - t_7)/2$
	V	I	t_1	t_2		t_2	t_3	t_4	t_5	t_6		
1.												
2.												

CALCULATION:

Mass Flow rate of air:-

$$m_a = \frac{C_d \frac{\pi}{4} d_1^2 d_2^2}{\sqrt{d_1^4 - d_2^4}} \rho_a \sqrt{2 \cdot g \cdot h_w \left(\frac{\rho_w}{\rho_a} - 1 \right)} \quad \text{Kg/s}$$

Where ρ_a is density of air at average temperature of air.

Heat lost by air = heat transferred across test specimen surface.

$Q = m_a C_{pa} (t_1 - t_7) = h.A_s (t_{av} - t_s)$

Therefore $$h = \frac{m_a C_{pa} (t_1 - t_7)}{A_s (t_{av} - t_s)}$$

Where C_{pa} is specific heat of air at the average temperature of air (t_{av}).

A_s is surface area of test specimen = $\pi d1$

Results:

Run No. 1. Heat transfer coeff. Is 14.78

Run No. 2. Heat transfer coeff. Is 13.62

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

PRECAUTION:

1. Keep dimmer state to zero position before start.
2. Keep the assembly undisturbed while testing.
3. Do not increase voltage above 150 volts.
4. Operate selector switch of temp. indicator gently.
5. Keep the water flow rate enough to cause minimum temperature rise.
6. Check the valve is open before the blower is started.
7. Increase voltage slowly.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

SHORT QUESTIONS:

1. Define forced convection?
2. What is Newton's law of cooling?
3. List the various factors on which the value of heat transfer coefficient depends.
4. Define the Nusselt Number?
5. Name the dimensionless numbers which are applied for forced convection?

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

EXPERIMENT No. -05

PIN FIN APPARATUS

OBJECT: To determine the heat transfer coefficient at the fin surface, temperature distribution and efficiency of fin in forced convection.

THEORY: In many engineering situations, means are often sought to improve heat dissipation from a surface to its surrounding. The Newton-Rikhman relation Q = hA (t-ta) reveals that the convective heat flow can be enhanced by increasing h, surface area "A" and the temperature difference (t-ta). the surface area exposed to surroundings is frequently increased by the attachment of protrusions can take a variety of forms. A pin fin is an extended surface of circular cross section which may be uniform or non-uniform. Thus a pin fin represents a thin cylindrical or conical rod protruding from a wall.

DESCRIPTION OF APPARATUS:-

The apparatus consist of a pin fin placed in side an open duct, the one side is open and other end of the duct is connected to the suction side of the blower. The air flow rate can be varied by operating the gate valve and can be measured on the mercury 'U' tube manometer connected to orifice meter. A heater is connected to the base of fin and five thermocouple is left in the duct to measure temperature of air. The panel of the apparatus consists of voltmeter, ammeter, digital type temperature indicator, dimmer to control power input to heater, thermocouple selector switch.

PROCEDURE:-

1. Switch on the mains.

2. Keep the thermocouple selector switch is zero position.

3. Turn the dimmer knob clockwise and set the power input to heater to any desired value.

4. Switch on the blower switch mounted on the blower.

5. Set the air flow rate to any desired value.

6. Note down the difference in level in U tube mercury manometer.

7. Allow the unit to stabilize.

8. Note down the temperatures along the length of fin (t_1, t_2, t_3, t_4, t_5,) and air temperature ($t_6=t_\infty$).

9. Repeat the experiment by:

(a) Varying the air flow rate and keeping the power input to the Heater constant.

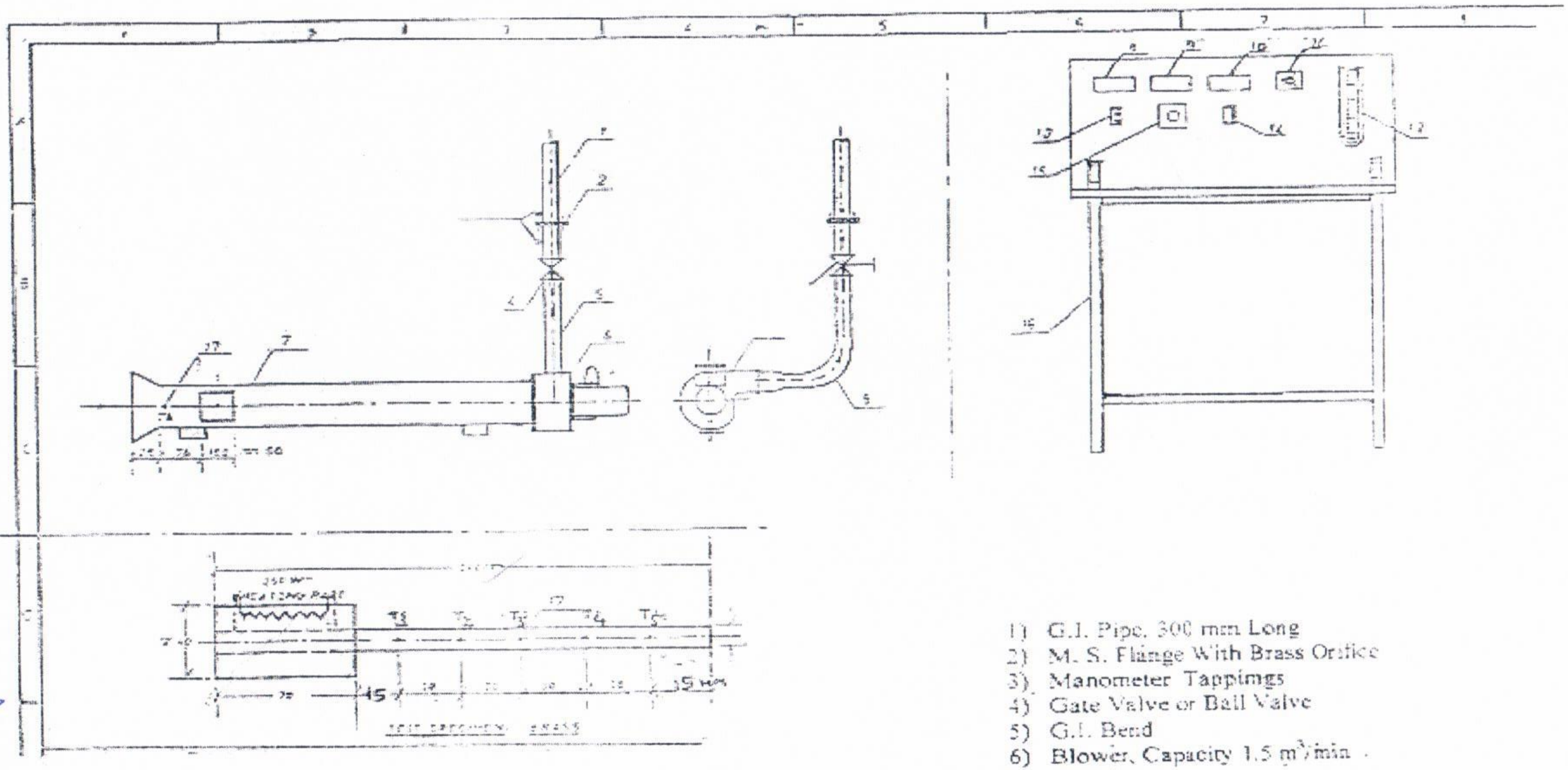
(b) Varying the power input to the heater and keeping the air flow rate constant.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Techno...
Moradabad - 24...

