DHANALAKSHMI COLLEGE OF ENGINEERING

Manimangalam, Tambaram, Chennai – 601 301

Department of Mechanical Engineering

ME 6512 – THERMAL ENGINEERING LABOURATORY - II

[MANUAL CUM OBSERVATION]

Name : …………………………………………….......

Reg.No : …………………………………………….......

Branch : …………………………………………….......

Year & Semester : …………………………………………….......

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III – Year / V – Semester

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Sl.No.	Date	Name of the Experiment	Mark	Staff Signature
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Completed date: **Staff - in - charge**

Average Mark:

Ex: No: **HEAT TRANSFER IN FORCED CONVECTION**
Date:

Aim:

To determine the heat transfer co-efficient by using forced convection Apparatus.

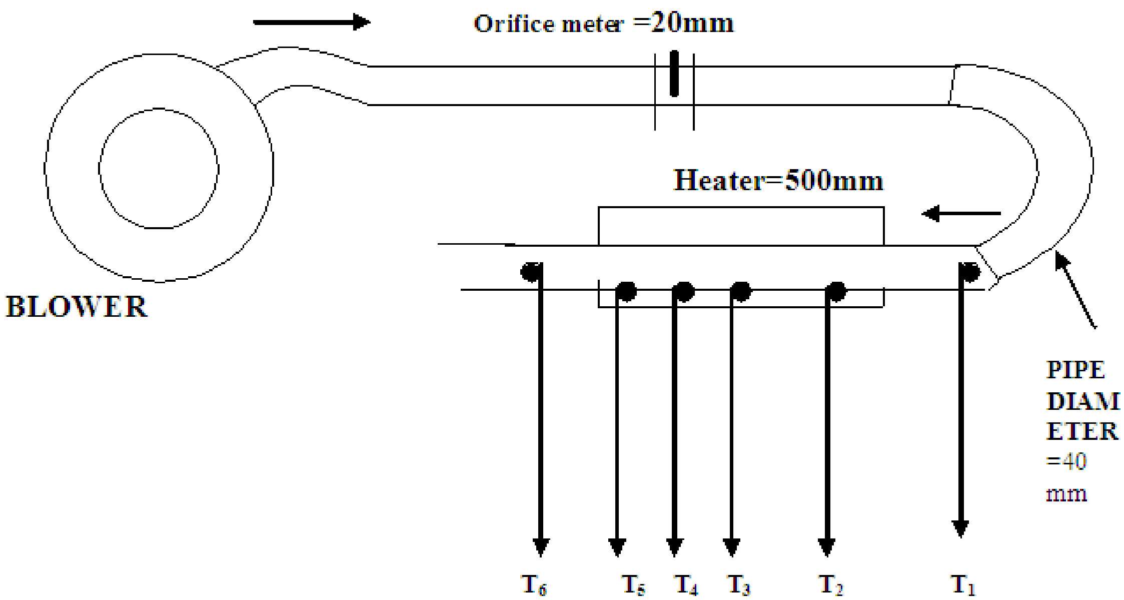
Apparatus Required:

(i) Experimental setup
(ii) Thermocouples
(iii) U – tube manometer

Theory:

Apparatus consist of blower unit fitted with the test pipe. The test section is surrounded by Nichrome band heater. Four thermocouples are embedded on the test section and two thermocouples 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 along with 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 utilized in heating the air. A temperature indicator with cold junction compensation is provided to measure temperatures of pipe wall at various points in the test section. Air flow is measured with the help of orifice meter and the water manometer fitted on the board.

FORCED CONVECTION



Tabulations:

Sl. No	Voltage & current setting		Temperature in ^0C						Manometer reading of water in h in meter
	V (volts)	I (Amps)	$T_1\ ^0C$	$T_2\ ^0C$	$T_3\ ^0C$	$T_4\ ^0C$	$T_5\ ^0C$	$T_6\ ^0C$	

Specifications:

1. Pipe diameter outside (Do) = 40 mm
2. Pipe diameter inner (Di) = 28 mm
3. Length of test section (L) = 500 mm
4. Blower = 0.28 HP motor
5. Orifice diameter (d) = 20 mm, connected with to water manometer.
6. Dimmerstat = 0 to 2 Amps. 260 Volts, A.C.
7. Temperature Indicator = Range 0 to 300^{0}C.
   (Calibrated for chromel alumel thermocouple)
8. Voltmeter = 0 -100/200 V,
9. Ammeter = 0-2 A
10. Heater = Nichrome wire heater wound on test pipe (Band type)
    (400 Watts)

Precautions:

1. Keep the dimmerstat at zero position before switching ON the power supply.
2. Start the blower unit.
3. Increase the voltmeter gradually.
4. Do not stop the blower in between the testing period.
5. Do not disturb thermocouples while testing.
6. Operate selector switch of temperature indicator gently.
7. Do not exceed 200 watts.

Procedure:

1. Start the blower and adjust the flow by means or gate 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 voltmeter and ammeter.
3. Take readings of all the six thermocouples at an interval of 10 minutes until the steady state is reached.
4. Note down the heater input.

Model Calculation:

Formulae Used:

1. The rate at which air is getting heated is calculated as

   $q_a = m \times Cp \times \Delta T$ kJ / hr.

   Where, m = mass flow rate of air (Kg / hr)

   Cp = Specific heat of air (kJ/ kg.k

   ΔT = Temperature rise in air (^oC)

   $= T_6 – T_1$.

2. m = Qa

   Where, a = density of air to be evaluated at $(T_1 + T_6)/ 2$ Kg / hr.

   Q = Volume flow rate.

   $Q = Cd \times (\pi/4)\ di^2 \sqrt{2gH} \times (\rho w / \rho a)$ m^3/hr

3. $h_a = q_a /A(Ts- Ta)$ w / m^2 k

   q_a = Rate of which air is getting heated.

   A = Test section area = $\pi \times$ Di x L m^2

   Ta = Average temperature of air = $(T_1 + T_6)/2$ ^oC

   Ts = Average surface temperature = $(T_2 + T_3 + T_4 + T_5)/4$ ^oC

   Cd = 0.64

   H = Difference of water level in manometer m

   ρw = Density of water = 1000 kg/m^3

   ρa = Density of air = [101.3/(0.287*Ta)] kg/m^3

   d = diameter of orifice meter = 0.014 m

   g = acceleration due to gravity = 9.81 m/s^2

   using this procedure obtain the value of ‘ha’ for different air flow rate.

4. **Reynold’s Number:**

   $Re = VDi/ \upsilon$ Dimensionless number

   Where, V = velocity of air = $Q/[(\pi \times Di^2)/4]$

Model Calculation:

υ = Kinematics viscosity to be evaluated at bulk mean temperature.

$(T_1 + T_6)/2$ °C

5. **Nusselt Number:**

Nu = (ha x Di)/ k   Dimensionless number

K = Thermal conductivity of air at $(T_1 + T_6)/6$ w/m-k

Plot the values of Nu vs Re on a log – log plot for the experiment readings.

6. **Prandtl Number:**

Pr = Cpμ / k

Cp = Specific heat of fluid kJ/kg.k

μ = Viscosity Ns/m^2

k = Thermal conductivity of fluid w/m^2.k

$Nu = 0.023 (Re)^{0.8} (Pr)^{0.4}$

Bulk mean temperature = $(T_1 + T_6)/2$

Results:

Thus the heat transfer coefficient in forced convection was determined by using forced convection apparatus.

h_{actual} = -------------- W/m^2K

$h_{theoritical}$ = -------------- W/m^2K

Faculty signature:

Ex: No: **HEAT TRANSFER TO LAGGED PIPE APPARATUS**

Date:

Aim:

To determine the heat transfer through lagged pipe using lagged pipe apparatus.

Apparatus Required:

(i) Experimental setup
(ii) Lagged pipe apparatus
(iii) Thermocouple
(iv) Ammeter
(v) Voltmeter

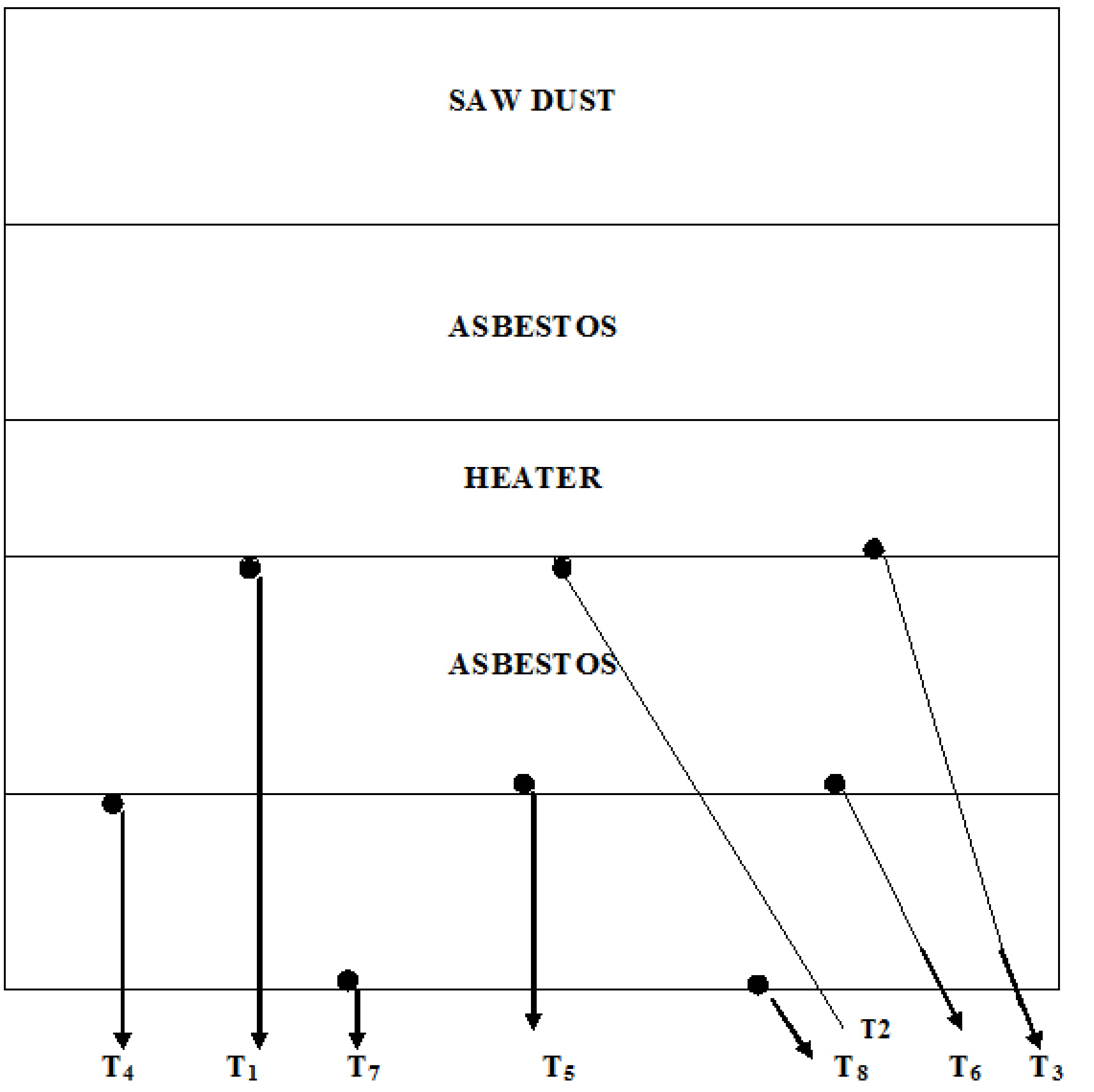
Theory:

The insulation is defined as a material which retards the heat flow with reasonable effectiveness. Heat is transferred through insulation by conduction, convection and radiation or by the combination of these three. There is no insulation which is 100 % effective to prevent the flow of heat under temperature gradient.

