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DEPARTMENT OF
MECHANICAL ENGINEERING

ME6512 – THERMAL ENGINEERING LABORATORY

V SEMESTER - R 2013

LABORATORY MANUAL

Name : ______________________________________

Register No. : ______________________________________

Section : ______________________________________

VISION

is committed to provide highly disciplined, conscientious and enterprising professionals conforming to global standards through value based quality education and training.

MISSION

- To provide competent technical manpower capable of meeting requirements of the industry
- To contribute to the promotion of academic excellence in pursuit of technical education at different levels
- To train the students to sell his brawn and brain to the highest bidder but to never put a price tag on heart and soul

DEPARTMENT OF MECHANICAL ENGINEERING

VISION

Rendering the services to the global needs of engineering industries by educating students to become professionally sound mechanical engineers of excellent caliber

MISSION

To produce mechanical engineering technocrats with a perfect knowledge intellectual and hands on experience and to inculcate the spirit of moral values and ethics to serve the society

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

1. Fundamentals

   To impart students with fundamental knowledge in mathematics and basic sciences that will mould them to be successful professionals

2. Core competence

   To provide students with sound knowledge in engineering and experimental skills to identify complex software problems in industry and to develop a practical solution for them

3. Breadth

   To provide relevant training and experience to bridge the gap between theory and practice which enable them to find solutions for the real time problems in industry and organization and to design products requiring interdisciplinary skills

4. Professional skills

   To bestow students with adequate training and provide opportunities to work as team that will build up their communication skills, individual, leadership and supportive qualities and to enable them to adapt and to work in ever changing technologies

5. Life-long learning

   To develop the ability of students to establish themselves as professionals in mechanical engineering and to create awareness about the need for lifelong learning and pursuing advanced degrees

PROGRAMME OUTCOMES (POs)

On completion of the B.E. (Mechanical) degree, the graduate will be able

1. To apply the basic knowledge of mathematics, science and engineering
2. To design and conduct experiments as well as to analyze and interpret data and apply the same in the career or entrepreneurship
3. To design and develop innovative and creative software applications
4. To understand a complex real world problem and develop an efficient practical solution
5. To create, select and apply appropriate techniques, resources, modern engineering and IT tools
6. To understand the role as a professional and give the best to the society
7. To develop a system that will meet expected needs within realistic constraints such as economical environmental, social, political, ethical, safety and sustainability
8. To communicate effectively and make others understand exactly what they are trying to tell in both verbal and written forms
9. To work in a team as a team member or a leader and make unique contributions and work with coordination
10. To engage in lifelong learning and exhibit their technical skills
11. To develop and manage projects in multidisciplinary environments

ME6512 – THERMAL ENGINEERING LABORATORY – II

COURSE OBJECTIVES

- To study the heat transfer phenomena predict the relevant coefficient using implementation. To study the performance of refrigeration cycle / components

LIST OF EXPERIMENTS:
HEAT TRANSFER LAB:

1. Thermal conductivity measurement using guarded plate apparatus
2. Thermal conductivity measurement of pipe insulation using lagged pipe apparatus
3. Determination of heat transfer coefficient under natural convection from a vertical cylinder
4. Determination of heat transfer coefficient under forced convection from a tube
5. Determination of Thermal conductivity of composite wall
6. Determination of Thermal conductivity of insulating powder
7. Heat transfer from pin-fin apparatus (natural & forced convection modes)
8. Determination of Stefan – Boltzmann constant
9. Determination of emissivity of a grey surface
10. Effectiveness of Parallel / counter flow heat exchanger

REFRIGERATION AND AIR CONDITIONING LAB:

11. Determination of COP of a refrigeration system
12. Experiments on Psychrometric processes
13. Performance test on a reciprocating air compressor
14. Performance test in a HC Refrigeration System
15. Performance test in a fluidized Bed Cooling Tower

COURSE OUTCOMES

1. Able to find out the thermal conductivity of various materials.
2. Able to determine the heat transfer through lagged pipe using lagged pipe apparatus
3. Able to find out the surface heat transfer coefficient of a vertical tube losing water by natural convection experiment.
4. Able to conduct and find out the heat transfer coefficient by forced convection apparatus
5. Able to find out the rate of heat transfer through different materials
6. Able to find out the thermal conductivity of insulating powder by conduction
7. Have attain the practical knowledge and able to find out the pin fin efficiency and net heat transfer rate.
8. Have attain the practical knowledge and able to find out the pin fin efficiency and net heat transfer rate.
9. Able to find out the Stefan Boltzman constant value.
10. Able to find out the emissivity of the given test plate.
11. Able to conduct the load test on a refrigeration test rig and find out the volumetric efficiency and co-efficient of performance for any type of refrigerant.
12. Have attain the practical knowledge on pscychrometric processes with air conditioning system
13. Able to find out the values of isothermal and volumetric efficiency by conducting the experiments at various delivery pressures
14. Able to conduct the experiment and find out the coefficient of performance.
15. Able to conduct the experiments and to find out the performance test in cooling tower of various FBC Boiler.

CONTENTS

Expt. No.1 THERMAL CONDUCTIVITY MEASUREMENT USING GUARDED PLATE APPARATUS

Aim:

To conduct an experiment 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 wound 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.

Formulae used:

1. Power input, Q $= V \times A / 2$ W
2. Thermal Conductivity, K $= (Q \times dx)/(A \times dt)$ W/mK
3. Area, A $= (\pi/4)\, d^2\, (10 + x)$ cm^2
4. Average Temperature, dT $= (T1+T2+T3+T4)/4 - (T5+T6)/2$

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.

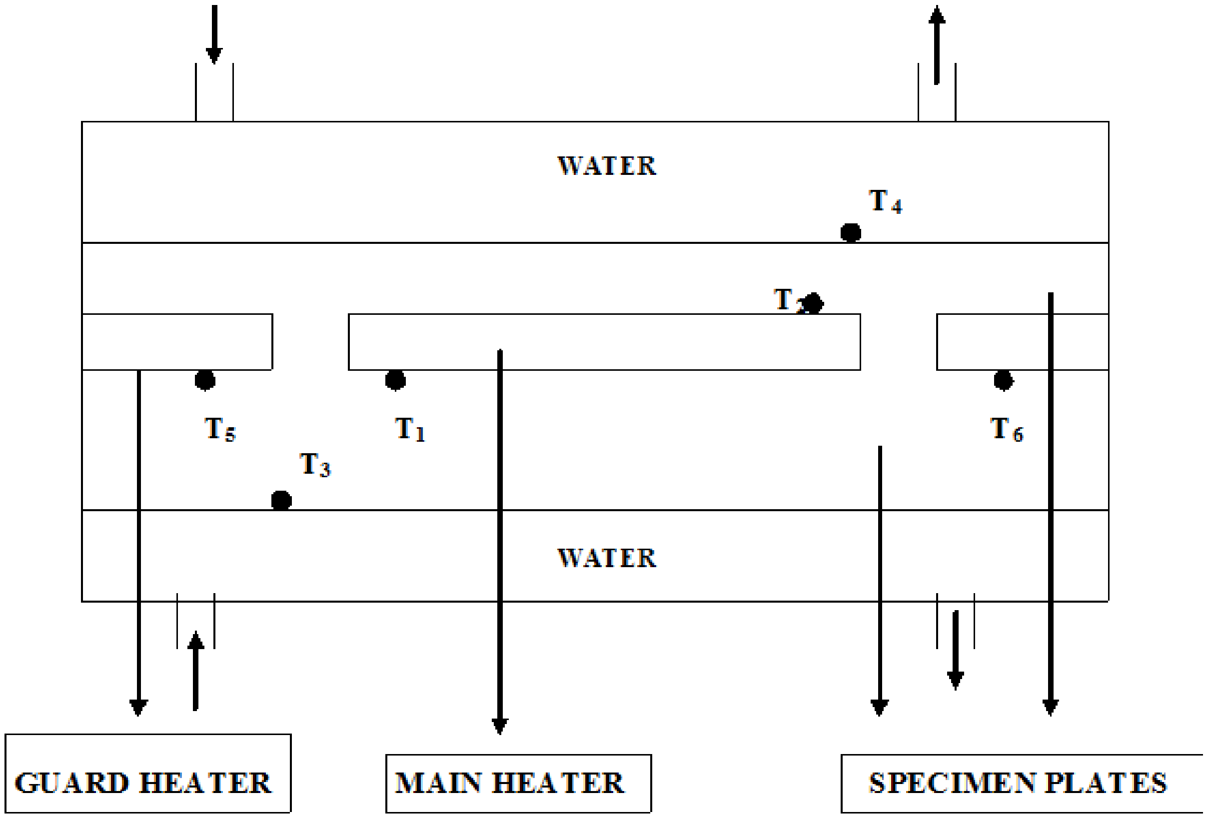
Specifications:

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. Outside diameter of the heating ring = 180 mm
5. Maximum thickness of the specimen = 25 mm
6. Minimum thickness of the specimen = 6 mm
7. Diameter of the specimen = 140 mm
8. Mean temperature range = 40^0C – 100 ^{0}C
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 W)
12. Guarded Heater Ring: Nichrome strip type sandwiched between mica sheets (400 W)
13. Dimmer stat 2 Nos. = (0 – 2 A) – 240 V
14. Voltmeter = 0 – 100 / 200 V
15. Ammeter = 0 – 2 A
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:

Sl. No.	Voltmeter V	Ammeter A	Main heater (^0C)				Test Plate (^0C)	
			T_1	T_2	T_3	T_4	T_5	T_6

Schematic view of the test set-up:



Procedure:

1. Place the specimens on either side of the heating plate assembly, uniformly touching the cooling plates. Fill the outer container with loose fill insulation such as glass wool.
2. Open the cooling water valve before switching ON the apparatus, and ensure that 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 dimmer stat.
4. Provide correct heat input to the central and guarded plates for adjusting the dimmer stat switch.
5. Adjust the guarded heater input in such a way that there is no radial heat flow which is checked from thermocouple readings and is adjusted accordingly.