PRECAUTION:

1. Keep dimmer state to zero position before start.
2. Increase voltage slowly.
3. Keep the assembly undisturbed while testing.
4. Do not increase voltage above 150 volts.
5. Operate selector switch of temperature indicator gently.
6. Read the mercury level in manometer carefully.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001



1) G.I. Pipe, 300 mm Long
2) M. S. Flange With Brass Orifice
3) Manometer Tappimgs
4) Gate Valve or Ball Valve
5) G.I. Bend
6) Blower, Capacity 1.5 m^3/min
7) M.S. Duct
8) Digital Voltmeter
9) Digital Temperature Indicator
10) Digital Ammeter
11) Thermocouple Selector Switch
12) 'U' Tube Manometer
13) Heater Plug Socket
14) Blower On Switch
15) Dimmer
16) Tube Frame
17) Thermocouple For Chamber Temperature

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

OBSERVATION :

i/o_m = Density of mercury $=136.6\times10^3$ Kg/m^2

ii.d_1 = diameter of pipe = 0.038 m

iii.d_2 =Diameter of orifice = 0.02 m

iv.w = Width of duct = 0.15 m

v.b = Breadth of duct = 0.1 m

vi.d_f = Characteristic length of fin (outside dia. of fin) = 0.012 m

vii.L = Length of fin = 0.15 m

viii.K_b = Thermal conductivity of fin material (Brass) = 107 W/m-K

S.No.	V Volt	A Amp	Manometer Reading h_m (m)	Temperatures along axis of fin t_1, t_2, t_3, t_4, t_5, t_6	Temp of air $t_6 = t_\infty$

CALCULATION:-

1. ***Calculation for heat transfer coefficient***

Velocity of air at orifice $$v_o = C_d \frac{d_1^2}{\sqrt{d_1^4 - d_2^4}} \sqrt{2.g.h_m\left(\frac{p_m}{p_a}-1\right)}$$

Velocity of air in the duct $$v_a = \frac{v_o \pi / 4 . d_2^4}{w.b}$$

Reynolds no. of air flow in the duct $$\text{Re} = \frac{d_{eq} v_a p_a}{\mu_a}$$

Where $d_{eq} = \dfrac{2.b.w}{b+w}$ is equivalent or hydraulic diameter and p_a and μ_a are density and viscosity of air at the temp. of air.

Depending upon the value of Reynolds No., following expressions are used to find out Nusselt No.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

$$Nu = 0.903\ Re^{0.33}\ Pr^{1/3} \qquad if\ 1 < Re < 4$$

$$Nu = 0.911\ Re^{0.385}\ Pr^{1/3} \qquad if\ 4 < Re < 40$$

$$Nu = 0.683\ Re^{0.466}\ Pr^{1/3} \qquad if\ 40 < Re < 4000$$

$$Nu = 0.193\ Re^{0.618}\ Pr^{1/3} \qquad if\ 4000 < Re < 40000$$

$$Nu = 0.0266\ Re^{0.805}\ Pr^{1/3} \qquad if\ Re > 4000$$

Following expression is used to calculated heat transfer coefficient

$Nu = \frac{h.d_f}{K_a}$ Where K_a is thermal conductivity of air at temperature of air.

2. ***Calculation for temperature distribution in fin:***

$\frac{t - t_\infty}{t_s - t_\infty} = \frac{\cosh M(L-x)}{CoshML}$ where $M\sqrt{\frac{h.p}{K_b A}}$ here P-perimeter of fin = πd_f

A= Cross sectional area of fin = $\pi/4\, d_f^2$

3. ***Calculation for fin efficiency***

$$\eta = \frac{Tanh(M.L)}{ML}$$

Results:

1. Heat transfer coefficient (h) = ______________
2. Temperature distribution in fin = ______________
3. Efficiency of fin = ______________

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

SHORT QUESTIONS:

1. What are various types of fins?
2. Discuss some of the important application s of the fin?
3. Point out the various factors which need consideration for the optimum design fin?
4. What is efficiency of fin?
5. What is effectiveness of fin?
6. Define Prandtl No.?

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

EXPERIMENT No. -06

TEST ON COUNTER FLOW HEAT EXCHANGER

OBJECT: To determine effectiveness, heat transfer rate and over all heat transfer coefficient in counter flow heat exchanger.

THEORY: Heat exchangers are devices in which heat is transferred from on e fluid to another. Common examples of heat exchangers are the radiator of a car, condenser at the back of domestic refrigerator etc. Heat exchangers are mainly classified into three categories: -

(I) Transfer type (II) Storage type (III) Direct contact type.

Transfer types of heat exchangers are most widely used.

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(b) Counter flow type-in which fluid flow in the opposite direction.

(c) Cross flow type-in which fluid flow at any angle to each other.