The experimental set-up in which the heat is transferred through insulation by conduction is understudy in the given apparatus. The apparatus consisting of a rod heater with asbestos lagging. The assembly is inside an MS pipe. Between the asbestos lagging and MS pipe, saw dust is filled.

Tabulation:

S. No	V	I	Heater Temperature				Asbestos Temperature				Saw dust Temperature		
			T_1	T_2	T_3	Average	T_4	T_5	T_6	Average	T_7	T_8	Average



Schematic View of Test Set-up

Specifications:

1. Diameter of the heater Rod = 20 mm.
2. Diameter of the heater Rod with Asbestos lagging = 40 mm
3. The diameter of the heater Rod with Asbestos and Saw dust lagging, ie.
   The ID of the outer MS pipe = 80 mm
4. The effective length of the above = 500 mm.

Precautions:

1. Adjust the temperature indicator to ambient level by using compensation screw, before starting the experiment (if needed)
2. Keep dimmerstat to zero volt position and increase it slowly.
3. Use the proper range of Ammeter and Voltmeter.
4. Never exceed 80 watts.

Formulae Used:

The heat flow through the lagging materials is given by

$Q = k_1\ 2\pi L\Delta T/\ln(r_2/r_1)$ (OR) $k_2\ 2\pi L\Delta T/\ln(r_3/r_2)$

Where, ΔT = Temperature drop across lagging

k_1 = Thermal conductivity of Asbestos lagging material

k_2 = Thermal conductivity of Saw dust.

L = Length of the cylinder, knowing the thermal conductivity of one lagging material the thermal conductivity of the other insulating material can be found.

Model Calculation:

Procedure:

1. Switch ON the units and check if all channels of temperature indicator showing proper temperature.
2. Switch ON the heater using the regulator and keep the power input at some particular value.
3. Allow the unit to stabilize for about 20 to 30 minutes.
4. Now note down the Ammeter, Voltmeter reading which gives the heat input.
5. Temperature 1,2 and 3 the temperature of heater Rod, 4,5 and 6 temperature on the asbestos layer, 7 and 8 temperatures on the saw dust lagging.
6. The average temperature of each cylinder is taken for calculation. The temperatures are measured by thermocouples (Fe/Ko) with multipoint digital temperature indicator.
7. The experiment may be repeat for different heat inputs.

Results:

The heat transfer through lagging material = ____________________ W.

The thermal conductivity of resistive material = _________________ W /m^2-K

Faculty Signature:

Ex: No: HEAT TRANSFER IN A PIN FIN (FORCED) APPARATUS

Date:

Aim:

To determine the pin-fin efficiency and heat flow of pin-fin forced convection

Apparatus required:

(i) Experimental setup
(ii) Thermocouples
(iii) U – tube manometer

Theory:

A brass fin of consist of circular cross section is fitted across a long rectangular duct. The other end of the duct is connected to the suction side of a blower and the air blows past the fin perpendicular to its axis. One end of the fin projects outside the duct and is heated by a heater. Temperatures at five points along the length of the fin are measured by chrome alumel thermocouples connected along the length of the fin. The air flow rate is measured by an orifice meter fitted on the delivery side of the blower. Schematic diagram of the set up is shown in fig. while the details of the pin fin are shown.

Specifications:

1. Duct size = 150 mm x 100 mm.
2. Diameter of the fin = 12.7 mm
3. Effective length of fin = 12.5 cm
4. Diameter of the orifice = 18 mm
5. Diameter of the delivery pipe (O.D) = 46 mm.
6. Diameter of the delivery pipe (I.D) = 42 mm.
7. Coefficent of the discharge (cd) = 0.64
8. Centrifugal blower = 0.56 HP, single phase motor.
9. No. of thermocouples on fin = 5
10. Thermocouple (6) reads ambient temperature inside of the duct.
11. Thermal conductivity of fin material (Brass) =110 w/m. ^{0}C.
12. Temperature indicator = 0 – 300 ^{0}C.
    (With compensation of ambient temperature up-to 50 ^{0}C)
13. Dimmersatat for heat input controls 230 V, 2 Amps.
14. Heater suitable for mounting at the fin end outside the duct = 400 watts (Band type)
15. Voltmeter = 0 – 100 / 200 V.
16. Ammeter = 0 – 2 Amps.

Precautions:

1. Keep the dimmer stat at zero position before switching ON the power supply.
2. Start the blower unit.
3. Increase the voltmeter gradually.
4. Do not stop the blower in between the testing period.
5. Do not disturb thermocouples while testing.
6. Operate selector switch of temperature indicator gently.
7. Do not exceed 200 watts.

Procedure:

Forced Convection:

1. Start heating the fin by switching ON the heater element and adjust the voltage on dimmerstat to say 100 volts.
2. Start the Blower and adjust the difference of level in the manometer with the help of gate valve.
3. Note down the thermocouple readings 1 to 5 at a time interval of 5 minutes.
4. When steady state is reached, record the final readings 1 to 5 and also record the ambient temperature reading 6.
5. Repeat the same experiment with different manometer readings.

Formulae Used :(Forced Convection)

1. Film Temperature $T_f = (T_\alpha + T_w) / 2$

Where, T_α = surface temperature (T_6)

$T_w = (T_1 + T_2 + T_3 + T_4 + T_5) / 5$ (average temperature of fin)

2. Discharge of air $Q = Cd \times \{(\pi \times D^2) /4\}\sqrt{2gha}$ m^3/s.

Where, ha (head of air) = ($\rho w / \rho a$) x H m

H = Difference of water level in manometer m

ρw = Density of water = 1000 kg/m^3

ρa = Density of air = 1.165 kg/m^3

g = acceleration due to gravity = 9.81 m/s^2

Cd = Coefficient of discharge = 0.64

D = diameter of the orifice

3. Velocity of air, $V = Q/A$ m/s

Where Q = discharge of air

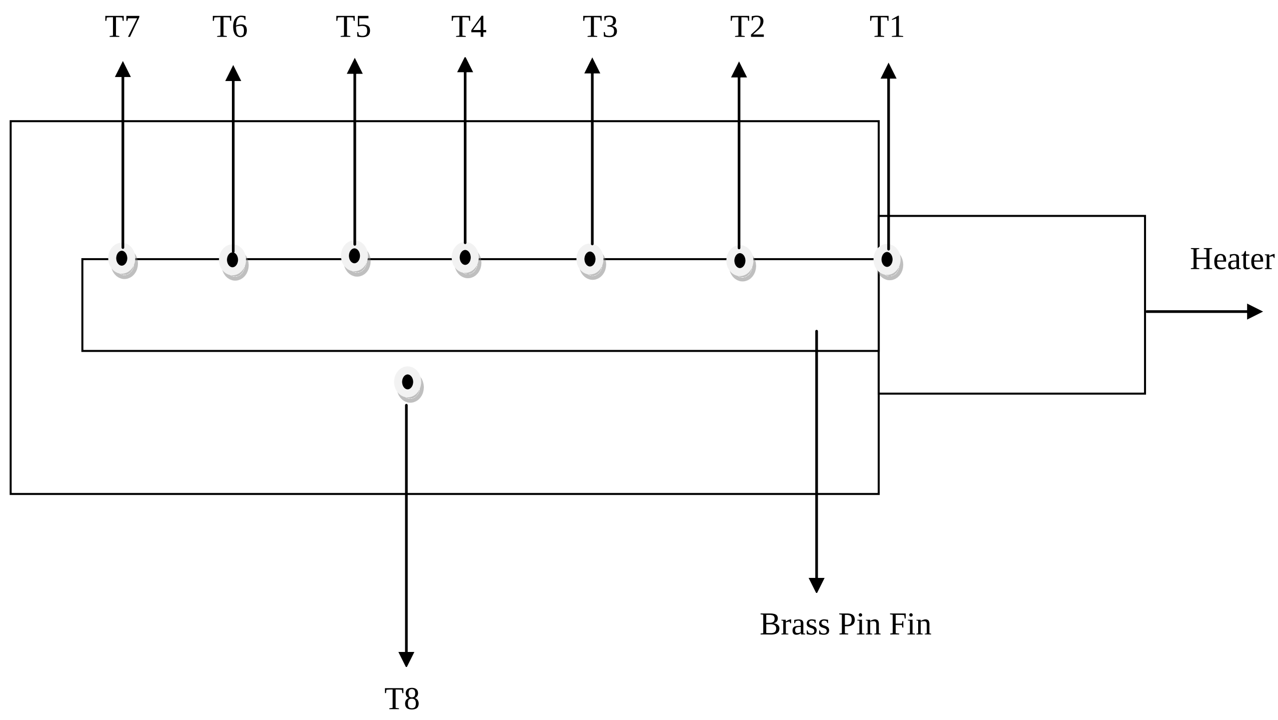
A = area of the duct

Tabulations:

Forced convection:

S. No	V	I	Manometer reading		Fin Temperatures					Ambient Temp
			h_1	h_2	T_1	T_2	T_3	T_4	T_5	T_6

Schematic View of the Test Set-up:



4. Reynold's Number:

$Re = V_{mf} D/ \upsilon$ Dimensionless number

Where, V_{mf} = velocity of air at mean film temp. = VT_f/ T_α

D = diameter of the fin

υ = Kinematics viscosity to be evaluate at average of bulk mean temperature.

$(T_1 + T_6) / 2$ ^oC

5. Heat transfer coefficient, h = Nu k / D

Where Nu = Nusselt Number

6. Nusselt Number:

$Nu = CRe^m (Pr)^{0.33}$

7. Heat flow, $Q = \sqrt{hpkA} \times (Tw - T\alpha) \tan h (mL)$

h = heat transfer coefficient,

Where, p = perimeter in m

k= 386 w/mk

$m= \sqrt{(hp/kA)}$

A = area of fin = $(\pi \times D^2) /4$

L = Length of the fin

T_w – average temperature

T_α – ambient (surface) temperature (T_6)

8. Efficiency, $\eta = \{\tan h (mL)\}/ mL$

Model Calculation:

Results:

Thus the experiment was conducted and results found were

Pin fin Efficiency, η = ___________ %

Heat transfer, Q = ___________ W

Faculty Signature:

Ex: No: **HEAT TRANSFER IN NATURAL CONVECTION**

Date:

Aim:

To find the surface heat transfer co-efficient for a vertical tube losing heat by natural convection.