6. Observe and record the current, voltage and thermocouples readings every 10 minutes till a reasonably steady state condition achieved.
7. Write the readings in the observation table.
8. Take the final steady state values for calculations.

Result:

Thus the experiment was done and thermal conductivity of given material was found to be

k = ___________________ W /mK.

Outcome:

From this experiment, finding the thermal conductivity of a given plate using two slab guarded hot plate method is learnt and this experiment could be used in the areas such as Pipe lines, IC engines, heat exchangers, etc. where thermal conductivity is to be found.

Applications:

Pipe lines, IC engines, heat exchangers

Viva – voce

1. Define – Thermal Conductivity
2. State Fourier's law of heat conduction.
3. State the applications of fins.
4. Define – Fins
5. State Newton's law of cooling or convection law.
6. What are the factors affecting the thermal conductivity?
7. What is the value of thermal conductivity for wood?
8. What are the various modes of heat transfer?
9. What is meant by conduction?
10. Define – Heat Transfer
11. State the purpose of heating ring provided in this experiment.
12. What is meant by transient heat conduction?
13. How heat transfer occurs through insulated medium?
14. What are the material used for making the guarded plate?
15. How many thermocouples were mounted in this experiment?
16. Specify the thermocouple numbers which was used to measure the cooling plate temperature.
17. What is unit for thermal conductivity?
18. What is meant by Newtonian and Non-Newtonian fluids?
19. What is meant by dimensional analysis?
20. State the advantages of dimensional analysis.

Expt. No.2 THERMAL CONDUCTIVITY MEASUREMENT OF PIPE INSULATION USING LAGGED PIPE APPARATUS

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.

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.
4. The ID of the outer MS pipe = 80 mm
5. 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 dimmer stat to zero volt position and increase it slowly.
3. Use the proper range of Ammeter and Voltmeter.
4. Never exceed 80W

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

Tabulation:

Sl. No.	Voltage (V)	Current (A)	Heater Temperature (^{0}C)				Asbestos Temperature (^{0}C)				Saw dust Temperature (^{0}C)		
			T_1	T_2	T_3	Average	T_4	T_5	T_6	Average	T_7	T_8	Average

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. Note the temperatures T1, T2 and T3 on the heater rod; T4, T5 and T6 temperatures on the asbestos layer and T7 and T8 temperatures on the saw dust lagging.
6. Take the average temperature of each cylinder for calculation. Measure the temperatures by thermocouples (Fe/Ko) with multipoint digital temperature indicator.
7. Repeat the experiment for different heat inputs.

Results:

The heat transfer through lagging material = ___________________ W.

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

Outcome:

From this experiment, finding the heat transfer through lagged pipe using lagged pipe apparatus is understood and this experiment could be used in the areas such as Exhaust pipe lines, IC engines, heat exchangers, etc. where heat transfer is to be found.

Applications:

Exhaust pipe lines, IC engines, heat exchangers

Viva – voce

1. Define – Nusselt Number(Nu)
2. What is meant by laminar flow and turbulent flow?
3. What is meant by free or natural convection?
4. What is meant by forced convection?
5. Define – Reynolds Number(Re)
6. Define – Prandtl Number(Pr)
7. Define – Convection
8. What is meant by transient heat conduction?
9. What is meant by thermal boundary layer?
10. How does the heat transfer occur through insulated medium?
11. What is the material of the pipe?
12. Where was the saw dust filled in this experimental set up?
13. What is meant by steady state heat conduction?
14. Define – Periodic Heat Flow
15. List out the examples for periodic heat flow.
16. What is meant by thermal diffusion?
17. What are the dimensionless parameters used in forced convection?
18. Define - Dimensional Analysis
19. State the demerits of dimensional analysis.
20. What is meant by hydrodynamic boundary layer?

Expt. No.3 DETERMINATION OF HEAT TRANSFER COEFFICIENT UNDER NATURAL CONVECTION FROM A VERTICAL CYCLINDER

Aim:

To conduct an experiment on heat transfer and to find the surface heat transfer co-efficient for a vertical tube losing heat by natural convection

Apparatus required:

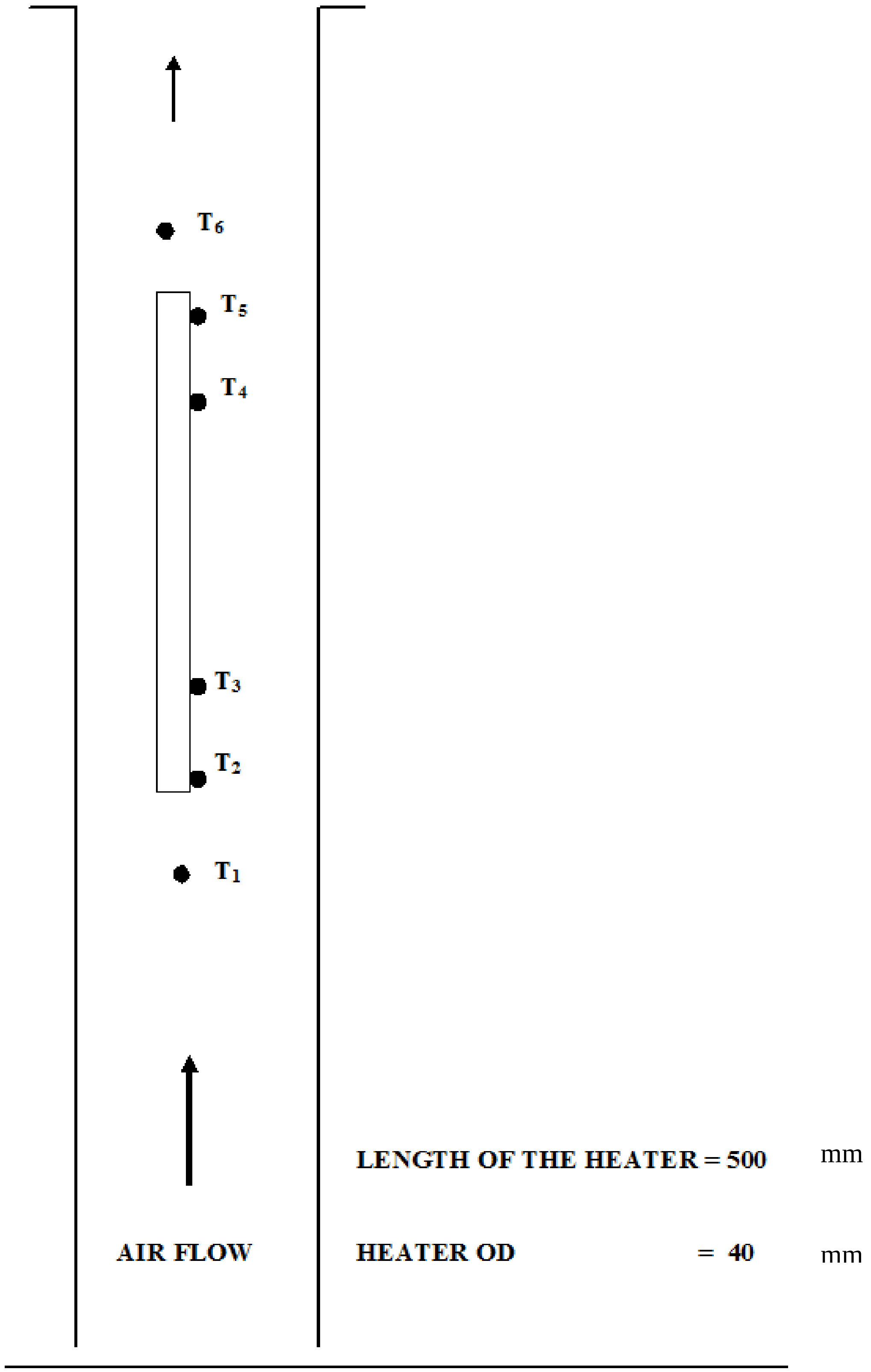
(i) Experimental setup
(ii) Thermocouple
(iii) Ammeter
(iv) Voltmeter

Theory:

The apparatus consists of a brass tube fitted in a rectangular duct in a vertical fashion. The duct is open at the top and bottom, and forms an enclosure and serves the purpose of undisturbed 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 dimmer stat.

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.