Simple heat exchanger of transfer type can be in the form of a tube 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.

DESCRIPTION OF APPARATUS:-

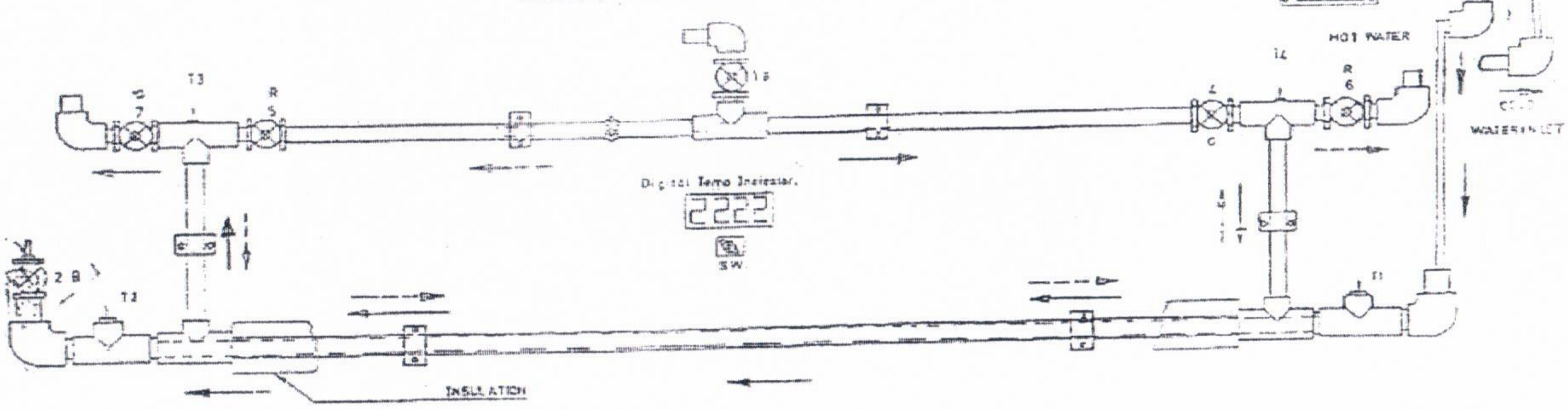
The apparatus consist of a concentric tube heat exchanger. The hot fluid i.e. hot water is obtained from an electrical geyser and it flows through the inner tube. The cold fulid i.e. cold water can be admitted at any one of the ends enabling the heat exchanger to run as a counter flow or parallel apparatus. This can be done by operating the different valves provided. Flow rate can be measured using stop clock and measuring flask. The outer tube is provided with adequate asbestos rope insulation to minimize the heat losses to the surroundings.

PROCEDURE:-

1. Keep the thermometers in position.
2. Start the flow on hot water side.
3. Start the flow on cold water side.
4. Put on the electric geyser.
5. Keep the flow rate same till the steady condition is reached.
6. Note the temperatures and measure the flow rates.
7. The experiment can be repeated for different flow rates.

SCHEMATIC DIAGRAM OF PARALLEL FLOW COUNTER FLOW HEAT EXCHANGER

(DOUBLE PIPE HEAT EXCHANGER)



VALVE NO.		PARALLEL FLOW	COUNTER FLOW
1	MAIN CONNECTION	OPEN	OPEN
2	HOT WATER	OPEN	OPEN
3	COLD WATER	OPEN	OPEN
4	VALVE ON COLD WATER SIDE	OPEN	CLOSE
5		CLOSE	OPEN
6		CLOSE	OPEN
7		OPEN	CLOSE

PARALLEL } COLD WATER
COUNTER
HOT WATER

G I PIPE

COPPER PIPE

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

OBSERVATION:

1. Length of heat exchanger = 1.2m
2. Surface area of heat exchanger (A) = 0.065 m^2

Hot Water			Cold Water			LMTD	Average rate heat transfer (W) $Q_{av}=(q_h+q_c)/2$	Overall heat transfer coeff. (U) $W/m^{2}\,^{0}C$	Effective-ness ε
Mass Flow (m_h) Kg/s	Inlet Temp. t_{hi}	Outlet Temp. Kg/s	Mass Flow (m_c) Kg/s	Inlet Temp t_{ci}	Outlet Temp t_{co}				

CALCULATION:

$$LMTD = \frac{(t_{hi} - t_{co}) - (t_{ho} - t_{ci})}{\ln \frac{[t_{hi} - t_{co}]}{[t_{ho} - t_{ci}]}}$$

Heat transfer fram hot water $(q_h) = m_h C_h (t_{hi} - t_{ho})$

Heat transfer fram cold water $(q_c) = m_c C_c (t_{co} - t_{cj})$

Where $C_h = C_c$ specific heat of water = 4.18 Kj/Kg-K

Overall heat transfer coefficient $(U) = \frac{q_{av}}{A(LMTD)}$

Effectiveness $\varepsilon = \frac{m_c c_c (t_{\infty} - t_{ci})}{C_{mm} (t_{hi} - t_{ci})}$

Where C_{min} = m C or m C (Whichever is less)

RESULTS:

1. Heat transfer rate (q_{av})= ____________________W
2. Overall heat transfer coeff. = ________________$W/m^2\,^0C$

PRECAUTION:

1. Keep dimmer state to zero position before start.
2. Keep the assembly undisturbed while testing.
3. Do not increase voltage above 150 volts.
4. Operate selector switch of temp. indicator gently.
5. Put on geyser after water flow is started.
6. Increase voltage slowly.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

EXPERIMENT No. -07

HEAT FLOW THROUGH THE LAGGED PIPE

OBJECT: To determine heat flow rate through the lagged pipe and thermal conductivity of lagging material.

THEORY: Multi-layer cylindrical walls are frequently employed to reduce heat losses from metallic pipes meant for handing hot fluid. The pipe is generally wrapped in one or more layers of heat insulation e.g. a steam pipe used for conveying high pressure stream in a steam power plant may have cylindrical metal wall, a layer of insulting material and then a layer of protecting plaster. The arrangement is called lagging of the pipe system.