Apparatus Required:

(i) Experimental setup
(ii) Thermocouple
(iii) Ammeter
(iv) Voltmeter

Theory:

The apparatus consist 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 surroundings. One side of the duct is made up of Perspex for visualization. An electric heating element is kept in the vertical tube which in turn heats the tube surface. The heat is lost from the tube to the surrounding air by natural convection. The temperature of the vertical tube is measured by seven thermocouples. The heat input to the heater is measured by an Ammeter and a Voltmeter and is varied by a dimmerstat.

When a hot body is kept in a still atmosphere, heat is transferred to surrounding fluid by natural convection. The fluid layer in contact with the hot body gets heated, rises up due to the decrease in its density and the cold fluid rushes in from bottom side. The process is continuous and the heat transfer takes place due to the relative motion of hot and cold fluid particles.

Tabulation:

S. No	Input Power		Temperature of Thermocouple								T_a ^{0} C
	V	I	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_S (average)	

Model Calculation:

Specifications:

1. Diameter of the tube (d)	= 40 mm.
2. Length of the tube (L)	= 500 mm.
3. Duct size	= 200 mm x 200 mm x 750 mm.
4. No. of thermocouples	= 7 and are shown as 1 to 7 and as marked on Temperature indicator switch.

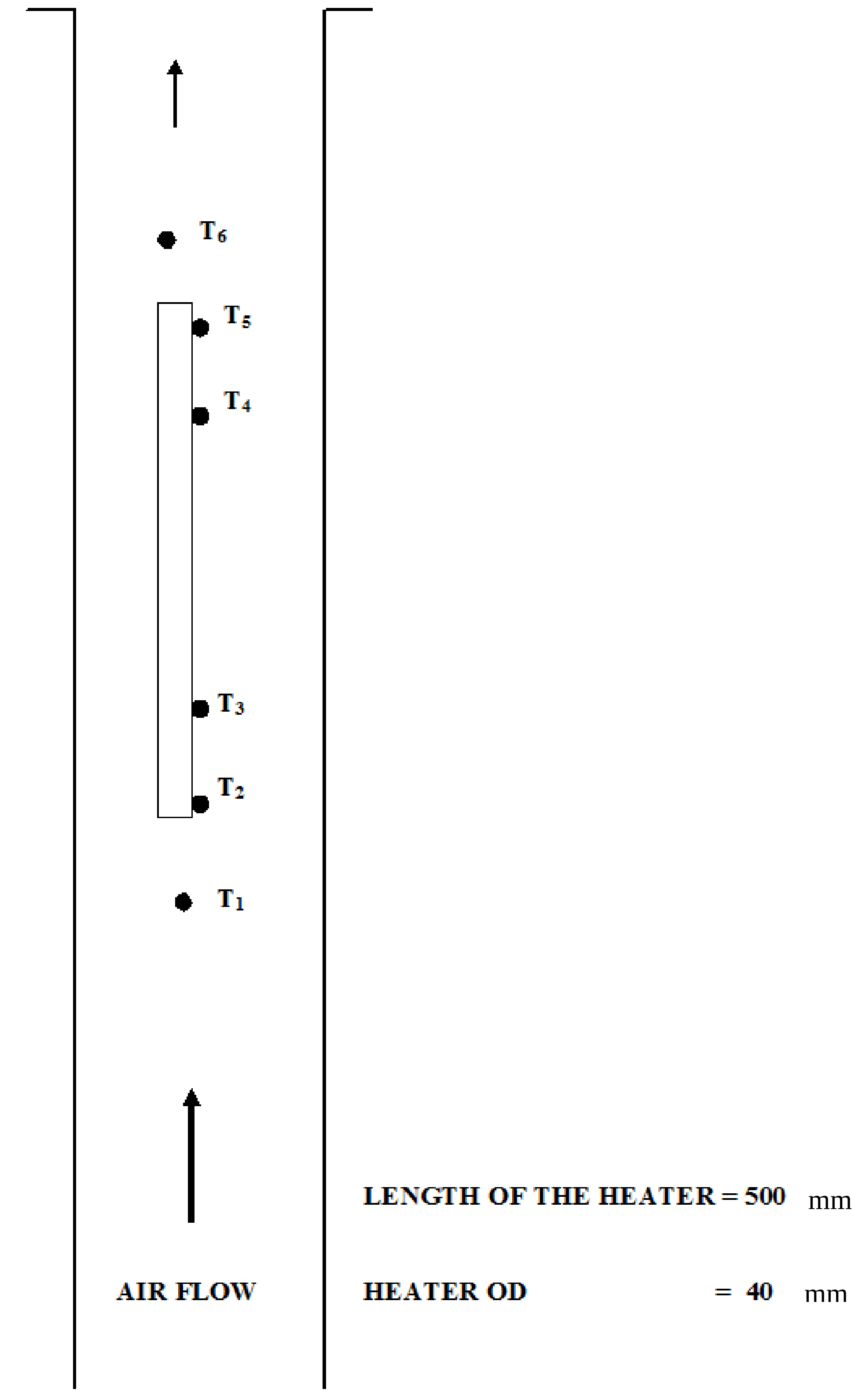
5. Thermocouple No. 6 reads the temperature of air in the duct.

6. Temperature Indicator	= 0 – 300^{0}C. Multichanel type, calibrated for chromel – alumel thermocouples.
7. Ammeter	= 0 – 2 Amps.
8. Voltmeter	= 0 – 100 / 200 Volts.
9. Dimmerstat	= 2 Amps. / 230 Volts.
10. Heater	= Cartridge type (400 watts)

Precautions:

1. Adjust the temperature indicator to ambient level by using compensation screw, before starting the experiment (if needed)
2. Keep dimmerstat to zero volt position and increase it slowly.
3. Use the proper range of Ammeter and Voltmeter.
4. Operate the changeover switch of Temperature Indicator gently from one position to other, i.e. from 1 to 8 positions.
5. Never exceed 80 watts.

Schematic View of the Test Set-up:



Formulae Used:

1. Heat transfer coefficient is given by

$h = q / \{As (Ts – Ta)\}$

Where, h = average surface heat transfer coefficient w/m^2 k

As = Area of heat transfer surface = π x d x l m^2

Ts = Average of surface Temperature = $(T_1 + T_2 + T_3 + T_4 + T_5 + T_6 + T_7) / 7$ ^0C

q = heat transfer rate w

Ta = T8 Ambient temperature in duct. ^0C

2. $hL / k = A \{ g L^3 \beta \Delta T Cp \mu / 2 \nu^2\}^n$

Where, hL / k are called Nusselt Number.

$L^3 g \beta \Delta T / \nu^2$ is called Grashof number

$\mu Cp / \kappa$ called Prandtl Number.

A and n are constants depending on the shape and orientation of the heat transferring surface.

Where, L = A characteristic dimension of the surface.

K = Thermal conductivity of fluid.

ν = Kinematics viscosity of fluid.

μ = Dynamic viscosity of fluid.

Cp = Specific heat of fluid.

β = Coefficient of volumetric expansion of the fluid.

G = Acceleration due to gavity.

$\Delta T = Ts – Ta$

For gas, $\beta = 1/ (T_f + 273)$ $^0 K^{-1}$

Where $T_f = (Ts + Ta)/ 2$

For a vertical cylinder losing heat by natural convection, the constant A and n of equation have been determined and the following empirical correlation obtained.

$hL / k = 0.56 (Gr.Pr)^{0.25}$ for $10^4 < Gr.Pr. < 10^8$

$hL / k = 0.13 (Gr.Pr)^{1/3}$ for $10^8 < Gr.Pr. < 10^{12}$

Here, L = Length of the cylinder.

Model Calculation:

Procedure:

1. Put ON the supply and adjust the dimmerstat to obtain the required heat input.
2. Wait till the fairly steady state is reached, which is confirmed from temperature readings (T1 to T7)
3. Note down surface temperatures at the various points.
4. Note the ambient temperature (T8)
5. Repeat the experiment at different heat inputs.

Results

The surface heat transfer coefficient of a vertical tube losing water by natural convection is fount as

Theoretical = _______________ W/m^2K

Experimental = _______________ W/m^2K

Faculty Signature:

Ex: No: **EMISSIVITY MEASUREMENT APPARATUS**

Date:

Aim :

To measure the property of emissivity of the test plate surface at various temperature.

Apparatus required:

(i) Experimental setup
(ii) Thermocouples
(iii) U – tube manometer

Theory:

The experiment set up consists of two circular aluminum plates identical in size and are provided with heating coils sandwiched. The plates are mounted on brackets and are kept in an enclosure so as to provide undistributed natural convection surroundings. The heat input to the heater is varied by separate Dimmerstats and is measured by using an ammeter and voltmeter with the help of double pole double throw switch. The temperatures of the plates are measured by thermocouples. Plates (1) is blackened by a thick layer of lamp black to form the idealized black surface whereas the plate (2) is the test plate whose Emissivity is to be determined.

Specifications:

1. Heater input to black plate W_1 = V_1 x I_1 watts
2. Heater input to test plate W_2 = V_2 x I_2 watts
3. Diameter of the plates (Aluminum) = 150 mm (Test plate and Black plate)
4. Heater for (1) & (2) Nichrome strip wound on mica sheet and sandwiched between two mica sheets.
5. Capacity of heater = 200 w each
6. Voltmeter = 0 -100/200 V,
7. Ammeter = 0-2 Amps
8. Dimmerstat for (1) & (2) 0 – 2 Amps, 0 – 260 V
9. Enclosure size = 580 mm x 300 mm x 300 mm.
10. Thermocouples = Chromel Alumel – 3 Nos.
11. Temperature Indicator = 0 – 300^0C.
12. D.P.D.T switch

Precautions:

1. Keep the dimmerstat at zero position before switching ON the power supply.
2. Use proper voltage range on Voltmeter.
3. Gradually increase the heater inputs.
4. Do not disturb thermocouples while testing.
5. Operate selector switch of temperature indicator gently.
6. See that the black plate is having a layer of lamp black uniformly.