Schematic view of the test set-up:



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
   Thermocouple No. 6 reads the temperature of air in the duct.
5. Temperature Indicator = 0 – 300^{0}C. Multichannel type, calibrated for chromel – alumel thermocouples
6. Ammeter = 0 – 2 A
7. Voltmeter = 0 – 100 / 200 V
8. Dimmerstat = 2 A / 230 V
9. Heater = Cartridge type (400 W)

Tabulation:

Sl. No.	Voltage	Current	Temperature of Thermocouple (^{0}c)					
	V	A	T_1	T_2	T_3	T_4	T_5	T_6

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) β

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

   Where, hL / k are called Nusselt Number.

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

   μCp / k 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

   v = 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 gravity

   $\Delta T = Ts - Ta$

   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

Procedure:

1. Switch ON the supply and adjust the dimmer stat to obtain the required heat input.
2. Wait till a 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 found as

Theoretical = ______________ W/ m^2K

Experimental = ______________ W/ m^2K

Outcomes:

From this experiment, finding the surface heat transfer coefficient of a vertical tube losing heat by natural convection experiment is studied and this experiment could be used in the areas such as IC engines, heat exchangers, Steam boilers, Pressure Cookers, etc. where heat transfer co. efficient is to be found.

Applications:

IC engines, heat exchangers, Steam boilers, Pressure Cooker.

Viva – voce

1. Define – Grash of Number(Gr)
2. What is meant by Newtonian and Non – Newtonian fluids?
3. Define – Boundary Layer Thickness.
4. What is the form of equation used to calculate heat transfer for flow through cylindrical pipes?
5. What is meant by dimensional analysis?
6. Define – Momentum Thickness
7. What are the advantages of dimensional analysis?
8. State the limitations of dimensional analysis.
9. Define –Stanton Number(St)
10. What are the types of boundary layer available in heat transfer?
11. What is meant by thermal boundary layer?
12. Define – Hydrodynamic Boundary Layer
13. What is meant by free convection?
14. Define – Energy Thickness
15. Differentiate free from forced convection.
16. Explain the significance of boundary layer in heat transfer.
17. Write the expression for Newton's law of cooling.
18. Define – Displacement Thickness
19. What is meant by critical radius of insulation?
20. Define – Overall Heat Transfer Coefficient

Expt. No. 4 DETERMINATION OF HEAT TRANSFER COEFFICIENT UNDER FORCED CONVECTION FROM A TUBE

Aim:

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

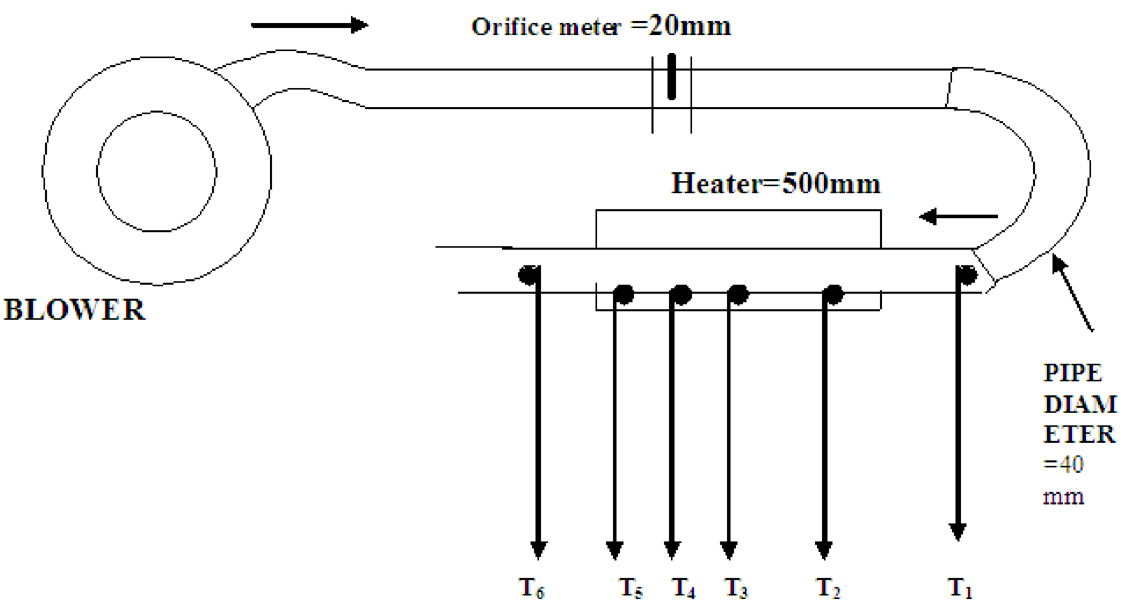
Apparatus required:

(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 dimmer stat 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	Temperature in (^{0}C)						Manometer reading of water in h in meter	
	(V)	(A)	T_1	T_2	T_3	T_4	T_5	T_6	h_1 cm	h_2 cm

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. Dimmer stat = 0 to 2 A, 260 V, 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 W)

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 W

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 dimmer stat 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.

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 (°C)

   $= T_6 - T_1$.

2. $m = Q\rho$

   Where, ρ = 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^2K

   q_a = Rate of which air is getting heated.

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

   Ta = Average temperature of air $= (T_1 + T_6)/2$ °C

   Ts = Average surface temperature $= (T_2 + T_3 + T_4 + T_5)/4$ °C

   Cd = 0.64

   H = Difference of water level in manometer m

   ρw Density of water = 1000 Kg/m³

   ρa = Density of air = [101.3/(0.287*Ta)] Kg/m³

   d = diameter of orifice meter = 0.014 m

   g = acceleration due to gravity = 9.81 m/s²

   using this procedure obtain the value of 'ha' for different air flow rate

4. Reynold's Number:

   $Re = VDi/ v$ Dimensionless number

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

   v = Kinematics viscosity to be evaluated at bulk mean temperature

   $(T_1 + T_6)/2$ °C

5. Nusselt Number:

   $Nu = (ha \times Di)/ k$ 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:

$Pr = C_p\mu / k$

C_p = 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^{2}K

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

Outcome:

From this experiment, determining the heat transfer co-efficient by using forced convection apparatus is understood and this experiment could be used in the areas such as IC engines, heat exchangers, Steam boilers, Pressure Cookers, Fins, Motor bodies, etc. where heat transfer co. efficient is to be found.

Applications:

IC engines, heat exchangers, Steam boilers, Pressure Cooker, Fins, Motor bodies.

Viva – voce

1. What is meant by boiling and condensation?
2. What is meant by pool boiling?
3. What is the scope of this experiment?
4. List the apparatus required to conduct this experiment.
5. State the purpose of blower fitted in this test set-up.
6. How many thermocouples were located in this experimental set-up?
7. What is the need of orifice provided in this set-up?
8. What is meant by LMTD?
9. Write about the applications of boiling and condensation.
10. How is the air flow measured in this experiment?
11. What are the various types of heat exchangers?
12. Define – Forced Convection
13. Distinguish between forced and free convection.
14. What are the dimensional parameters used in forced convection?
15. Define – Momentum Thickness

Expt. No.5 HEAT TRANSFER THROUGH COMPOSITE WALLS

Aim:

To conduct and determine the rate of heat transfer through different layers of composite wall

Description of apparatus:

When heat conduction takes place through two or more solid materials of different thermal conductivities, the temperature drop across each material depends on the resistance offered to heat conduction and the thermal conductivity of each material. The experimental set-up consists of test specimen made of different materials aligned together on both sides of the heater unit. The first test disc is next to a controlled heater. The temperatures at the interface between the heater and the disc is measured by a thermocouple, similarly temperatures at the interface between discs are measured. Similar arrangement is made to measure temperatures on the other side of the heater. The whole set-up is kept in a convection free environment. The temperature is measured using thermocouples (Iron-Cons) with multi point digital temperature indicator. A channel frame with a screw rod arrangement is provided for proper alignment of the plates. The apparatus uses a known insulating material, of large area of heat transfer to enable unidirectional heat flow. The apparatus is used mainly to study the resistance offered by different slab materials and to establish the heat flow is similar to that of current flow in an electrical circuit. The steady state heat flow $Q = \Delta t/R$ Where, Δt = is the overall temperature drop and R is the overall resistance to heat conduction. Since the resistance are in series $R = R_1 + R_2$ Where R_1, R_2 are resistance of each of the discs.

Specification:

1. Thermal conductivity Of sheet asbestos = 0.116 W/mK : Thickness = 6mm
2. Thermal conductivity of wood = 0.052 W/mK Thickness = 10mm
3. Dia. of plates = 300mm
4. The temperatures are measured from bottom to top plate T_1, T_2,………….T_8.

Procedure:

1. Turn the screw rod handle clockwise to tighten the plates.
2. Switch on the unit and turn the regulator clockwise to provide any desired heat input.
3. Note the ammeter and voltmeter readings.
4. Wait till steady state temperature is reached.
5. (The steady state condition is defined as the temperature gradient across the

plates that does not change with time.)