DESCRIPTION OF APPARATUS:-

The apparatus consists of three concentric pipes mounted on suitable stand. The hollow space of the innermost pipe consist of the heater. Between first two cylinders the insulating material with which lagging is to be done is filled completely. Between second and third cylinders, another material used for lagging is filled. The third cylinder is concentric to an other outer cylinder, water flows between these two cylinders. The thermocouples are attached to the surface of cylinders appropriately to measure the temperatures. The input to heater is varied through a dimmerstate and measured on voltmeter and ammeter.

PROCEDURE:-

1. Switch on the mains.
2. Start the supply of heater and by varying dimmer state adjust the input for desired value by using .voltmeter and ammeter.
3. Also start water supply.
4. Allow the unit to stabilize.
5. Take readings of all the six thermocouples.
6. Note down steady readings in observation table.
7. Repeat the experiment for different input of heater.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

OBSERVATION:

1. Inner pipe radius (r_1) = 0.03m
2. Outer Pipe radius (r_o) = 0.0535 m
3. Mean radius of middle pipe = 0.0425 m
4. Length of the pipe (l) = 1m

S.No.	V(Volt)	I(Amp)	t_1 t_2 $t_i - (t_1+t_2)/2$	t_3 t_4 $t_m - (t_3+t_4)/2$	t_5 t_6 $t_{Co} - (t_5+t_6)/2$

CALCULATION :

K_1 (Thermal conductivity of asbestos powder)

$$k_1 = \frac{q.1_n(r_m/r_i)}{2.\pi 1.(t_i - t_m)} \quad \text{W/m K}$$

K_2 (Thermal conductivity of saw dust)

$$k_2 = \frac{q.1_n(r_o/r_m)}{2.\pi 1.(t_m - t_o)} \quad \text{W/m K}$$

Now heat flow rate through the composite cylinder can be found using following relation:

$$q = \frac{t_i - t_o}{\frac{1}{2.\pi.1}\left[\frac{1}{k_1} 1_n\left(\frac{r_m}{r_i}\right) + \frac{1}{k_2} 1_n\left(\frac{r_o}{r_m}\right)\right]} W$$

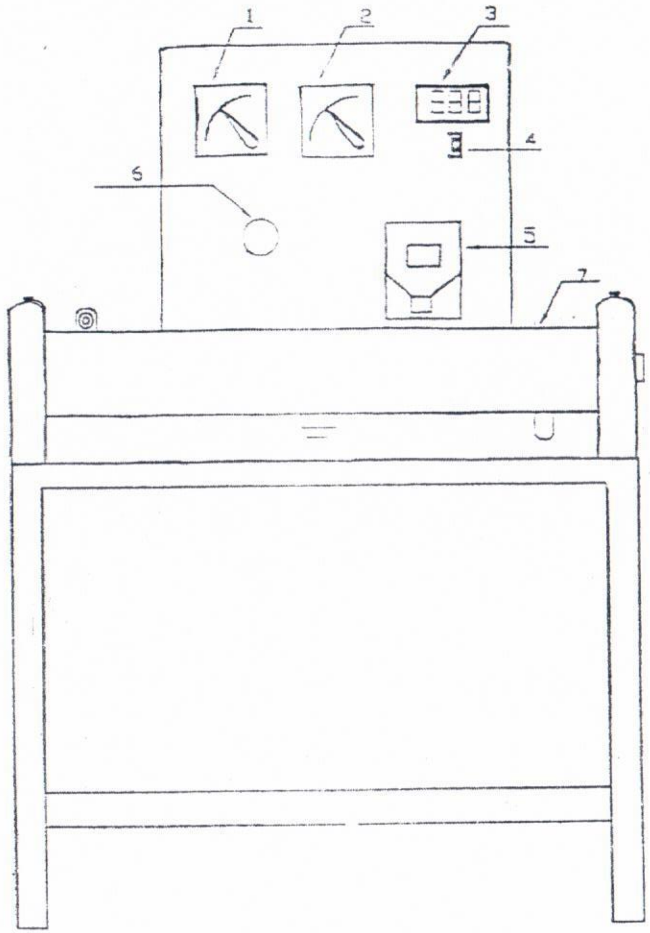
RESULTS

1. Thermal conductivity of asbestos powder.
2. Thermal conductivity of saw dust.
3. Heat flow through the composite cylinder.

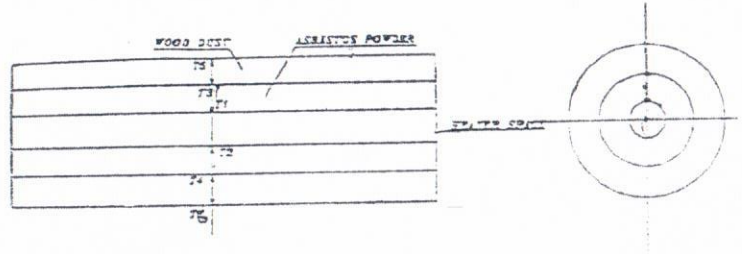
PRECAUTION:

1. Keep dimmer state to zero position before start.
2. Increase voltage slowly.
3. Keep the assembly undisturbed while testing.
4. Do not increase voltage above 150 volts.
5. Operate selector switch of temp. Indicator gently.

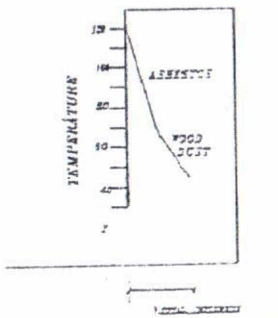
Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001



1. VOLTMETER
2. AMMETER
3. TEMP. INDICATOR
4. SELECTOR SWITCH
5. MAIN SWITCH
6. HEATER CONTROL
7. ASSEMBLY



1 TO 6 THERMOCOUPLES FITTING



GRAPH OF TEMPERATURE GRADIENT

LAGGED PIPE APPARATUS

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

SHORT QUESTIONS:

1. What is the unit of thermal conductivity?
2. What is lagging?
3. Why lagging is required in pipe system?
4. What are common insulating materials used for lagging?
5. What are the insulating materials used in experiment?
6. What is the effect of temperature on thermal conductivity of metals and non- metallic amorphous solids?
7. What do you understand by critical thickness of insulation?