Tabulation:

Sl. No	Test Plate			Black Plate			Enclosure Temp. (T_3)
	V_1	I_1	T_1	V_2	I_2	T_2	

Formulae Used:

Under steady state condition,

$W_1 – W_2 = (Eb – E) \sigma (Ts^4 – Ta^4) A$

$Eb – E = (W_1 – W_2) / \sigma (Ts^4 – Ta^4) A$

$E = Eb – \{(W_1 – W_2) / \sigma (Ts^4 – Ta^4) A\}$

Where,

$W_1 =$ Heater input to black plate = $V_1 \times I_1$ watts

$W_2 =$ Heater input to test plate = $V_2 \times I_2$ watts

A = area of plates = $2 (\pi/4) \times \square d^2 m^2$

T = Temperature of black plate, k = (Ts + Ta) / 2

Ta = Ambient temperature of enclosure

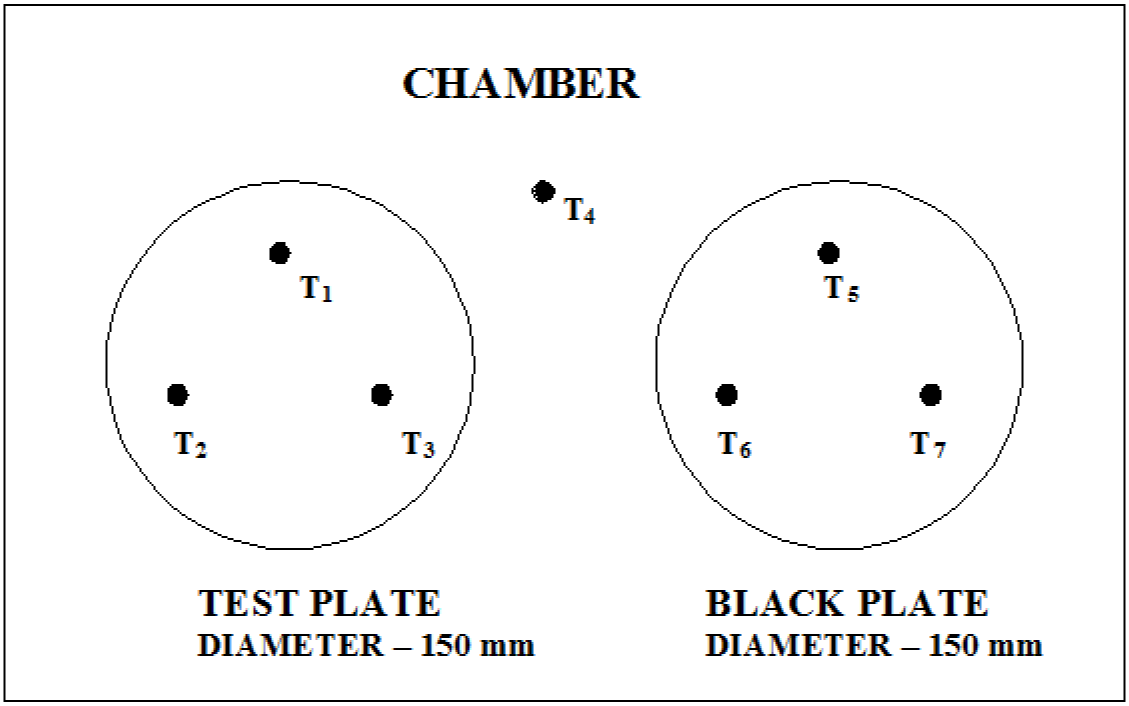
Ts = surface temperature of the discs (or T_1)

Eb = Emissivity of black plate = 1

E = Emissivity of Test plate

σ = Stefan boltzman constant = 5.67×10^{-8} $w/m^2 k^4$

Schematic View of the Test Set-up:



Model Calculation:

Procedure:

1. Gradually increase the input to the heater to black plate and adjust it to some value viz. 30, 50, 75 watts. And adjust the heater input to test plate slightly less than the black plate 27, 35, 55 watts. Etc.
2. Check the temperature of the two plates with small time intervals and adjust the input of test plate only, by the dimmerstat so that the two plates will be maintained at the same temperature.
3. This will require some trial and error and one has to wait sufficiently (more than one hour or so) to obtain the steady state condition.
4. After attaining the steady state condition record the temperatures, Voltmeter and Ammeter readings for both the plates.
5. The same procedure is repeated for various surface temperatures in increasing order.

Model Calculation:

Results:

The Emissivity of the test plate surface is found to be _____________.

Faculty Signature:

Ex: No: THERMAL CONDUCTIVITY OF GUARDED HOT PLATE METHOD

Date:

Aim:

To find the thermal conductivity of a given plate using two slab guarded hot plate method.

Apparatus Required:

(i) Experimental setup

(ii) Thermocouple

(iii) Ammeter

(iv) Voltmeter

Theory:

The heater plate is surrounded by a heating ring for stabilizing the temperature of the primary heater and to prevent heat jobs radially around its edges. The primary and guard heater are made up of mica sheets in which is a would closely spaced Nichrome wire and packed with upper and lower mica sheets. These heaters together form a flat which together with upper and lower copper plates and rings form the heater plate assembly.

Two thermocouples are used to measure the hot face temperature at the upper and lower central heater assembly copper plates. Two more thermocouples are used to check balance in both the heater inputs.

Specimens are held between the heater and cooling unit on each side of the apparatus. Thermocouples No.5 and No. 6 measure the temperature of the upper cooling plate and lower cooling plate respectively.

The heater plate assembly together with cooling plates and specimen held in position by 3 vertical studs and nuts on a base plate are shown in the assembly drawing.

The cooling chamber is a composite assembly of grooved aluminum casting and aluminum cover with entry and exit adaptors for water inlet and outlet.

Specifications:

1. Diameter of the heating plate = 100 mm
2. Width of the heating ring = 37 mm
3. Inside diameter of the heating ring = 106 mm
4. Out side diameter of the heating ring = 180 mm
5. Maximum thickness of the specimen = 25 mm (12 mm)
6. Minimum thickness of the specimen = 6 mm (12 mm)
7. Diameter of the specimen = 140 mm
8. Mean temperature range = 40^0C – 100^0C.
9. Maximum temperature of the hot plate = 170^0C.
10. Diameter of the cooling plates = 180 mm
11. Central Heater: Nichrome strip type sandwiched between mica sheets (400 watts)
12. Guarded Heater Ring: Nichrome strip type sandwiched between mica sheets (400 watts)
13. Dimmerstat 2 Nos. = (0 – 2 Amps.) – 240 Volts.
14. Voltmerter = 0 – 100 / 200 V.
15. Ammeter = 0 – 2 Amps.
16. Thermocouples = 6 Nos. (Chromel Alumel)
17. Insulation Box = 375 mm x 375 mm (Approx)
18. Temperature indicator = 0 – 200^0C.
19. Width of gap between two heater plates (x) = 2.5 mm
20. Specimen thickness (L) = 12.5 mm
21. Specimen used = Press wood.

Tabulation:

S. No	Central heater				Guarded heater				Cooling Plate	
	V_1	I_1	T_1	T_2	V_2	I_2	T_3	T_4	T_5	T_6

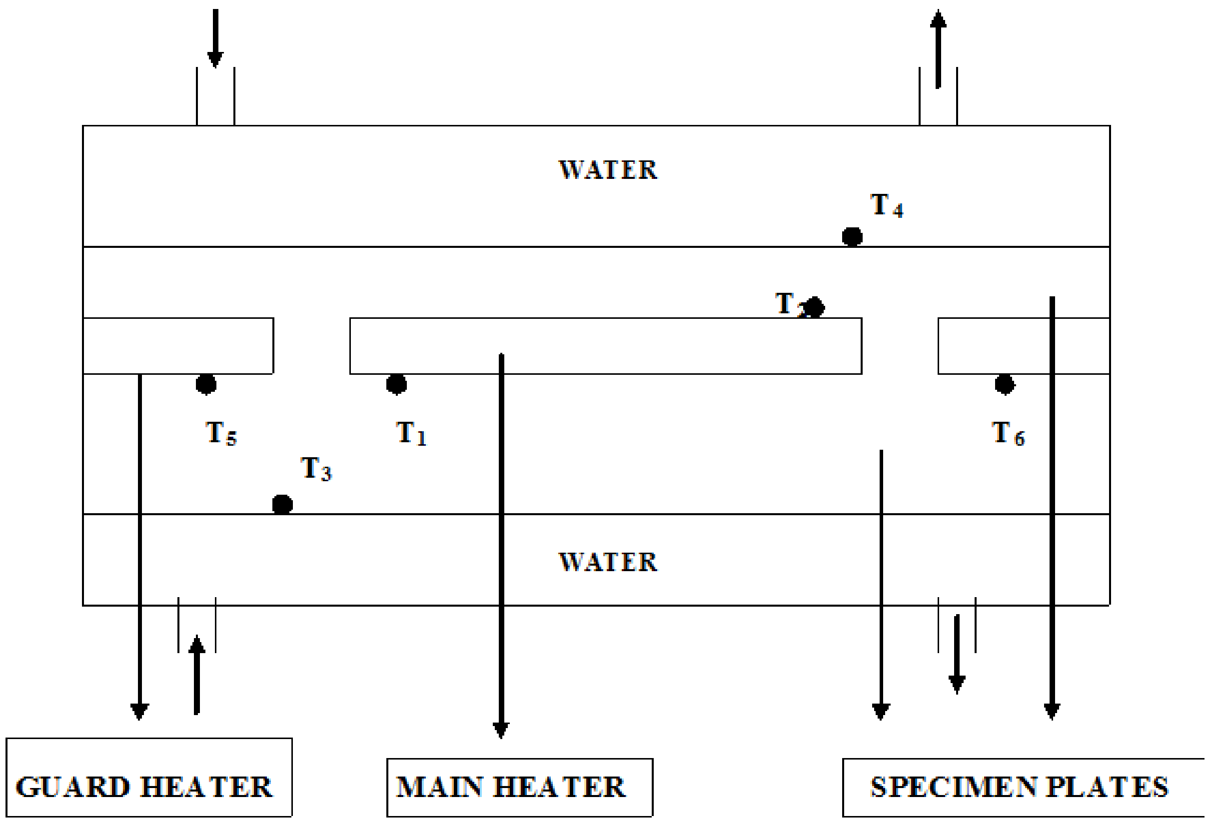
Formulae Used:

1. Central heater input (W_1) = $V_1 I_1$
2. Guarded heater input (W_2) = $V_2 I_2$
3. Area, A = $(\pi/4)(10 + x)^2$ Cm^2
4. T_L = $(T_1 + T_2) / 2$ ^{0}C
5. Tc = $(T_5 + T_6) / 2$ ^{0}C
6. k = $W_1 L / \{2A(T_L - Tc)\}$ W/mk

Precautions:

1. Keep dimmer stat to zero volt position before start.
2. Increase the voltage gradually.
3. Start the cooling circuit before switching ON the heaters and adjust the flow rate so that practically there is no temperature rise in the circuiting fluid.
4. Keep the heater plate undisturbed and adjust the cooling plates after keeping the samples with the help of nuts gently
5. Keep the loosely filled insulation (Glass wool) packets gently and remove them slowly so that they do not disturb the thermocouples terminals and heater wires.