6. When steady state is reached note temperatures and find the temperature gradient across each slab.
7. Since heat flows from the bottom to top of the heater, the heat input is taken as Q/2 and the average temperature gradient between top and bottom slabs from the heater is to be taken for calculations. Different readings are tabulated as follows.

Calculation:

Now the resistance (R) offered by individual plates for heat flow

$R_1 = L_1/AK_1$ $R_2 = L_2 / AK_2$ $R_3 = L_3/AK_3$

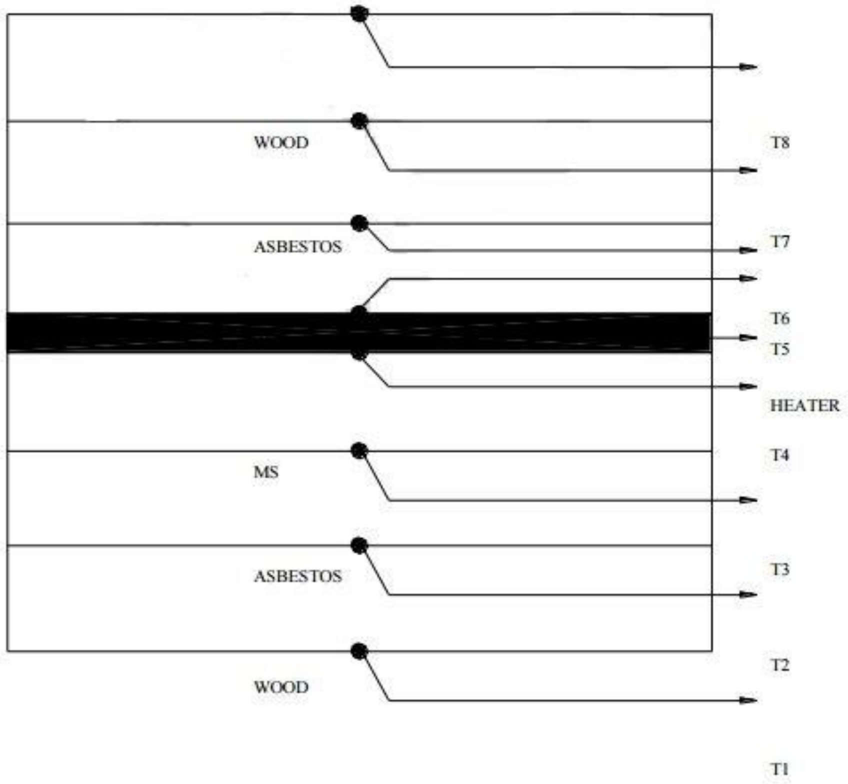
Where, A=Area of the plate K=Thermal Conductivity L=Thickness of the plate

Knowing the thermal conductivities

$Q = (T_4–T_1)/R = (T_2–T_1)/R_1 = (T_3–T_2)/R_2 = (T_4–T_3)/R$

Tabulation:

Sl.No.	Voltmeter reading (V)	Ammeter reading (A)	T_1 (^{0} C)	T_2 (^{0} C)	T_3 (^{0} C)	T_4 (^{0} C)	T_5 (^{0} C)	T_6 (^{0} C)	T_7 (^{0} C)	T_8 (^{0} C)



Composite wall apparatus set-up

Result:

The rate of heat transfer through different materials are found to be

a. MS section = ------------------W

b. Wood section = ---------------W

c. Asbestos section = ------------W

Outcome:

From this experiment, determining the rate of heat transfer through different materials is learnt and this experiment could be used in the areas such as IC engines, heat exchangers, Steam boilers, Pressure Cookers, Fins, Motor bodies, etc. where rate of heat transfer is to be found.

Applications:

IC engines, heat exchangers, Steam boilers, Pressure Cooker, Fins, Motor bodies.

Viva – voce

1. Define – Heat Transfer
2. How does heat transfer occur through composite walls?
3. Write about the merits of drop wise condensation.
4. What is meant by film wise and drop wise condensation?
5. What happens when heat conduction takes place through two or more solids of different thermal conductivities?
6. Give the expression for heat transfer through a composite pipes or cylinder.
7. State Newton's law of cooling.
8. Explain the significance of Fourier number.
9. What is meant by effectiveness?
10. Define – Heat Exchanger
11. What is meant by fouling factor?
12. Give the expression for heat transfer through a composite plane wall.

Expt. No.6 DETERMINATION OF THERMAL CONDUCTIVITY OF INSULATING POWDER

Aim:

To find out the thermal conductivity of insulating powder by conduction

Apparatus required:

The apparatus consists of concentric spheres made of copper. The inner sphere is a heater, and in between the spheres insulating powder (magnesium oxide) is filled and sealed. There are two thermo couples, T1 and T2, fixed to the heater, and two thermocouples, T3 and T4, fixed on the inner wall of the outer sphere. A multiunit digital temperature indicator is provided to measure temperature at different locations. The whole unit is mounted on a laminated work bench with panel. An ammeter - voltmeter is provided to measure the input power and dimmer stat is provided to vary the input power.

Procedure:

1. Switch on the unit and adjust the input power to the required extent.
2. Allow the temperature to stabilize.
3. Note the ammeter and voltmeter readings.
4. Note the temperature at different locations from T_1 to T_4.
5. Repeat the experiments for different power inputs.

The readings are tabulated below

Sl.No.	Voltmeter reading(V)	Ammeter reading (A)	T_1 (^{0}C)	T_2 (^{0}C)	T_3 (^{0}C)	T_4 (^{0}C)

Calculations:

The radius of the inner sphere (r_1) - 38 mm

The radius of the outer sphere (r_2) - 75mm

The power input Q =V x A=4π(t_1-t_2)kr_2-r_1/r_2-r_1

Where K is the thermal conductivity of the insulating powder t_1 and t_2 are the average temperature of the inner sphere, and the outer sphere respectively.

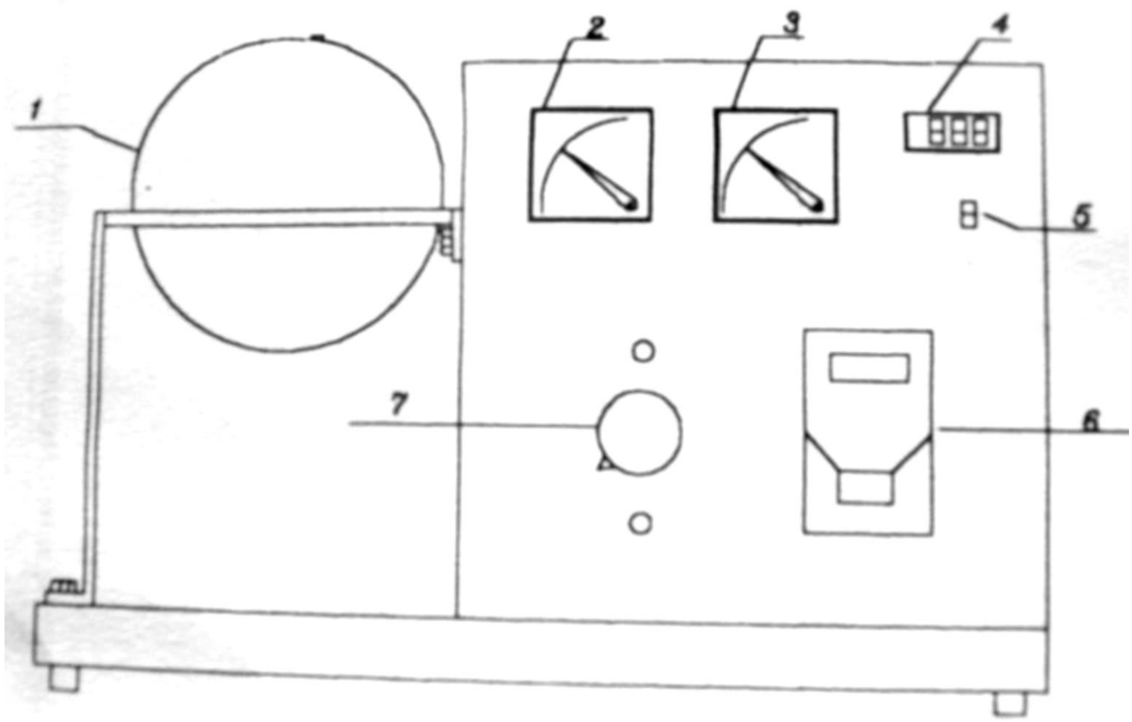


Fig. 1 Apparatus of thermal conductivity of insulating powder

[1. Shell, 2.Voltmeter, 3.Ammeter, 4.Temperature indicator, 5.Selector switch, 6.Main switch & 7.Heater control]

Result:

The thermal conductivity of insulating powder by conduction is found and the result is, ___________

Outcome:

From this experiment, evaluating the thermal conductivity of insulating powder by conduction is analyzed and this experiment could be used in the areas such as IC engines, heat exchangers, Steam boilers, Pressure Cookers, Fins, Motor bodies, etc. where the thermal conductivity of insulating material is to be found.

Applications:

IC engines, heat exchangers, Steam boilers, Pressure Cooker, Fins, Motor bodies.

