NEHRU COLLEGE OF ENGINEERING AND RESEARCH CENTRE
(NAAC Accredited)
(Approved by AICTE, Affiliated to APJ Abdul Kalam Technological University, Kerala)

Moulding True Citizen
Since 1968

DEPARTMENT OF MECHATRONICS ENGINEERING

LAB MANUAL

MRL202 MECHANICAL ENGINEERING LAB

VISION OF THE INSTITUTION
To mould true citizens who are millennium leaders and catalysts of change through excellence in education.
MISSION OF THE INSTITUTION
NCERC is committed to transform itself into a center of excellence in Learning and Research in Engineering and Frontier Technology and to impart quality education to mould technically competent citizens with moral integrity, social commitment and ethical values. We intend to facilitate our students to assimilate the latest technological know-how and to imbibe discipline, culture and spiritually, and to mould them in to technological giants, dedicated research scientists and intellectual leaders of the country who can spread the beams of light and happiness among the poor and the underprivileged.

ABOUT DEPARTMENT

- Established in: 2013
- Course offered: B.Tech Mechatronics Engineering
- Approved by AICTE New Delhi and Accredited by NAAC
- Affiliated to the University of A P J Abdul Kalam Technological University.

DEPARTMENT VISION

To develop professionally ethical and socially responsible Mechatronics engineers to serve the humanity through quality professional education.

DEPARTMENT MISSION

1) The department is committed to impart the right blend of knowledge and quality education

to create professionally ethical and socially responsible graduates.

2) The department is committed to impart the awareness to meet the current challenges in technology.

3) Establish state-of-the-art laboratories to promote practical knowledge of mechatronics to meet the needs of the society

PROGRAMME EDUCATIONAL OBJECTIVES

I. Graduates shall have the ability to work in multidisciplinary environment with good professional and commitment.

II. Graduates shall have the ability to solve the complex engineering problems by applying electrical, mechanical, electronics and computer knowledge and engage in lifelong learning in their profession.

III. Graduates shall have the ability to lead and contribute in a team with entrepreneur skills, professional, social and ethical responsibilities.

IV. Graduates shall have ability to acquire scientific and engineering fundamentals necessary for higher studies and research.

PROGRAM OUTCOME (PO'S)

Engineering Graduates will be able to:

PO 1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO 4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO 5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO 6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO 7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO 8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO 11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOME (PSO'S)

PSO 1: Design and develop Mechatronics systems to solve the complex engineering problem by integrating electronics, mechanical and control systems.

PSO 2: Apply the engineering knowledge to conduct investigations of complex engineering problem related to instrumentation, control, automation, robotics and provide solutions.

PREPARATION FOR THE LABORATORY SESSION

GENERAL INSTRUCTIONS TO STUDENTS

1. Read carefully and understand the description of the experiment in the lab manual. You may go to the lab at an earlier date to look at the experimental facility and understand it better. Consult the appropriate references to be completely familiar with the concepts and hardware.

2. Make sure that your observation for previous week experiment is evaluated by the faculty member and your have transferred all the contents to your record before entering to the lab/workshop.

3. At the beginning of the class, if the faculty or the instructor finds that a student is not adequately prepared, they will be marked as absent and not be allowed to perform the experiment.

4. Bring necessary material needed (writing materials, graphs, calculators, etc.) to perform the required preliminary analysis. It is a good idea to do sample calculations and as much of the analysis as possible during the session. Faculty help will be available. Errors in the procedure may thus be easily detected and rectified.

5. Please actively participate in class and don't hesitate to ask questions. Please utilize the teaching assistants fully. To encourage you to be prepared and to read the lab manual before coming to the laboratory, unannounced questions may be asked at any time during the lab.

6. Carelessness in personal conduct or in handling equipment may result in serious injury to the individual or the equipment. Do not run near moving machinery/equipment. Always be on the alert for strange sounds. Guard against entangling clothes in moving parts of machinery.

7. Students must follow the proper dress code inside the laboratory. To protect clothing from dirt, wear a lab coat. Long hair should be tied back. Shoes covering the whole foot will have to be worn.