Schematic View of the Test Set-up:



Procedure:

1. The specimens are placed on either side of the heating plate assembly, uniformly touching the cooling plates. Then the outer container is filled with loose fill insulation such as glass wool.
2. Before switch ON the apparatus, the cooing water valve is open and enough cooling water is passed through the cooling plates
3. Switch ON the apparatus and Heat input to the Central and guarded heaters through separate single phase supply lines with dimmerstat.
4. Give correct heat input to the Central and guarded plates for adjusting the immerstat switch.
5. The guarded heater input is adjusted in such a way that there is no radial heat flow which is checked from thermocouple readings and is adjusted accordingly.
6. The input to the Central heater (Current and Voltage) and the thermocouples readings are recorded after every 10 minutes till a reasonably steady state condition is reached.
7. The readings are recorded in the observation table.
8. Finally the final steady state values are taken for calculations.

Model Calculation:

Result:

Thus the experiment was done and thermal conductivity of given material was found to be
k = ____________________ w /mk.

Faculty Signature:

Ex: No: **STEFAN BOLTSMAN APPARATUS**

Date:

Aim:

To determine the Stefan Boltzman Constant by using boltzman apparatus.

Apparatus Required:

(i) Thermometer
(ii) Electric Heater
(iii) Stop watch
(iv) Geyser water

Theory:

The apparatus is centered on 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. The hemispherical shape of B is chosen solely on the grounds that it simplifies the task of draining water between B & C. Four chromel alumel thermocouples are attached to various points on surface of B to measure its mean temperature.

The disc D, which is mounted in an insulating bakelite sleeve S is fitted in a hole drilled in the centre of base plate A. The base of S is conveniently supported from under side of A. A chromel alumel thermocouple is used to measure the temperature of D (T5). The thermocouple is mounted on the disc to study the rise of its temperature.

When the disc is inserted at the temperature T5 (T5 > T i.e the temperature of the enclosure), the response of temperature change of disc with time is used to calculate the Stefan Boltzman constant.

Tabulations:

S. No	T_1	T_2	T_3	T_4	T_0 (T_5)	Time (Sec)

Specifications:

1. Hemispherical enclosure diameter = 200 mm
2. Suitable sized water jacket for hemisphere.
3. Base plate, bakelite diameter = 240 mm
4. Sleeve size, diameter = 44 mm
5. Fixing arrangement for sleeve
6. Test disc, diameter = 20 mm
7. Mass of test disc = 0.008 kg
8. Specific heat, s of the test disc = 0.41868 kJ / Kg ^{0}C
   = (or) 0.1 Kcal / kg ^{0}C
9. No. of thermocouples mounted on B = 4 Nos.
10. No. of thermocouples mounted on D = 1 No.
11. Temperature indicator digital 0.1^{0}C L.C 0 - 200^{0}C with built-in cold junction compensation and a timer set for 5 sec. to display temperature rise of the disc.
12. Immersion water heater of suitable capacity = 1.4 kW.
13. Tank for hot water.

Precautions:

Start the cooling circuit before switching ON the heaters (geyser) and adjust the flow rate so that practically there is no temperature rise in the circuiting fluid.

Formulae Used:

Stefan Boltzman constant = σ = {m_{cp} (dT / dt)t = 0} / A (Te^4 – Ta^4)

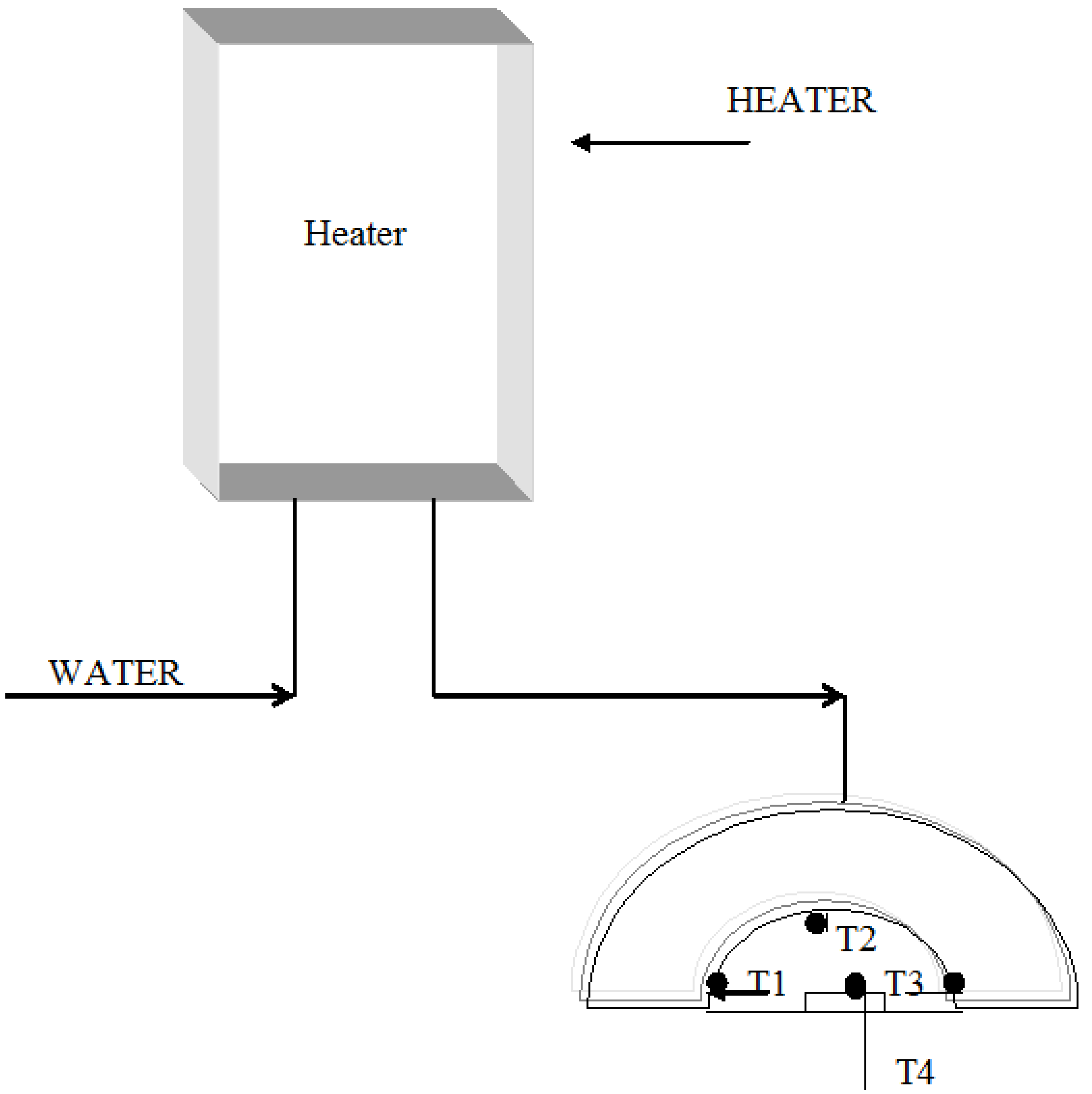
Where, A = area of the disc

Te = Emitter temperature (average of T1, T2, T3 & T4)

Ta = Absorber temperature = T0

dT / dt find the slope from the graph, Temperature T in Y axis, and time t in X axis.

Schematic View of the Test Set-up:



Procedure:

1. The water in the tank by the immersion heater up to a temperature of about 90^0C.
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 T in short time after filling the hot water in the jacket. The thermal inertia of hot water is quite adequate to present 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 saying T5 (to be sensed by a separate thermocouple).

Model Calculation:

Result:

The Stefan Boltzman constant was found out to be = ________________________ m/m^2k^4.

Faculty Signature:

Ex: No: **PARALLEL FLOW AND COUNTER FLOW HEAT EXCHANGER**

Date:

Aim:

To determine the values of effectiveness of heat exchanger for parallel and counter flow.

Apparatus required:

(i) Experimental Setup

(ii) Stop watch

(iii) Thermometer

Theory:

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 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 one.

The transfer type exchangers are further classified accordant to flow arrangements as:

i. PARRALLE FLOW in which fluids flow in the same direction.

ii. COUNTER FLOW in which fluids flow in opposite direction.

iii. CROSS FLOW in which fluids flow at right angles to each other.

The apparatus consist of a tube in tube type concentric tube heat exchanger. The hot fluid is not water which is obtained from an electric geyser and it flows through the inner tube while the cold fluid is cold water flowing through the annulus. The hot water flows always in one direction and the flow rate is controlled by means of a gate vale. The cold water can be admitted at one of the ends enabling the heat exchanger to run as a parallel flow apparatus or a counter flow apparatus. This is done by valve operations.

Specifications:

1. Inner tube material – copper Internal diameter (I.D) = 12.0 mm
2. Inner tube material – copper Internal diameter (O.D) = 15.0 mm
3. Outer tube material – G.I Internal diameter (I.D) = 40.0 mm
4. Length of the heat exchanger (L) = 1800 mm
5. Thermometers (for cold water) = 0 – 50^{0}C - 2 Nos.
6. Thermometers (for hot water) = 0 – 100^{0}C - 2 Nos.
7. Measuring flask = 0 – 1000 CC.
8. Geyser: single phase type to obtain hot water supply
9. Thermo Cole insulation for outer pipe.

Precautions:

Start the cooling circuit before switching ON the heaters (geyser) and adjust the flow rate so that practically there is no temperature rise in the circuiting fluid.

Tabulations:

S. No	Flow	Hot Fluid ^{0} C.		Cold Fluid ^{0} C		Time for collection of hot fluid kg/sec	Time for collection of cold fluid kg/sec
1	Parallel flow	Thi (T_1)	(Tho T_2)	Thi (T_3)	(Th_o T4)		
2	Counter flow						

Formulae Used: (Parallel flow & Counter flow)

1. Area of the pipe $A = \pi (D - d) L$

   Where, D = inlet diameter of the outer tube

   d = outlet diameter of the inner tube

   L = Length of the tube

2. Heat transferred from hot water $Qa = m_{cp} (T_{hi} - T_{ho})$ w

   Where, m = mass flow rate kg/ sec.