Viva – voce

1. What is the need for conducting this experiment?
2. Define - Thermal Conductivity
3. What is the unit for thermal conductivity?
4. What is meant by mass transfer?
5. What are the factors which affect the thermal conductivity?
6. Write the examples of mass transfer.
7. Mention the insulating powder used in this experiment.
8. What are the different modes of mass transfer?
9. How many thermocouples were mounted in this test rig?
10. What is meant by molecular diffusion?
11. What is meant by Eddy diffusion?
12. What was the material selected for constructing sphere?
13. Define – Reynolds Number(Re)
14. Define – Prandtl Number(Pr)
15. Define – Convection
16. What is meant by transient heat conduction?
17. What is meant by thermal boundary layer?
18. How heat transfer occurs through insulated medium?
19. In which location the saw dust were filled in this experimental set up?
20. What is meant by steady state heat conduction?

Expt. No.7 HEAT TRANSFER FROM PIN-FIN APPARATUS (NATURAL AND FORCED CONVECTION MODES)

Aim:

To determine the pin-fin efficiency and heat flow through pin-fin by forced convection.

Apparatus required:

(i) Experimental setup

(ii) Thermocouples

(iii) U – tube manometer

Theory:

A brass fin 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 fin are shown.

Tabulations:

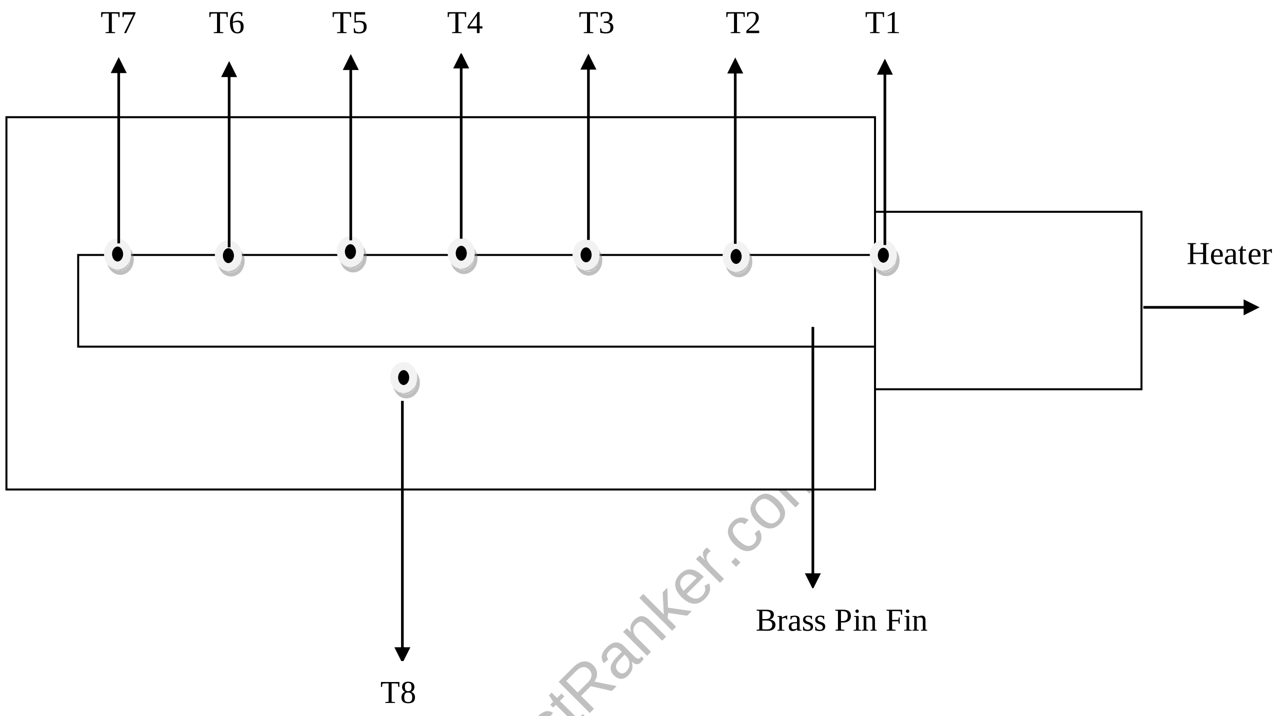
Forced convection:

Sl. No.	V	I	Fin Temperatures (^{0}C)							Ambient Temp (^{0}C)	Manometer Reading	
	(V)	(A)	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	h_1 cm	h_2 cm

Specifications:

1. Duct size = 150 mm x 100 mm.
2. Diameter of the fin = 12 mm
3. Effective length of fin = 14.5 cm
4. Diameter of the orifice = 24 mm
5. Diameter of the delivery pipe (O.D) = 46 mm

Schematic view of the test set-up:



6. Diameter of the delivery pipe (I.D) = 42 mm
7. Coefficient 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. Dimmer stat for heat input controls 230 V, 2 A
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 A

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 during the testing period.
5. Do not disturb thermocouples while testing.
6. Operate selector switch of temperature indicator gently.
7. Do not exceed 200 W.

Procedure:

Forced Convection:

1. Start heating the fin by switching ON the heater element and adjust the voltage on dimmer stat 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) = (ρw / ρa) 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

4. Reynold's Number:

$Re = V_{mf} D/ v$ Dimensionless number

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

D = diameter of the fin

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

$(T_1 + T_6) / 2$ °C

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 = √hpkA x (Tw – Tα) tan h (mL)

h = heat transfer coefficient,

Where, p = perimeter in m

k= 386 w/mk

m= √(hp/kA)

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

L = Length of the fin

T_w – average temperature

Tα – ambient (surface) temperature (T_6)

8. Efficiency, ŋ = {tan h (mL)}/ mL

Results:

Thus the experiment was conducted and results found were

Pin fin Efficiency, ŋ = __________

Heat transfer, Q = __________ W

Outcome:

From this experiment, determining the pin-fin efficiency and heat flow through pin-fin by forced convection is learnt and this experiment could be used in the areas such as IC engines, heat exchangers, Steam boilers, Pressure Cookers, Fins, Motor bodies, etc. where the pin-fin efficiency and heat flow through pin-fin is to be found.

Applications:

IC engines, heat exchangers, Steam boilers, Pressure Cooker, Fins, Motor bodies.

Viva – voce

1. Define – Extended Surface
2. What is meant by convective mass transfer?
3. State the applications of fins.
4. What is meant by free convective mass transfer?
5. Define – Heat Transfer
6. Define – Fin Efficiency
7. What are the various modes of heat transfer?
8. Define – Conduction
9. What is meant by fin effectiveness?
10. What is meant by steady state heat conduction?
11. Define – Convection
12. What is meant by transient heat conduction?
13. What is meant by radiation?
14. Define – Reynold's Number
15. Give the expression for calculating velocity of air.

Expt. No.8 DETERMINATION OF STEFAN – BOLTZMANN CONSTANT

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.

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 0.1⁰C L.C 0 - 200⁰C 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 = $\sigma = \{m \times Cp\ (dT / dt)t = 0\} / A\ (T_h^4 - T_d^4)$

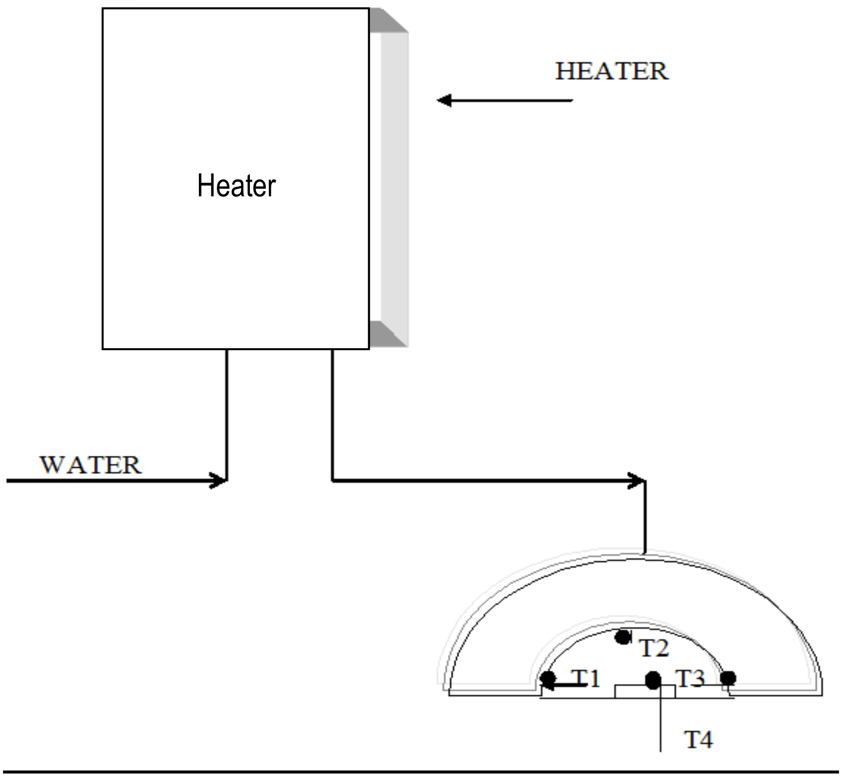
Where, A = area of the disc

T_h = Emitter temperature (average of T1, T2, T3)

T_d = Absorber temperature = T_0

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:



Tabulations:

Sl. No.	Hemisphere Temperature(^{0}C)			Avg. Temp. of the Hemisphere (T_h)	T_4	Steady Temp. of Disc T_0 (T_d)	Time (Sec)
	T_1	T_2	T_3				

Procedure:

1. Heat the water in the tank by the immersion heater up to a temperature of about 90^{0}C.
2. Remove the disc, D before pouring the hot water in the jacket.
3. Pour the hot water in the water jacket.
4. Let the hemispherical enclosure B and A 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. Let the enclosure come to thermal equilibrium conditions.
6. Insert the disc D now in A at a time when its temperature is T5 (to be sensed by a separate thermocouple).