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

EXPERIMENT No. -08

COMPOSITE WALL APPARATUS

OBJECT: To determine total thermal resistance of composite wall and also plot temperature gradient along thickness of composite wall

THEORY: A composite wall refers to a wall of several heterogeneous layers e.g. walls of dwelling houses where bricks are given a layer of plaster on either side. Likewise walls of furnaces, boilers and other heat exchange devices of several layers. The current flow in a conductor is governed by the voltage potential and electrical resistance of the material. Like wise heat flow in a material is governed by temperature potential and thermal resistance of material. The concept of thermal resistance is advantageously applied while making computing for heat flow in a composite wall.

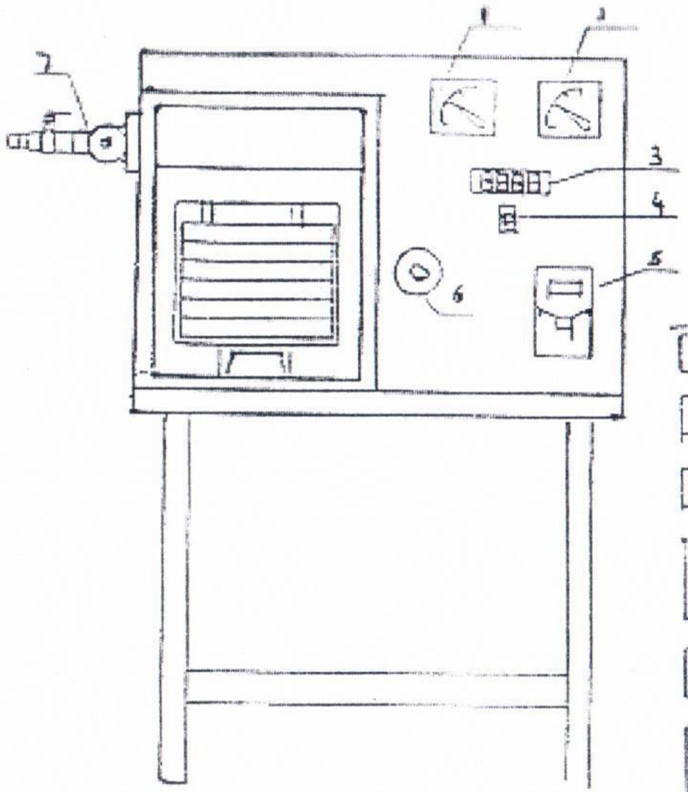
DESCRIPTION OF APPARATUS:-

The apparatus consists of a plates of different materials sandwiched between two aluminum plates three type of slabs are provided on both sides of heater which forms a composite structure. A small hand press frame is provided to ensure the perfect contact between the slabs. A dimmers stat is provided for verying the input to heater and measurement of input is carried out by a voltmeter and ammeter. Thermocouples are embedded between interfaces of slabs, to read the temperature at the surface.

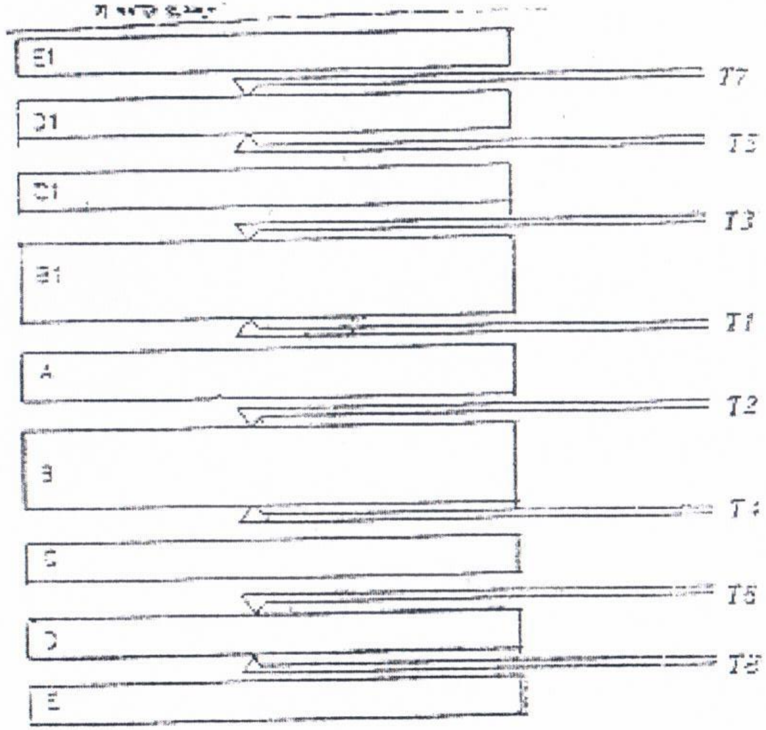
PROCEDURE:-

1. Arrange the plates properly on both side of heater plate.
1. Operate the hand press properly to ensure perfect contact between the plates.
2. Close the box by cover sheet to achieve steady environmental conditions.
3. Start the supply of water.
4. By varying the dimmer state adjust the input wattage.
5. Let the system to stabilize for 30 minutes.
6. Take readings of all the thermocouples after the steady sate is reached.
7. Record the readings in observation table.
8. Repeat the experiment by varying heat supplied

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001



1) VOLTMETER
2) AMMETER
3) TEMP. INDICATOR
4) THUMBWILL SWITCH
5) MAIN SWITCH
6) HEATER CONTROL
7) WATER SUPPLY



Thermocouple setting

COMPOSITE WALLS APPARATUS

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

OBSERVATION:

Wall thickness of plates:-

1. Mild Steel = 2.5 cm
2. Bakelite = 1.0 cm
3. Brass = 1.0 cm

S.No.	V(Volt)	I(Amp)	t_1 t_2 $t_A-(t_1+t_2)/2$	t_3 t_4 $t_B-(t_3+t_4)/2$	t_5 t_6 $t_C-(t_5+t_6)/2$	t_7 t_8 $t_D-(t_7+t_8)/2$

CALCULATION:

Total thermal resistance of composites slab:

$$R_{total} = \frac{t_A - t_D}{q} \deg/w$$

Where q = V.I

RESULT:

Total thermal resistance of composite slab is ________________ deg/W

PRECAUTION:

1. Keep the dimmer state zero before start.
2. Increase voltage slowly.
3. Keep all the assembly undisturbed.
4. Remove air gap between plates by moving hand press gently.
5. When removing the plates, do not disturb the thermocouples.
6. Do not increase voltage above 200 V.
7. Operate selector switch of temperature indicator slowly.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

EXPERIMENT No. -09

HEAT PIPE EXPERIMENT

OBJECT: To compare the heat transfer rate by plotting following graph using heat pipe apparatus.