   $m = \rho v/t$, ρ = density of water and t = time taken for hot water

   Cp = Specific heat of capacity 4.187 kJ/kg -k

   T_{hi} = Temperature of hot water inlet

   T_{ho} = Temperature of hot water outlet

3. Heat transfer from cold water $Qc = m_{cp} (T_{co} - T_{ci})$ w

   Where, m = mass flow rate

   Cp = Specific heat of capacity

   T_{co} = Temperature of cold water inlet

   T_{ci} = Temperature of cold water outlet

4. Effectivesness, $E = Q_{\alpha} / \{m_{cp} (T_{hi} - T_{ci})\}$ w

   Where, $Q_{\alpha} = (Qa + Qc) / 2$

5. Logarithmic mean temperature difference(L M T D)

   $$\Delta Tm = (\Delta Ti - \Delta To) / \text{In} (\Delta Ti/\Delta To)$$

   Where, $\Delta To = T_{ho} - T_{co}$

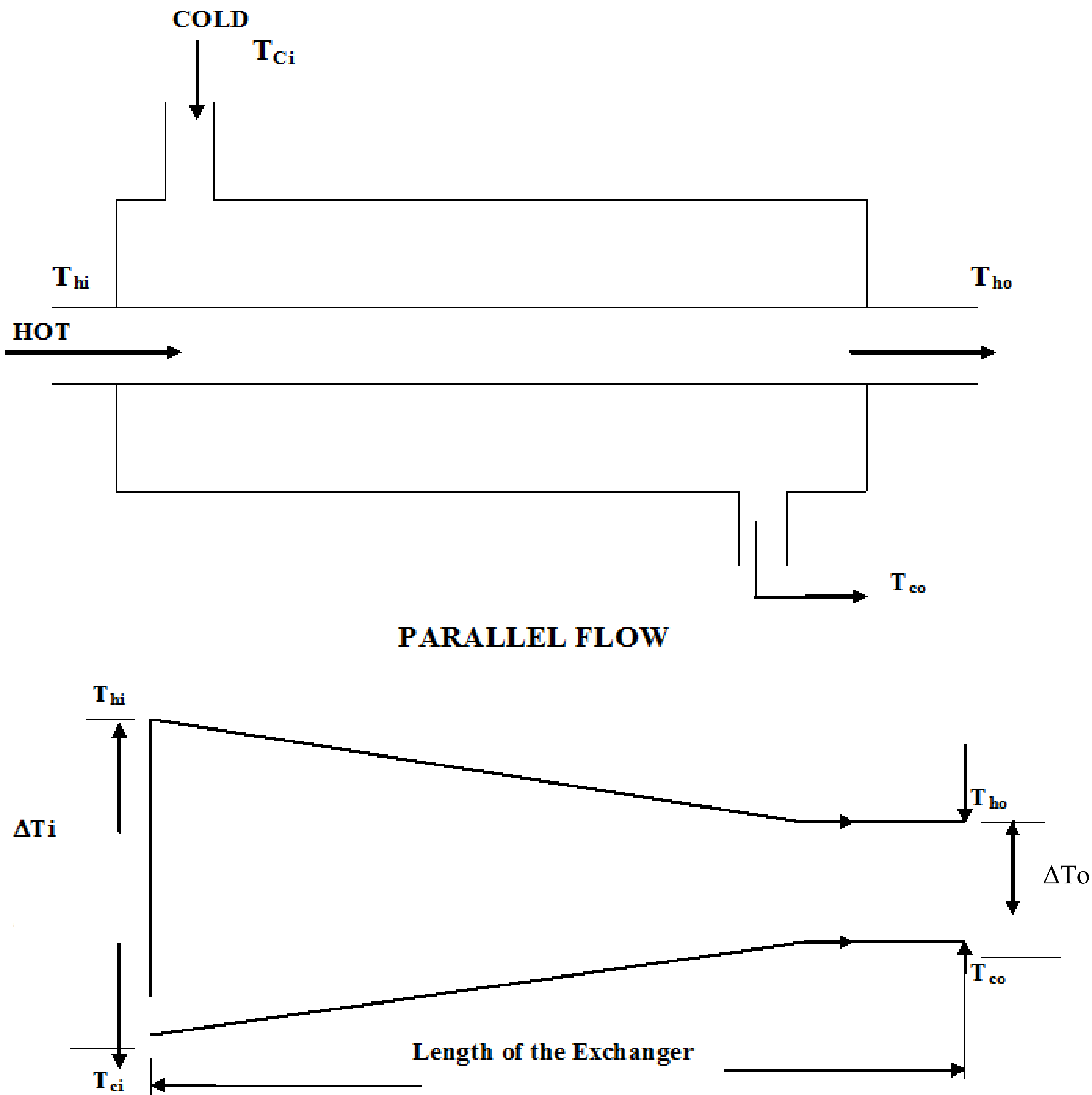
   $\Delta Ti = T_{hi} - T_{ci}$

6. Over all heat transfer coefficient

   $h = Q_{\alpha} / \Delta Tm\ A$ w/m^2k

   where $Q_{\alpha} = (Qa + Qc) / 2$

Schematic View of the Test Set-up (Parallel Flow Heat Exchanger):

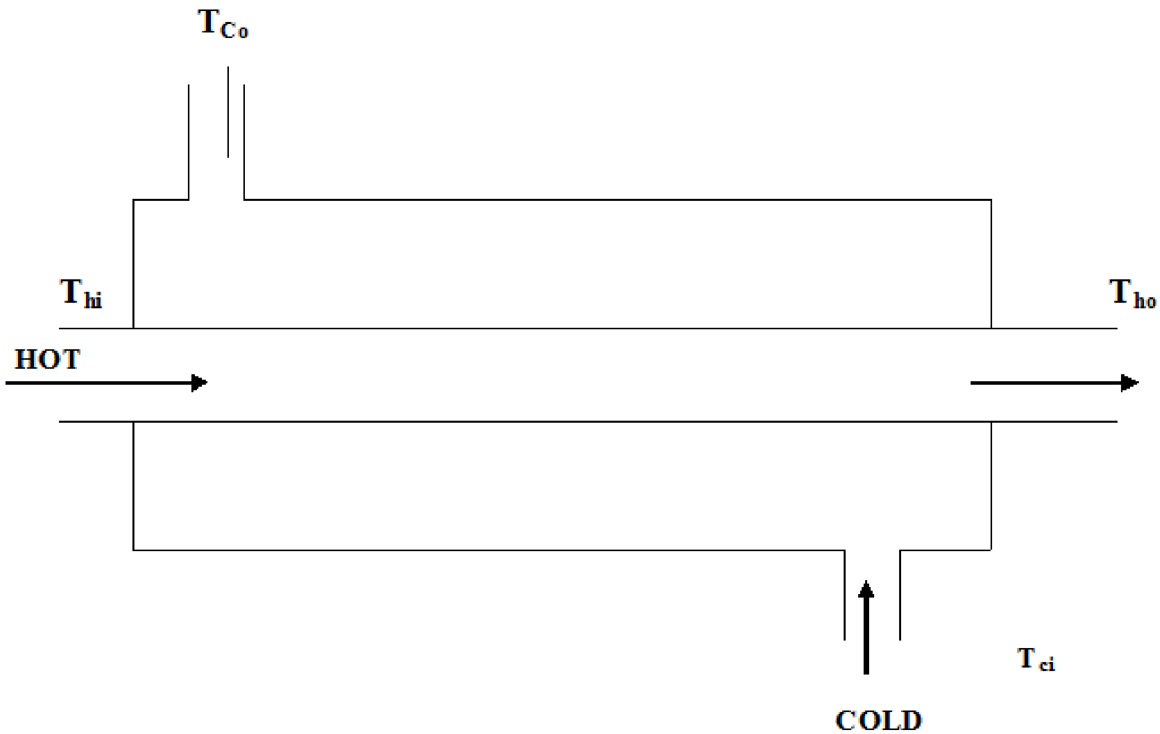


$\Delta T_m = (\Delta T_i - \Delta To)/(Log_e\ (\Delta T_i/\Delta T_o))$

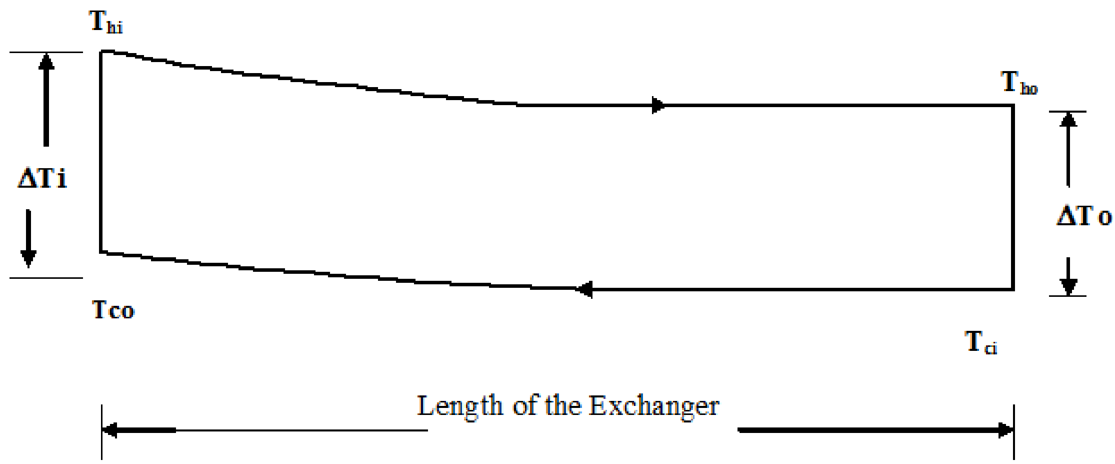
Procedure:

1. Place the thermometers in position and note down their readings when they are at room temperature and no water is flowing at either side. This is required to correct the temperature.
2. Start the flow on hot water side.
3. Start the flow through annulus and run the exchanger as parallel flow unit.
4. Put ON the geyser.
5. Adjust the flow rate on hot water side, between the ranges of 1.5 to 4 L/min.
6. Adjust the flow rate on cold water side between ranges of 3 to 8 L/min.
7. Keeping the flow rates same, wait till the steady state conditions are reached.
8. Record the temperatures on hot water and cold water side and also the flow rates accurately.
9. Repeat the experiment with a counter flow under identical flow conditions.
10. Correct the temperatures by suitable correction obtained from initial readings of thermometers.

Schematic View of the Test Set-up (Counter Flow Heat Exchanger):



COUNTER FLOW



$$\Delta T_m = (\Delta T_i - \Delta T_o)/(\log_e(\Delta T_i/\Delta T_o))$$

Model Calculation:

Model Calculation:

Result:

1. The values of effectiveness of heat exchanger were found as
    (i) Parallel flow = _________.
    (ii) Counter flow = __________.
2. Over all heat exchanger (heat transfer coefficient)
    (i) Parallel flow = _________.
    (ii) Counter flow = __________.

Faculty Signature:

Ex: No: **REFRIGERATION TEST RIG**

Date:

Aim:

To conduct a load test on refrigeration test rig and determine the coefficient of performance of refrigeration system.