Result:

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

Outcome:

From this experiment, calculating the Stefan Boltzman Constant by using boltzman apparatus is learnt and this experiment could be used in the areas such as IC engines, heat exchangers, Steam boilers, Pressure Cookers, Fins, Motor bodies, etc. where the Stefan Boltzman Constant is to be found by using boltzman apparatus.

.Applications:

IC engines, heat exchangers, Steam boilers, Pressure Cooker, Fins, Motor bodies.

Viva – voce

1. Define – Emissive Power[E]
2. What are meant by black body?
3. State Planck's distribution law.
4. Define – Biot Number
5. State Wien's displacement law.
6. What is the significance of Biot Number?
7. State Stefan – Boltzmann law.
8. What are the various types of convection?
9. Define – Condensation
10. What are the various modes of condensation?
11. Define – Monochromatic Emissive Power[$E_{b\lambda}$]
12. What is meant by gray body?
13. State Krichoff's law or radiation
14. What is meant by shape factor?
15. Explain the concept of black body.

Expt. No.9 DETERMINATION OF EMISSIVITY OF A GREY SURFACE

Aim:

To measure 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 dimmer stats 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 = $V_1 \times I_1$ W
2. Heater input to test plate W_2 = $V_2 \times I_2$ W
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. Capacity of heater = 200 W each
5. Voltmeter = 0 -100/200 V
6. Ammeter = 0-2 A
7. Dimmer stat for (1) & (2) 0 – 2 A, 0 – 260 V
8. Enclosure size = 580 mm x 300 mm x 300 mm.
9. Thermocouples = Chromel Alumel – 3 Nos.
10. Temperature Indicator = 0 – 300^{0}C.

Precautions:

1. Keep the dimmer stat 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	Voltage	Current	Black body temp(^{0}C)			Avg. temp.	Polished body temp (^{0}C)			Avg. temp.	Enclosure Temp.
	(V)	(I)	T_5	T_6	T_7	T_b	T_1	T_2	T_3	T_p	(T_4)

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 = $V_1 \times I_1$ W

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

A = area of plates = $2\ (\pi/4)\ xd^2$ m^2

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

Ta = Ambient temperature of enclosure

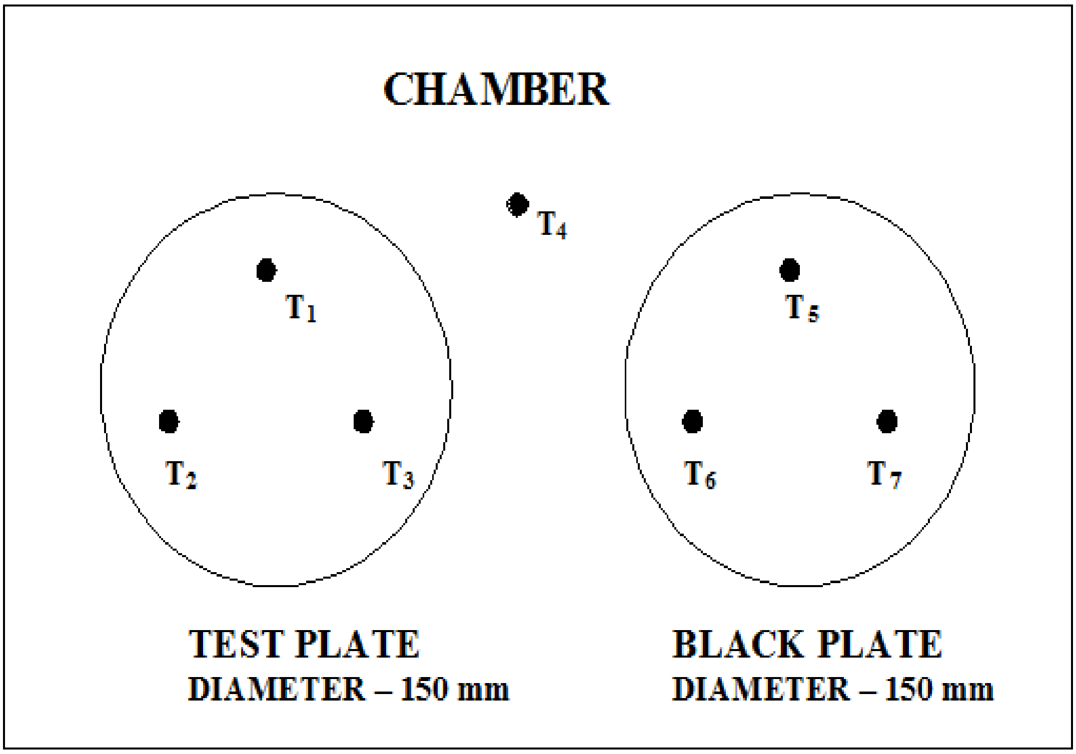
Ts = surface temperature of the discs (or T_1)

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:



Procedure:

1. Increase the input to the heater gradually 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 dimmer stat so that the two plates will be maintained at the same temperature.
3. Follow trial and error method and wait sufficiently (more than one hour or so) to obtain the steady state condition.

Results:

The emissivity of the test plate surface is found to be ____________.

Outcome:

From this experiment, finding the emissivity of the test plate surface at various temperatures is learnt and this experiment could be used in the areas such as IC engines, heat exchangers, Steam boilers, Pressure Cookers, Fins, Motor bodies, etc. where emissivity is to be found.

Applications:

IC engines, heat exchangers, Steam boilers, Pressure Cooker, Fins, Motor bodies.

Viva – voce

1. Define – Emissivity
2. State Kirchoff's law of radiation.
3. What is meant by reflectivity?
4. State Lambert's cosine law.
5. What is the purpose of radiation shield?
6. What is meant by shape factor?
7. Define – Radiation
8. What is meant by monochromatic emissive power?
9. Define – Emissive Power
10. What is meant by absorptivity?
11. Define – Black Body
12. What is meant by transmissivity?
13. State Plank's distribution law
14. What is meant by gray body?
15. Define – Irradiation

Expt. No.10 EFFECTIVENESS OF PARALLEL / COUNTER FLOW HEAT EXCHANGE

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. PARALLEL 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:

Sl. 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
		T_{hi} (T_1)	T_{ho} (T_2)	T_{ci} (T_3)	T_{co} (T_4)		
1	Parallel flow						
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)

   $$\Delta Tm = (\Delta Ti - \Delta To) / \ln (\Delta Ti/\Delta To)$$

   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/m²K

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

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.

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 = _________.

Outcome:

From this experiment, determining the values of effectiveness of parallel and counter flow heat exchangers is learnt and this experiment could be used in the areas such as IC engines, heat exchangers, Steam boilers, Pressure Cookers, Fins, Motor bodies, etc. where the effectiveness is to be found.

Applications:

IC engines, heat exchangers, Steam boilers, Pressure Cooker, Fins, Motor bodies.

Viva – voce

1. Define – Heat Exchanger
2. What are the types of heat exchangers?
3. What is meant by indirect contact heat exchanger?
4. Write about the merits of drop wise condensation.
5. What is meant by film wise and drop wise condensation?
6. What is meant by effectiveness?
7. Define – Direct Heat Exchanger
8. What is meant by fouling factor?
9. Distinguish between regenerator and recuperates.
10. What is meant by parallel flow heat exchanger?
11. What is meant by counter flow heat exchanger?
12. What is meant by cross flow heat exchanger?
13. What is meant by shell and tube heat exchanger?

Expt. No.11 DETERMINATION OF COP OF A REFRIGERATION SYSTEM

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 either 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^{0}C 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^{0}C.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^{0}C and cut in at 10^{0}C 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.

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 Imp / 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 = $(\pi/4)\ d^2l = 12.58 \times 10^{-6}\ m^3$

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

Observation Table: **I**

Sl. No.	Initial Temp. of water	Final Temp. of water	Duration of exp.	Delivery pressure	Delivery Temp.	Condense Outlet Pressure	Condense Outlet Temp.	Pressure after throttling	Temp. After Throttling	Suction pressure

Procedure:

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. Allow The temperature in water calorimeter 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.

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 = ___________.

Outcome:

From this experiment, conducting the load test on a refrigeration test rig and finding out the volumetric efficiency and co-efficient of performance for any type of refrigerant is learnt and this experiment could be used in the areas such as Refrigerator and Air Conditioning.