(1) Plot the graph of heat sink water temperature rise for pipes.

(2) Plot longitudinal temperature distribution for pipes.

THEORY: Heat pipe is used to transfer heat from one location to another. It works with the help of evaporation and condensation of water which is filled inside the heat pipe as a working medium. Heat pipe is evacuated and partially filled with water. When heat is applied at lower end of pipe, water inside it evaporates and vapor passes to upper end of pipe. The vapor condenses giving its latent heat of evaporation to surrounding medium. the condensed vapor returns to bottom through the mesh packing. Thus because of circulation of vapor, heat pipeoperates at near to isothermal operation and conducts much heat than conventional conductors, Rapid rise of temperature of water in the heart sink of heat pipe clearly demonstrates high (apparent) thermal conductivity of heat pipe.

DESCRIPTION OF APPARATUS:-

The experimental apparatus consists of three pipes viz a heat pipe, copper pipe, and stainless steel pipe. All the pipes have same physical dimensions. Copper and stainless steel pipes serve the purpose of comparison of heat pipe performance with copper pipe as good conductor of heat and with stainless steel pipe as same material of construction. All pipes are mounted vertically with a hand heater at lower end and water filled heat sink at upper end. The power to all the three heaters is supplied by the same dimmer state, so that power input to all the heaters remains same.

PROCEDURE:-

1. Fill up sufficient water in heat sinks.
2. Keep dimmer state at zero position and start the electric supply to the unit.
3. Increase the dimmer so that power is supplied to heaters.
4. Note down the temperature of water in heat sinks every 5 minutes (stir the water before noting down the temperature)
5. After around 30 minutes, note down the longitudinal temperature of the pipes.
6. Plot the graph of heat sink water temperature rise for all the pipes.
7. Plot longitudinal temperature distribution for pipes.
8. Compare the heat transfer rate with the help of graph.
9. Repeat the experiment at different heat inputs.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

OBSERVATION:

(1) HEAT SINK WATER TEMPERATURE

Time (Minutes)	Heat Pipe	Stainless Steel Pipe	Copper Pipes
5			
10			
15			
20			
25			
30			

(2) LONGITUDINAL TEMPERATURE DISTRIBUTION

Heat Pipe	Stainless Steel Pipe	Copper Pipes
T_1	T_6	T_{11}
T_2	T_7	T_{12}
T_3	T_8	T_{13}
T_4	T_9	T_{14}
T_5	T_{10}	T_{15}

RESULT: Discuss the nature and behavior of graphs drawn for all the pipes.

PRECAUTION:

1. Keep dimmer state to zero position before start.
2. Increase voltage slowly.
3. Keep the assembly undisturbed while testing.
4. Proper earthing is necessary.
5. Stir the water before noting the water temperature in heat sink.
6. Do not remove water from heat sinks till the pipes become cool.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

QUESTIONS:

1. What is a heat pipe?
2. Discuss the construction of heat pipe?
3. Why the surface of heat pipe is almost isothermal?
4. What is the reason of high heat transfer rate through heat pipe?

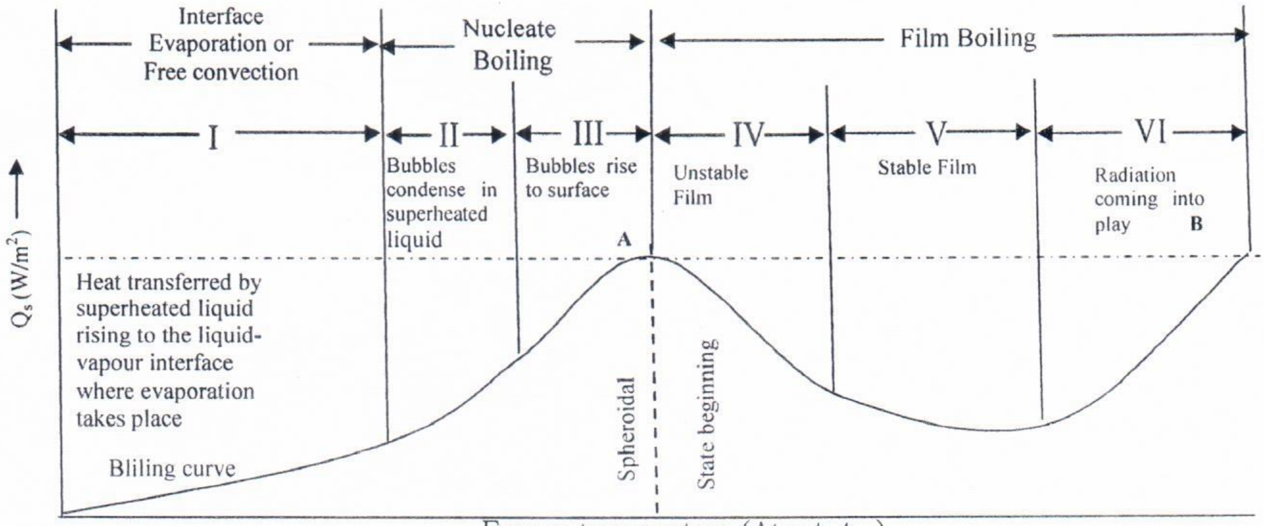
Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

EXPERIMENT No. -10

CRITICAL HEAT FLUX APPARATUS

OBJECT : To Study the pool boiling phenomenon up to critical heat flax point.