Apparatus Required:

(i) Thermometer

(ii) Electric Heater

(iii) Stop watch

(iv) Experimental setup

Description:

1. The test rig consist of compressor, condenser unit placed inside trolley and fitted with (i) R-134a reciprocating compressor (ii) Air cooled condenser, (iii) Cooling fan for condenser and (iv) Liquid receiver.
2. The chilled water calorimeter consisting of a refrigerated stainless steel vessel placed inside an insulated wooden box and provided with (i) Evaporative coil, (ii) Stirrer, (iii) Electric heater, (iv) Sensing bulb of a low temperature thermostat, (v) A high temperature thermostat and (vi) A thermometer to measure the temperature of chilled water. The above unit is located on the trolley behind front panel.
3. The front panel of the test rig consist of (i) Capillary expansion tube with isolation valve, (ii) Thermostatic expansion valve and solenoid thermostat, solenoid switch, indicator and isolating valve (iii) Drier cum strainer and sight glass, (iv) Thermostat at inlet and outlet of both evaporator and condenser, (v) Pressure gauge at inlet and outlet of evaporator and condenser,(vi) Main switch and compressor safety high pressure / low pressure (HP/LP) cut-out, (vii) Heat power regulator switch and regulator, (viii) Energy meter to measure the power consumed eithr by hater or by compressor.

Specifications:

A. A compressor condenser unit placed inside trolley and fitted with

1. R-134a reciprocating compressor
2. Condenser
3. 0.5 hp, 220 V, single phase capacitor start induction motor with condenser cooling fan
4. A receiver with angle check valve

B. Chilled water calorimeter consisting of a refrigerated S.S vessel of ample capacity placed inside a well insulated wooden box and provided with

5. Evaporator coil
6. Stirrer
7. Electric heater 230 V, A.C.
8. The sensing bulb of low temperature thermostat.
9. A high temperature thermostat.
10. A Thermometer to measure the chilled water temperature

C. The front panel on which are mounted the following

11. Capillary expansion tube with isolating valve.
12. Thermostatic expansion valve and solenoid thermostat, solenoid switch, indicator and isolating valve
13. Drier cum strainer and sight glass
14. Thermostat at inlet and outlet of both evaporator and condenser
15. Pressure gauge at inlet and outlet of evaporator and condenser
16. Main switch and compressor safety high pressure / low pressure (HP/LP) cut-out
17. Heat power regulator switch and regulator
18. Energy meter to measure the power consumed either by hater or by compressor.

Precautions:

1. Make sure that the three pin main cable is properly earthed to avoid any electrical shocks.
2. The heater regulator should be switched off whenever not in use. Heating water beyond 40^0C may lead to permanent damage of the entire system. A high temperature cut off thermostat is provided in the water chiller, to cut off the heater beyond 30^0C.Check the setting of the same before operation.
3. The (low pressure) LP cut-off is adjusted to cut on reading 10 psig. Do not alter this setting.
4. The (high pressure) HP cut-off is adjusted to cut at 280 psig. Do not alter this setting.
5. The solenoid thermostat is adjusted to cut at 15^0C and cut in at 10^0C of the chilled water. Do not alter the same.
6. The main switch contains a fuse unit inside. The same has to be rewired if blown of.
7. The space near the condenser should permit good ventilation to aid proper fan performance.
8. The pressure gauges used are calibrated in psig: (the corresponding saturation temperature are marked in ^{0} F on the dial for Freon-22 and is irrelevant here. Reliable pressure gauges for Freon-12 use, calibrated in SI units, are not available.)
9. Hence the reading should be converted into absolute (psia) units by adding 14.7 and dividing by 145 to obtain the pressure in MN/m^2.e.g. P = x psig
   = (x + 14.7) psia
   = (x + 14.7) / 145 MN/m^2 (MPa)
10. The water in the chiller is to be stirred properly for some time before taking readings T4 & T5.

Observation Table: **I**

Expansion Device = **Capillary tube**

Amps: ------------, Volts: ____________

S. No	Equilibrium temperature of water (^0C)	Pressure (Bar)				Temperature (^0C)				Specific enthalpy (kJ/kg)				Pressure (Bar)		Time (Sec)		Q_e kW	W kW	C.O.P	
		P_1	P_2	P_3	P_4	T_1	T_2	T_3	T_4	h_1	h_2	h_3	h_4	$P_c = P_2 + P_3 /2$	$P_e = P_1 + P_4 /2$	t_1	t_2			Actual	Theoretical

Observation Table: **II**

Expansion Device = **Thermostatic Expansion (Solenoid**)

Amps: ------------, Volts: ___________

S. No	Equilibrium temperature of water (^0C)	Pressure (Bar)				Temperature (^0C)				Specific enthalpy (kJ/kg)				Pressure (Bar)		Time (Sec)		Q_e kW	W kW	C.O.P	
		P_1	P_2	P_3	P_4	T_1	T_2	T_3	T_4	h_1	h_2	h_3	h_4	$P_c = P_2 + P_3 /2$	$P_e = P_1 + P_4 /2$	t_1	t_2			Actual	Theoretical

Formulae Used:

Let, State 1 indicates the entry of compressor.

State 2 indicates the exit of compressor.

State 3 indicates the exit from condenser.

State 4 indicates the entry to evaporator

P = Pressure (bar)

T = Temperature (^{0}C)

H = Specific enthalpy (KJ/Kg)

v = Specific Volume (m^3/kg)

n = Number of revolutions of energy meter disc.

t_1 = Time taken for ‘n’ revolutions of energy meter disc for heater (sec)

t_2 = Time taken for ‘n’ revolutions of energy meter disc for compressor (sec)

K = Energy meter constant = 3200 lmp / kWh

N = Speed of compressor = 2840 rpm

h_1 = Specific enthalpy of vapour at P_e and T_1 (kJ/kg)

h_2 = Specific enthalpy at P_c and T_2 (kJ/kg) assuming isomeric compression, i.e., $s_1 = s_2$

h_3 = Specific enthalpy at P_c and T_3 (kJ/kg)

$h_4 = h_3$

Stroke volume of compressor = $(\pi/ 4)\, d^2 l = 12.58 \times 10^{-6}\ m^3$

1. Average evaporator pressure, $P_e = (P_1 + P_4) / 2$ bar
2. Average condenser pressure, $P_c = (P_2 + P_3) / 2$ bar
3. Heater input, $Q_e = (n / t_1) \times (3600 / k)$ kW
4. Compressor input, $W = (n / t_2) \times (3600 / k)$ kW
5. Actual C.O.P = Heater input / Compressor input = Qe / W = t_2 / t_1
6. Theoretical C.O.P = $(h_1 – h_4) / (h_2 – h_1)$
7. Refrigeration flow rate, $m = Q_e / (h_1 – h_4)$ kg/s

Model Calculation:

Procedure:

I. Load Test with Capillary tube as expansion device:

1. Fill the chilled water calorimeter with pure water so that the evaporative coils are fully immersed.
2. Select the capillary tube line by opening the shut-off valve on this line and closing the one on the thermostatic expansion valve line. The solenoid switch is switched OFF.
3. Start the compressor and run for some time so that the chilled water temperature is lowered to the given test temperature.
4. Switch on the heater and slowly increase the power.
5. The temperature in water calorimeter is allowed to reach the equilibrium temperature.
6. Connect energy meter to motor and heater by the selector switch one after another and note down the time taken for 10 pulses of the energy meter disc.
7. Note down the pressure and temperature readings at locations 1,2,3 & 4 as mentioned.
8. Switch OFF the heater and the mains.

II. Load test with Thermostatic Expansion valve as expansion device:

1. Fill the chilled water calorimeter with pure water so that the evaporative coils are fully immersed.
2. Select the thermostatic expansion valve line by opening the shit-off valve on this line and closing the one on the capillary line. The solenoid switch is switched ON.
3. Start the compressor and run for some time so that the chilled water temperature is lowered to the given test temperature.
4. Switch on the heater and slowly increase the power.
5. The temperature in water calorimeter is allowed to reach the equilibrium temperature.
6. Connect energy meter to motor and heater by the selector switch one after another and note down the time taken for 10 pulses of the energy meter disc.

Model Calculation:

7. Note down the pressure and temperature readings at locations 1, 2, 3 & 4 as mentioned.
8. Switch OFF the heater and the mains.

Result:

The load test on a refrigeration test rig was conducted and the results are as follows.

1. Actual C.O.P. of the system =____________.
2. Rhetorical C.O.P. of the system = ___________.
3. Volumetric Efficiency = ___________.

Faculty Signature:

Ex: No: **AIR CONDITIONING TEST RIG**

Date:

Aim:

To conduct a performance test on air conditioning test rig and determine the C.O.P. of air conditioning system.

Apparatus Required:

(i) Thermometer
(ii) Electric Heater
(iii) Stop watch
(iv) Digital anemometer
(v) Experimental setup

Description:

The test rig consist of

1. An air duct support of stand
2. A Blower to set up air flow through the duct along with a speed control to vary the velocity of air.
3. A heater to rise the air temperature with regulator and energy meter.
4. Water spray, collecting tray, reservoir with gauge pump.
5. Wet and dry bulb bi-metallic dial type thermometer at stations 1, 2,3 &4. (i.e., before heater, after heater or before sprayer, after sprayer or before cooing coil, after cooling coil).
4. The test rig consist of compressor, condenser unit placed inside trolley and fitted with (i) Freon-22 (CCI_2F_2) reciprocating compressor (ii) Air cooled condenser, (iii) Cooling fan for condenser and (iv) Liquid receiver.

Observation Table: **I**

Expansion Device = **Capillary tube**

Amps: ------------, Volts: _____________

S. No	Station1 (^{0}C)		Station2 (^{0}C)		Station3 (^{0}C)		Station4 (^{0}C)		Velocity of moist air, V	Mean velocity V_m	Specific enthalpy (kJ/kg)				Sp. Volume V4	Mass flow rate, m	Heat added, Q_1	Cooling effect produced, Q_c	Compressor power, W	C.O.P
	t_{db1}	t_{wb1}	t_{db2}	t_{wb2}	t_{db3}	t_{wb3}	t_{db4}	t_{wb4}	(m/s)	(m/s)	h_1	h_2	h_3	h_4	(m^3/kg)	(kg/s)	kW	kW	kW	

Observation Table: **II**

Expansion Device = **Thermostatic Expansion (Solenoid)**

Amps: ------------, Volts: _____________

S. No	Station1 (^{0}C)		Station2 (^{0}C)		Station3 (^{0}C)		Station4 (^{0}C)		Velocity of moist air, V	Mean velocity V_m	Specific enthalpy (kJ/kg)				Sp. Volume V4	Mass flow rate, m	Heat added, Q_1	Cooling effect produced, Q_c	Compressor power, W	C.O.P
	t_{db1}	t_{wb1}	t_{db2}	t_{wb2}	t_{db3}	t_{wb3}	t_{db4}	t_{wb4}	(m/s)	(m/s)	h_1	h_2	h_3	h_4	(m^3/kg)	(kg/s)	kW	kW	kW	

Precautions:

1. In case of low voltage motor may be overloaded, get heated up and the coils may be burnt up. Hence avoid operation at voltage less than 220 V. If necessary use a stabilizer of 2 kw only for the motor circuit.
2. Natural air currents in the room if in the direction of air duct may defect the experimental results and hence the duct should be placed such that no wind from doors, windows, fan and cooling air from other test rigs are directly incline with the duct. Any cross currents should only aid the condenser fan and should not oppose it as otherwise the delivery pressure of the refrigerating systems will increase beyond 240 psi.
3. Never exceed dry bulb temperatures of 40^0C after the heater (station 2) otherwise the air duct may be damaged.
4. Do not operate heater without operating cooler also, otherwise the vapour pressure thermometer may exceed its maximum of 32^0C and calibration may be affected.
5. Fan is connected to the main switch so that it is always in operation. Never operate when fan is not running this will lead to rise in temperature at the heater and may damage the heater and the air duct.
6. After completing experiments always allow the fan only to operate for at least 15 minutes so that their duct is cooled to room temperature and is also dried, otherwise the duct will be damaged.
7. Never run the pump without water in the reservoir, otherwise pump seals will be damaged. A strainer is placed inside the reservoir at the top. This may have to the cleaned when necessary.
8. Do not open the gate valve fully otherwise water may be splashed outside and the waster measurement may be in error.
9. If the low pressure cut out comes in to action, it means that the Freon charge is insufficient and may have to be filled up. The suction pressure should never go below 2 psi as otherwise the compressor seals will be damaged and air and moisture may enter the system.