Applications:

Refrigerator, Air Conditioning.

Viva – voce

1. Define – COP
2. Which thermodynamic cycle is used in air conditioning of airplanes using air as refrigerant?
3. Define – Ton of Refrigeration
4. What is meant by refrigeration?
5. What is meant by air conditioning?
6. What are the four important properties of a good refrigerant?
7. How does the actual vapour compression cycle differ from that of the ideal cycle?
8. Name any four commonly used refrigerants.
9. What are the expansion devices used in a vapour compression plant?
10. Why throttle valve is used in place of expansion cylinder for vapour compression refrigerant machine?
11. What are the merits of air refrigeration system?
12. What are the demerits of air refrigeration system?
13. Define – Refrigerant
14. What is net refrigerating effect of the refrigerant?
15. What are the methods to obtain sub cooling of refrigerant?

Expt. No.12 EXPERIMENTS ON PSYCHROMETRIC PROCESS

Aim:

To conduct an experiment on psychrometric processes with 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).

6. The test rig consist of compressor, condenser unit placed inside trolley and fitted

with (i) Freon-22 (CCl_2F_2) reciprocating compressor (ii) Air cooled condenser, (iii) Cooling fan for condenser and (iv) Liquid receiver.

7. The inside of air duct and all metal parts should be painted at least once a year to avoid moisture and corrosion damage.

Observation Table: I

S. No	Inlet temp		Outlet temp		Pressure P_1	Temp. T_1	Pressure P_2	Temp. T_2	Pressure P_3	Temp. T_3	Pressure P_4	Temp. T_4	Energy for 10 revolutions
	T_{wet}	T_{dry}	T_{wet}	T_{dry}	L_b/in	^{0}C	L_b/in	^{0}C	L_b/in	^{0}C	L_b/in	^{0}C	

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^{0}C 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^{0}C 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 psychrometric 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. 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
4. 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
5. 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

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.

Result:

Experiment on psychrometric processes with air conditioning system was drawn

Outcome:

From this experiment, conducting the test on psychrometric processes with air conditioning system is learnt and this experiment could be used in all types of air conditioning systems.

Applications:

Air Conditioning.

Viva – voce

1. What is the commonly used unit of refrigeration?
2. Distinguish between summer air conditioning and winter air conditioning.
3. Define – RSHF Line
4. Define – By Pass Factor of a Heating Coil
5. What is the effect of sub cooling a refrigerant in a vapour compression cycle?
6. What is the function of analyzer and rectifier in an absorption system?
7. What is the purpose of generator assembly in vapour absorption refrigeration system?
8. State the substance used in the Lithium Bromide system and their functions.
9. Differentiate wet compression from dry compression.
10. Define – Apparatus Dew Point
11. What is meant by dew point temperature?
12. Define – Wet Bulb Temperature
13. Define – Degree of Saturation
14. What is meant by specific humidity?
15. Define – Relative Humidity

Expt. No.13 PERFORMANCE TEST ON A RECIPROCATING AIR COMPRESSOR

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.

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

Observation Table: I

Sl. No.	Pressure p	Manometer h_1	Manometer h_2	Time for 5 revolutions Energy meter	Speed of the compressor	T
	Kg/cm^2	Cm	cm	sec	rpm	

Observation Table: II

Sl. No.	Actual Discharge V_a	Theoritical Discharge V_t	Volumetric Efficiency η	Power Input	Output Power	Overall Efficiency η_0	Isothermal Workdone IwD	Pol Wo P
	m^3 /sec	m ^{3} /sec	%	kW	kW	%	J/Kg	J

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 that gauge pressure in the tank is zero.
2. Start the compressor. Read the receiver pressure gauge for a particular pressure.
3. Maintain the pressure constant by adjusting the outlet valve.
4. Note down the manometer reading and time taken for 3 revolution of the energy

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:

$$V_{a\,RTP} = C_d \times A_o \times \sqrt{2\, g\, h_{a\,RTP}}$$

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:

$$V_{a\,NTP} = \frac{V_{a\,RTP} \times T_{NTP}}{T_{RTP}}$$

Where,

T_{NTP} = Normal temp - 273°k

T_{RTP} = Room temp - °c (273 + T_{ROOM})

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

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

D = LP Bore diameter = 88.5 mm.

L = Stroke length = 88.9 mm.

Nc = Compressor speed rpm.

6. Volumetric Efficiency:(for LP stage)

$$\eta_{vol} = \frac{Va\ NTP}{V_t} \times 100\%$$

7. Shaft Input through Energy meter:

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

Where,

Ec = 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:

$$= \frac{Pa \times Va_{RTP} \times \log_e(R)}{1000} \quad W$$

Pa = Atmospheric pressure in N/ m² = 1.01325 x 10⁵ N / m².

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

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 and Pressure Vs Isothermal efficiency are drawn.

Outcome:

From this experiment, conducting the load test on two stage reciprocating air compressor for determining the isothermal and volumetric Efficiencies at various delivery pressures is understood and this experiment could be used in the areas such as Refrigerator, Air Conditioning, IC engines, etc.

Applications:

Refrigerator, Air Conditioning, IC engines.

Viva – voce

1. How are air compressors classified?
2. Define – Isothermal Efficiency of Air Compressor
3. What is meant by FAD (Free Air Delivery)?
4. What is meant by perfect inter-cooling?
5. Define – Clearance Ratio of an Air Compressor
6. List out the applications of compressed air.
7. What are the types of air compressors?
8. What is meant by single acting compressor?
9. What is meant by double acting compressor?
10. What is meant by single stage compressor?
11. What is meant by multi stage compressor?
12. Indicate the applications of reciprocating compressors in industry>
13. Define – Mechanical Efficiency
14. What is meant by compression ratio?
15. What are the factors that affect the volumetric efficiency of a reciprocating compressor?

Expt. No.14 PERFORMANCE TEST IN A HC REFRIGERATION SYSTEM

Aim:

To conduct the performance test on Vapour Compression Refrigeration System and to determine the Coefficient of Performance using solenoid valve by throttling method

Description:

In this system the working fluid is a HC out of a refrigeration system. The HC compression system is most important system from the view point of commercial and domestic utility. The HC refrigerant at low temp and pressure enters the reciprocating compressor, where it is compressed isentropically and subsequently its temp and pressure increases considerably. This HC after leaving the compressor enters the condenser where it is cooled into low temperature. Then it is sucked by reciprocating compressor and is thus repeated.

Formula used:

$$\text{Actual COP} = \frac{\text{refrigerant effect}}{\text{I/p energy to compressor}}$$

$$\text{Refrigerant effect} = \frac{m \times C_p \times \Delta T}{t}$$

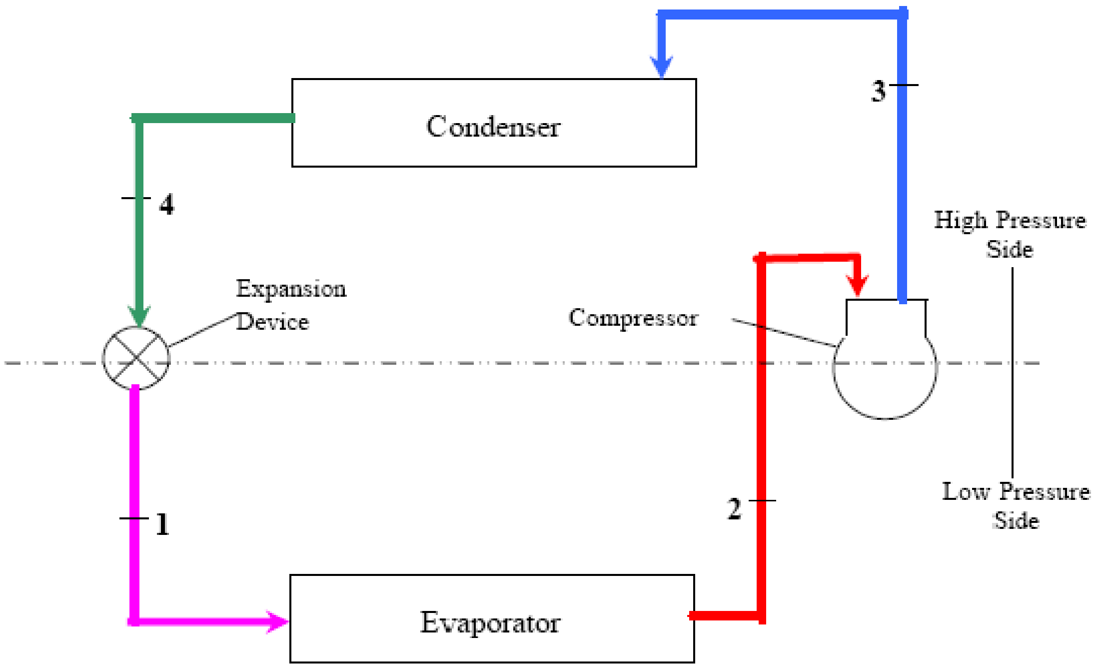
m - mass of water (kg)
Cp - Sp. Heat of water (4.2 kJ/kg K)
ΔT – decrease in temp (Ti-Ts)
t - timetaken duration of expt (sec)

Energy input =n x 3600 /k x t

n – number of revolutions in energy meter
t – time taken of 'n' revolutions
k – energy meter constant (3200)

Tabulation:

Pressure of the refrigerant (Mpa)				Temperature						Time for n' rev of energy meter in sec
P_1	P_2	P_3	P_4	Circulating fluid temp		Refrigerant temp				
				T_i	T_f	T_1	T_2	T_3	T_4	



Model calculation:

Actual COP = $\frac{\text{refrigerant effect}}{\text{I/p energy to compressor}}$

Refrigerant effect = $\frac{mxCpx\Delta T}{t}$

m - mass of water (kg)
Cp - Sp. Heat of water (4.2 kJ/kg K)
ΔT – decrease in temp (Ti-Ts)
t - time taken duration of experiment (sec)
Refrigerating effect = 8x4.2x (27-6)/1200=0.588 kw

Energy input = n x 3600
n – Number of revolutions in energy meter
t – Time taken of 'n' revolutions

k – Energy meter constant

=3 x 3600/(1200 x 54)

=0.166 kW

Actual COP = $\frac{\text{refrigerant effect}}{\text{I/p energy to compressor}}$

= 0.588/0.166
=3.526

Result:

The experiment was conducted successfully and coefficient of performance was found out is _______.