THEORY :.When heat is added to a liquid from a submerged solid surface which is at a temperature higher than th saturation temperature of the liquid, it is usual for a part of the liquid to change phase. This change c phase is called boiling. Boiling is of various types which are shown in Fig. 1. in this Fig.1. the heat flu supplied to the surface is plotted against excess temperature ($\Delta t = t_s - t_{sat}$) i.e. difference between th temperature of the surface and the saturation temperature of the liquid.



The Boiling curve for water

DIFFERENT TYPE OF BOILING:-

1. Interface Evaporation: The boiling takes place in a thin layer of liquid which adjoins the heat surface. The liquid in the immediate vicinity of the wall become superheated and th superheated liquid rises to the liquid-vapor interface where evaporation takes place.

2. Nucleate Boiling: With the increase in Δt, the formation of bubbles on the surface starts certain favorable spots called nucleation or active sites. The nucleation boiling is th characterized by the formation of bubbles at the nucleation sites and the resulting liqu agitation. The bobble agitation induces considerable fluid mixing and that promotes substant increase in the heat flux.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

3. Film Boiling: In this region the bubble formation is very rapid. The bubbles blanket the heating surface and prevent the fresh liquid to come near the heated surface. Eventually the bubbles coalesce and form a vapor film which covers the surface completely. Insulating effect of the vapor film drops the heat flux going away from the heated surface.

The burn out point A on the boiling curve represents the point of maximum heat flux at which transition occurs from nucleate to film boiling. The maximum heat flux is called the critical heat flux. The point A is also called boiling crises because the boiling process beyond this point is unstable till the point B is reached. The temperature at point B is extremely high and normally above the melting of the solid. So if the heating of the metallic surface is not limited to point A it is possible that the metal may get damaged or it may even be melt.

DESCRIPTION OF APPARATUS:

The apparatus consist of a cylindrical glass housing the test heater and heater coil for heating the water. The heater coil is directly connected to the mains and the test wire is also connected to mains via variac, an ammeter is connected in series and a voltmeter in parallel to read the current and voltage respectively. The glass container is kept on a stand. There is provision of observing the test heater wire with the help of a lamp light from back and the boiling phenomenon on the surface of wire can be observed through a lense

PROCEDURE:-

1. Take sufficient amount of distilled water in the container.
2. See that both the heaters are completely submerged.
3. Connect the heater coil R-1 and test heater wire across the studs and make the necessary electrical connections.
4. Keep it on the required bulk temperature of water in the container is obtained say 50^0C, 60^0C, 70^0C.
5. Switch off the heater R-1.
6. Gradually increase the voltage across test heater by slowly changing the variac position and stop a while at each position to observe the boiling phenomenon wire.
7. Go on increasing the voltage till wire breaks and carefully note the voltage and current at this point.
8. Repeat the experiment by altering the bulk temperature of water.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

OBSERVATION:

1. Diameter of test heater wire (d) = 0.17mm
2. Length of test heater wire (L) = 0.1 m
3. Surface area of wire, $A = \pi d L$ = ...m^2

S.No.	Bulk Temperature of Water, ^0C	Experimental critical heat flux			Theoretical critical heat flux using Zuber equation
		I, Amp	V, Volt	$\frac{Q}{A} = \frac{VI}{A}$	
1.	40^0 C				
2.	50^0 C				
3.	60^0 C				

CALCULATION :

Critical heat flux can be determined theoretically by using the expression given by Zuber.

$$q = \frac{Q}{A} = 0.18 h_{fg} (p_v)^{1/2} \left[g \sigma (p_l - p_v) \right]^{1/4} W/m^2$$

Where h_{fg} = Latent heat of vaporization J/Kg. (From Steam Table)

σ = Liquid vapor surface tension, N/m (From Table)

P_l = Density of liquid, Kg/m^3 (From Steam Table)

P_v = Density of vapor, Kg/m^3 (From Steam Table)

The above values are taken at bulk temperature of warter.

RESULT:

1. The experimental value of critical heat flux at 40^0 C bulk temperature of water is = ...W/m^2
2. The experimental value of critical heat flux at 50^0 C bulk temperature of water is = ...W/m^2

PRECAUTION:

1. Keep the variac to zero voltage position before starting this experiment.
2. Take sufficient amount of distilled water in the container so that both the heaters are completely immersed.
3. Do not touch the water or terminal points when the main switch is on.
4. Operate the variac gently in steps and sufficient time in between.
5. After the attainment of critical heat flux, decrease the voltage slowly and bring it to zero position.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

SHORT QUESTIONS:

1. What is boiling? When does it occur?
2. Explain pool boiling flow does it differ from forced convection boiling?
3. Define critical heat flux and boiling crisis.
4. When does radiation play role in boiling heat transfer? What is Leindenfrost effect?
5. Which boiling region is preferred in industrial boilers?
6. Explain the phenomenon of nucleate boiling list the factors that affect nucleate boiling?

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

EXPERIMENT NO. -11

THERMAL CONDUCTIVITY OF INSULATING POWDER

OBJECT : To determine the thermal conductivity of an insulating powder .

THEORY : There are many heat exchange equipments where heat loss to surrounding to surrounding is to be minimized. In such cases they are converted by materials of lower thermal conductivity, called as insulators. These materials are available in different shapes, sizes and forms. One important class of these materials is in the form of powders. The advantage of using them is that they can take any complicated shape between any two confining surfaces. In addition its conductivity will be much lower than that of the solid form of the same material. This is because of a very large number of air spaces, which have very low thermal conductivity, in between the particles of powder. Thermal conductivity of such material is a complicated function of the geometry of the particles, thermal conductivity of particle, the nature of heat transfer, in air spaces which is determined by the air space size and temperature level etc. thus it is very difficult quality to estimate and in almost all practical cases it is measured experimentally.