10. The refrigerant strainer placed on the front panel should always be warm. If it cools and moisture condenser on it, then the strainer might have to be charged by an experienced refrigeration mechanics.
11. The refrigerating system can work continuously for 2 hours, however if the room temperature is above 25^0C the condenser may be heated up and the delivery pressure may rise. Do not exceed 240 psi. Pour one or two glasses of drinking water over the fins of the condenser in order to reduce the delivery pressure.
12. After some months of operation the compressor may have to be topped up with oil and some quantity of Freon-22 may have to be charged by an experienced mechanics.
13. See that distilled water is filled up in the plastic dishes provided under the wet bulb thermometers and that the wicks are in tact otherwise erroneous readings may be obtained. These thermometers will show correct readings only when the fan is in operation.
14. The inside of air duct and all metal parts should be painted at least once a year to avoid moisture and corrosion damage.

Formulae Used:

1. Corresponding to the dry and wet bulb temperature at all the stations obtain the specific enthalpy and specific humidity values from psychometric chart.
   i.e., h_1 and w_1 at tb_1 and tw_1 and so on.
2. Air flow rate, $m_a = (A \times V) / v_4$ kg / sec
   Where, A = Area of duct at outlet in m^2 (0.46 m x 0.086 m)
   V = Air velocity (m / sec)
   V_4 = Specific volume of moist air at station 4 using psychometric chart m^3/kg
3. Heat added, $Q_1 = m_a (h_2 – h_1)$ kW
   Where, h_1 = Specific enthalpy at station 1 kJ/kg
   h_2 = Specific enthalpy at station 2 kJ/kg

4. Moisture added from psychrometric chart, $m_{w1} = m_a (w_3 - w_2)$ kg / sec.
   Where, w_3 = Specific humidity at station 3
   w_2 = Specific humidity at station 2
5. Compressor power, W = (n / t) x (3600 / k) kW.
   Where, n = No. of pulses of energy meter disc
   t = Time taken for 'n' no. of pulses (sec)
   k = Energy meter constant (3200 lmp / kW-hr)
6. Actual C.O.P = Cooling effect produced on air / Compressor power.
7. Cooling effect produced on air, $Q_e = m_a (h_3 – h_4)$ kW.
   Where, h_3 = Specific enthalpy at state 3 kJ/kg
   h_4 = Specific enthalpy at state 4 kJ/kg
8. Moisture condensed, $m_{cl} = m_a (w_3 – w_4)$ kg/sec
   Where, w_3 = Specific humidity at station 3
   w_4 = Specific humidity at station 4
9. Draw the psychrometric process.

Model Calculation:

Procedure:

1. Fill water in the wet bulb temperature probe trays.
2. Start the main.
3. Start the blower and run it the required speed by keeping the speed regulator at position.
4. Start the spray pump and open the gate valve suitably.
5. Start the heater.
6. Select the expansion device (**Capillary tube / Thermostatic expansion valve)**
7. Start the cooling compressor.
8. Wait for some time till thermometers shown practically constant readings and note down the following readings:
   (i) Dry bulb temperatures t_{db1}, t_{db2}, t_{db3}, t_{db4}.
   (ii) Wet bulb temperatures t_{wb1}, t_{wb2}, t_{wb3}, t_{wb4}.
   (iii) Spray water temperature, ts
   (iv) Surface temperature of cooler, t_m (at control panel)
   (v) Pressure gauge reading, pd (at control panel)
   (vi) Compound gauge reading, Ps (at control panel)
   (vii) Level reduction'l' in spray reservoir (mm) during 5 min.
   (viii) Amount of condensate collected 'l_c', in a measuring jar at cooler tray during a run of 5 minutes at constant conditions.
   (ix) Time in second 'S_H' for 10 pulses of the energy meter disc connected to the heater.
   (x) Time in seconds S_c for 10 pulses of the energy meter disc connected to cooler compressor.
9. Repeat the above procedures for four more different settings of the fan Regulator (Position 1,2,3,4 & 5). If sensible cooling range is narrow, then switch off the spray and repeat as above. If the atmosphere is cool, the heater may be set for greater dissipation. If more readings are required for cooling below dew point and dehumidification switch off heater and repeat procedure.
10. Switch OFF all the mains.

Model Calculation:

Caution:

Heater regulator should not be adjusted beyond the position where dry bulb temperature at station 2 may exceed 40^0C.

Result:

The Load test on the AIR CONDITIONING TEST RIG was conducted and the results are as follows.

1. Actual C.O.P of the system = _______________.

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Ex: No: **LOAD TEST ON AIR COMPRESSOR**

Date:

Aim:

To conduct a load test on the 2 - stage reciprocating air compressor to determine the isothermal and volumetric Efficiencies at various delivery pressures.

Apparatus Required:

* Air compressor with accessories.
* Stop watch.

Description:

Two stage air compressors is a reciprocating type driven by a prime mover. The test rig consist of a base on which the tank is mounted. The outlet of the compressor is connected to the receiver. The suction is connected to air tank with a calibrated orifice plate through a water manometer. The input to the motor is recorded by an energy meter. The temperature and pressure of the air compressed is indicated by a thermometer and pressure gauge.

S.No	Delivery pressure.	Manometer read			Time taken for 3 rev. of energy meter disk.	Actual vol. at RTP.	Actual vol. at NTP.	Theoretical Vol. V_T	Shaft Input	Isothermal power.	Isothermal efficiency.
UNIT	Kgf / cm^2	h_1x 10^{-2} m	h_2x10^{-2} m	^hx10^{-2} m	x10^{-3} m^3/s	x10^{-3} m^3/s	x10^{-3} m^3/s	x10^{-3} m^3/s	kw	kw	%

Specifications:

1. Air compressor:

   * LP Bore, DLP = 63.0 mm.
   * HP Bore, DHP = 79.0 mm.
   * Stroke, L = 80.0 mm.
   * Speed, N = 1440 rpm (5 HP)
   * Effective radius = 0.193 m

2. Air receiver capacity = 0.33 m3
3. Orifice, diameter, d_0 = 12 mm
4. Orifice area,. A_0 : $\pi d_0^2 / 4$ = ----------- m^2
5. Coefficient of discharge C_d. = 0.6
6. Energy-meter constant = 200 rev / kWh.

Precautions:

1. Check whether manometer is filled with water up to the required level.
2. The maximum pressure in the receiver tank should not exceed 12 kg / cm^2

Procedure:

1. Ensure zero gauge pressure in the tank.
2. The compressor is started. The receiver pressure gauge is read for a particular pressure.
3. The pressure is maintained constant by adjusting the outlet valve.
4. Note down the manometer reading and time taken for 3 revolution of the energy meter disc.
5. Repeat the same procedure for various pressures.
6. Stop the compressor motor and release the pressure in receiver.

Model Calculation:

Formulae Used:

1. Density of air at RTP:

$$\rho_{RTP} = \frac{\rho_{NTP} \times 273}{(273 + \text{Room Temp})} \quad Kg/m^3$$

Where density of air at NTP = 1.293 Kg/m^3.

2. Air head causing flow:

$$h_{a\,RTP} = \frac{(h_1 - h_2) \times \rho_{water}}{\rho_{a\,RTP}} \quad m$$

Where,

$(h_1 - h_2)$ = Difference in manometer liquid, in m.

3. Actual volume at RTP:

$$Va_{RTP} = C.d \times A_o \times \sqrt{2\, g\, ha_{RTP}}$$

Where,

C_d= Coefficient of discharge = 0.6.

A_o = Area of orifice = $\frac{\pi (d_0)^2}{4}$ m^2.

Diameter of orifice d_o = 0.01 m.

4. Actual volume at NTP:

$$Va_{NTP} = \frac{Va_{RTP} \times T_{NTP}}{T_{RTP}}$$

Where,

T_{NTP} = Normal temp - 273^{θ}k

T_{RTP} = Room temp - $^{\theta}$c (273 + T_{ROOM})

5. Theoretical Volume of air: (at intake conditions)

$$V_T = \frac{\pi D^2 \times L \times Nc}{4 \times 60} \quad m^3/sec.$$

i.

D = LP Bore diameter = 88.5 mm.

L = Stroke length = 88.9 mm.

Nc = Compressor speed rpm.

Model Calculation:

6. Volumetric Efficiency:(for LP stage)

$$\eta_{vol} = \frac{V_{a\,NTP} \times 100\%}{V_t}$$

7. Shaft Input through Energy meter:

$$= \frac{1 \times n \times \eta_t \times \eta_m \times 3600}{(E_c \times t)} \quad \text{kw.}$$

Where,

E_c = Energy meter constant = 200 rev / kWh

η_t = Efficiency for transmission = 0.95.

η_m = Efficiency for motor = 0.90.

t = Time for 'n' revolution of energy meter disc.

n = no. of rev. of Energy meter disc.

8. Isothermal power:

$$= \frac{P_a \times V_{a\,RTP} \times \log_e(R)}{1000} \quad \text{watts}$$

P_a = Atmospheric pressure in N/ m^2 = 1.01325×10^5 N / m^2.

$$R = \frac{\text{(Pressure gauge reading + atmospheric pressure)}}{\text{atmospheric pressure.}}$$

9. Isothermal efficiency:

$$\eta_{ISO} = \frac{\text{Isothermal power} \times 100\%}{\text{Shaft input}}$$

Result:

The values of isothermal and volumetric efficiency at various delivery pressures have been studied & graph between

- Pressure Vs Volumetric efficiency.
- Pressure Vs Isothermal efficiency is drawn.

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