Outcome:

From this experiment, conducting the performance test on Vapour Compression Refrigeration System and to determine the Coefficient of Performance using solenoid valve by throttling method is understood and this experiment could be used in the areas such as Refrigerator and Air Conditioning systems.

Applications:

Refrigerator, Air Conditioning.

Viva – voce

1. What is the difference between air conditioning and refrigeration?
2. Write any three important properties of a good refrigerant.
3. What is the function of analyzer and rectifier in an absorption system?
4. How does humidity affect human comfort?
5. What is the commonly used unit of refrigeration?
6. Distinguish between summer air conditioning and winter air conditioning.
7. Define – RSHF Line
8. Define – By Pass Factor of a Heating Coil
9. What is the effect of sub cooling a refrigerant in a vapour compression cycle?
10. What is the function of analyzer and rectifier in an absorption system?
11. What is the purpose of generator assembly in vapour absorption refrigeration system?
12. State the substance used in the Lithium Bromide system and their functions.
13. Differentiate wet compression from dry compression.
14. Define – Apparatus Dew Point
15. What is meant by dew point temperature?
16. Define – Wet Bulb Temperature
17. Define – Degree of Saturation
18. What is meant by specific humidity?
19. Define – Relative Humidity
20. What is meant by dew point temperature?

Expt. No.15 PERFORMANCE TEST IN A FLUIDIZED BED COOLING SYSTEM

Aim:

To determine the performance test on cooling tower

Introduction:

The cooling tower is one of the most important device in chemical industries for example when the hot water come from heat exchanger we use the cooling tower to cool it The purpose of cooling tower is to cool relatively warm water by contacting with unsaturated air. The evaporation of water mainly provides cooling. In typical water cooling water tower warm water flows countercurrent to an airstream. Typically, the warm water enters the top of the packed tower and cascades down through the packing , leaving at the bottom Air enters at the bottom of the tower and flows upward through the descending water . The tower packing often consist of slats of plastic or of packed bed. The water is distributed by troughs and overflows to cascade over slat gratings or packing that provides large interfacial areas of contact between the water and air in the form of droplets and films of water. The flow of air upward through the tower can be induced by the buoyancy of the warm air in the tower (natural draft) or by the action of a fan . The water cannot be cooled below the wet bulb temperature. The driving force for the evaporation of water is approximately the vapour pressure of the water less the vapour pressure it would have at the wet bulb temperature

Procedure:

1. Introduce water and record its flow rate.
2. Switch ON the heaters on so that water is heated to the required temperature.
3. Introduce air and record its flow rate.
4. Wait for steady state then record steady state dry and wet bulb temperature of air at the entrance and exit.
5. Record the inlet and outlet temperature and flow rate of water also record temperature at different stages.

Tabulation:

Sl.No.	T1 (^{0}c)	T_2 (^{0}c)	T_3 (^{0}c)	Efficiency

T_1 = room temperature

T_2 = water inlet
T_3 = water outlet

Efficiency of cooling tower

ECT = T3/T2/*100

Model calculation:

Efficiency of cooling tower = water outlet
--------------- *100
Water inlet

= 36/40 *100

= 90

Result:

The performance test in cooling tower is determined as ______%.

Outcome:

From this experiment, conducting the performance test on cooling tower is understood and this experiment could be used in various power plants where cooling tower is used.

Applications:

Power Plant Cooling Tower, Cooling Tower.

Viva – voce

1. What are functions of a draught system?
2. What are the advantages of burning coal in pulverized form?
3. What are the functions of cooling tower?
4. What are the different types of draught system?
5. What are the methods used for handling of coal?
6. What is meant by fluidized bed combustion?
7. What is the use of fluidized bed boiler?
8. What are the types of fluidized bed boiler?
9. State the purpose of condenser in fluidized bed boiler.
10. What is meant by pulveriser and why it is used?
11. State the disadvantages of pulverized coal firing.
12. Distinguish between fouling and slagging.

ADDITIONAL EXPERIMENTS

BEYOND THE SYLLABUS

Expt. No.16 AIR CONDITIONING TEST RIG

Aim:

To conduct a performance test on air conditioning test rig and determine the Coefficient of Performance 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).
6. The test rig consists of compressor, condenser unit placed inside trolley and fitted with (i) Freon-22 (CCl_2F_2) reciprocating compressor (ii) Air cooled condenser, (iii) Cooling fan for condenser and (iv) Liquid receiver.

Observation Table: I

Sl. No	Inlet temperature		Outlet temperature		Pressure P_1	Temp. T_1	Pressure P_2	Temp. T_2	Pressure P_3	Temp. T_3	Pressure P_4	Temp. T_4	Energy for 10 revolutions
	T_{wet}	T_{dry}	T_{wet}	T_{dry}	L_b/in	^oC	L_b/in	^oC	L_b/in	^oC	L_b/in	^oC	

Air conditioning Test Rig

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.

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 Imp / 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.

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:
   (ii) Dry bulb temperatures t_{db1}, t_{db2}, t_{db3}, t_{db4}.
   (ii) Wet bulb temperatures t_{wb1}, t_{wb2}, t_{wb3}, t_{wb4}.
   (xi) Spray water temperature, ts
   (xii) Surface temperature of cooler, t_m (at control panel)
   (xiii) Pressure gauge reading, pd (at control panel)
   (xiv) Compound gauge reading, Ps (at control panel)
   (xv) Level reduction'l' in spray reservoir (mm) during 5 min.
   (xvi) Amount of condensate collected 'l_c', in a measuring jar at cooler tray during a run of 5 minutes at constant conditions.
   (xvii) Time in second 'S_H' for 10 pulses of the energy meter disc connected to the heater.
   (xviii) Time in seconds S_c for 10 pulses of the energy meter disc connected to cooler

1. 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.

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 = ______________.

Outcome:

From this experiment, conducting the performance test on air conditioning test rig and determining the Coefficient of Performance of air conditioning system is understood and this experiment could be used in the areas such as Refrigerator and Air Conditioning systems.

Applications:

Refrigerator, Air Conditioning.

Viva – voce

1. What is meant by dew point temperature?
2. Define – Effective Temperature
3. Define – COP of Refrigeration
4. Define – Relative Humidity and Wet Bulb Temperature
5. Differentiate heat pump from refrigerator.
6. Define – RSHF Line
7. Define – By Pass Factor of a Heating Coil
8. What is the effect of sub cooling a refrigerant in a vapour compression cycle?
9. What is the function of analyzer and rectifier in an absorption system?
10. What is the purpose of generator assembly in vapour absorption refrigeration system?
11. State the substance used in the Lithium Bromide system and their functions.
12. Differentiate wet compression from dry compression.
13. Define – Apparatus Dew Point
14. What is meant by dew point temperature?
15. Define – Wet Bulb Temperature

Project Work

1. Waste heat recovery system from domestic refrigerator for water and air heating
2. Waste heat recovery system from domestic refrigerator for oven
3. Numerical Investigation and Statistical Analysis on Tree Shaped Fin for Natural Convection
4. CFD and Taguchi Analysis on Tree Fin for Natural Convection
5. The rate of heat transfer of seawater and NaCl solutions under conditions of one- and two-phase flow in tubes
6. Experimental analysis of emission characteristics in spark ignition engines at the presence of ortho hydrogen
7. Solar Energy for Cooling and Refrigeration
8. Thermal analysis and design of shell and heat type heat exchanger
9. Thermodynamic analysis of refrigeration system including all parts
10. Thermal analysis of air conditioner to decide its COP
11. Thermal design of domestic refrigerator to improve the performance
12. Performance analysis of a gasket plate heat exchanger by varying port diameter
13. Theoretical performance of magnetic hydrodynamics power plant with aluminum as fuel
14. Investigation on performance characteristics of blended biodiesel with multifunctional additives
15. Performance analysis of basin type solar still under the effect of vacuum pressure