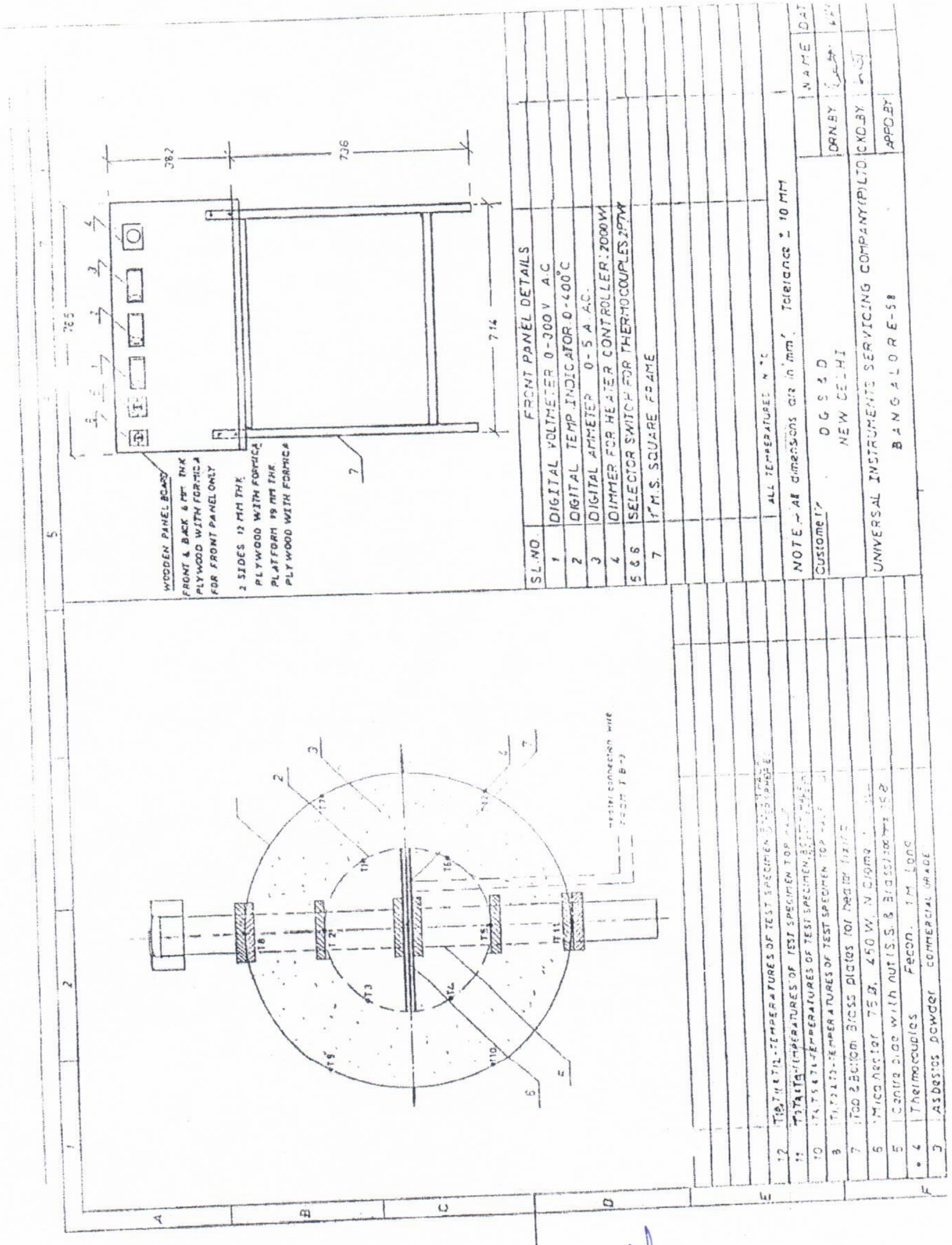
DESCRIPTION OF APPARATUS:-

The experimental apparatus consists of two concentric copper spheres between which the insulating powder, whose thermal conductivity is to be determined, is filled. Heater is provided inside the inner sphere for uniform heating of the spheres and six thermocouples are provided in each of the tow spheres to measure the temperature difference across the powder specimen. Provision has been made to measure the heat input.

PROCEDURE:-

1. Switch on the mains.
2. Switch on the Heater.
3. Set the dimmer to suitable value of voltage.
4. Allow the unit to stabilize for half an hour.
5. Note the readings of heat input to heater.
6. Note the temperature at the inner sphere surface of inner sphere, ie., $t_1, t_2, t_3, t_4, t_5, t_6$ and then average temperature of the inner sphere surface is determined.
7. Note the temperature at the surface of outer sphere, ie., $t_7, t_8, t_9, t_{10}, t_{11}, t_{12}$ and then average temperature of the outer sphere surface is determined.
8. Note the geometrical data of the set up.
9. Repeat the experiment for different inputs and tabulate the readings for calculations.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001



Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

OBSERVATION:

1. Radius of inner sphere (r_i) = 50 mm.
2. Radius of outer sphere (r_o) = 100 mm.

S.No.	V	I	Heat Input (q) Watt.	Thermocouple Readings			
				Inner Sphere t_1 t_2 t_3 t_4 t_5 t_6 °C	Avg t_i °C	Outer Sphere t_7 t_8 t_9 t_{10} t_{11} t_{12} °C	Avg. t_o °C
1.							
2.							
3.							

Thermal Conductivity of powder is given by:

$$k = \frac{q \times (r_o - r_i)}{4 \pi r_i r_o (t_i - t_o)}$$

Where:

q= Rate of heat transfer (watt) = **V. A**

k= Thermal Conductivity, **W/m - °C**

RESULT : The average value of thermal conductivity is .... **W/m - °C**

PRECAUTION:

1. Keep dimmerstate to zero position before start.
2. Increase voltage slowly.
3. Keep the assembly undisturbed while testing.
4. Do not increase voltage above 150 Volts.
5. Operate Selector switch of temperature indicator gently.
6. Take reading after the system is stabilized.

Dr. Manish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001

SHORT QUESTIONS:

1. Define thermal conductivity.
2. Define thermal resistance and thermal conductance.
3. What is the unit of thermal conductivity?
4. Explain the mechanism of thermal conduction in gases, liquids and solids.
5. Discuss the effect of temperature on thermal conductivity.
6. Point out and explain the various factors which affect the thermal conductivity of a material.

Dr. Munish Chhabra
Professor & Head
Deptt. of Mechanical Engg.
Moradabad Institute of Technology
Moradabad - 244001