8. In performing the experiments, please proceed carefully to minimize any water spills, especially on the electric circuits and wire.

9. Maintain silence, order and discipline inside the lab. Don't use cell phones inside the laboratory.

10. Any injury no matter how small must be reported to the instructor immediately.

11. Check with faculty members one week before the experiment to make sure that you have the handout for that experiment and all the apparatus.

AFTER THE LABORATORY SESSION

1. Clean up your work area.

2. Check with the technician before you leave.

3. Make sure you understand what kind of report is to be prepared and due submission of record is next lab class.

4. Do sample calculations and some preliminary work to verify that the experiment was successful

MAKE-UPS AND LATE WORK

Students must participate in all laboratory exercises as scheduled. They must obtain permissionfrom the faculty member for absence, which would be granted only under justifiablecircumstances. In such an event, a student must make arrangements for a make-up laboratory, which will be scheduled when the time is available after completing one cycle. Late submission will be awarded less mark for record and internals and zero in worst cases.

LABORATORY POLICIES

1. Food, beverages & mobile phones are not allowed in the laboratory at any time.

2. Do not sit or place anything on instrument benches.

3. Organizing laboratory experiments requires the help of laboratory technicians and staff. Be punctual.

SYLLABUS

MECHATRONICS

MRL202	MECHANICAL ENGINEERING LAB	CATEGORY	L	T	P	CREDIT
		PCC	0	0	3	2

Preamble: The main objective of this course is to demonstrate the applications of heat transfer, heat exchangers, and the principles of dynamics of machinery.

Prerequisite: MRT202 Thermodynamics,

Course Outcomes: After the completion of the course the student will be able to:

CO 1	Estimate heat transfer coefficient, LMTD and assess the performance of heat exchangers.
CO 2	Acquire necessary skills to conduct experiments on modes of heat transfer, collect data, perform analysis and interpret results to draw valid conclusions through standard test procedures.
CO 3	Asses the performance of vapour compression refrigeration and air conditioning systems.
CO 4	Evaluate the performance of heat pipes.
CO 5	Perform calibration of thermometers and pressure gauges.
CO 6	Demonstrate the effect of unbalances resulting from rotary motions.
CO 7	Visualise the effect of dynamics on vibrations in single and multi degree of freedom systems.
CO 8	Demonstrate the working principle of governor/ gyroscope and demonstrate the effect of forces and moments on their motion.

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	3	2	1	1	-	-	-	-	2	1	-	-
CO 2	3	2	1	1	-	-	-	-	2	1	-	-
CO 3	3	2	1	1	-	-	-	-	2	1	-	-
CO 4	3	2	1	1	-	-	-	-	2	1	-	-
CO 5	3	2	1	1	-	-	-	-	2	1	-	-
CO 6	3	3	1	2	-	-	-	-	2	1	-	-
CO 7	3	3	1	2	-	-	-	-	2	1	-	-
CO 8	3	3	1	2	-	-	-	-	2	1	-	-

Assessment pattern
Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	75	75	2.5 hours

Continuous internal evaluation pattern:
Attendance : **15 Marks**
Continuous Assessment : **30 Marks**
Internal Test (Immediately before the second series test) : **30 Marks**

End semester examination pattern: The following guidelines should be followed regarding award of marks:
(a) Preliminary work : 15 Marks

(b) Implementing the work/Conducting the experiment : 10 Marks
(c) Performance, result and inference
(Usage of equipments and trouble shooting) : 25 Marks
(d) Viva voce : 20 marks
(e) Record : 5 Marks

Course level assessment questions:

Course Outcome 1 (CO 1):

1. Define effectiveness of a heat exchanger.
2. Under what conditions is the effectiveness NTU method preferred over LMTD method as a method of analysis of a heat exchanger?
3. Under what conditions can a counter flow heat exchanger have an effectiveness of one? What would be your answer for a parallel flow heat exchanger?
4. Explain LMTD for counter flow heat exchanger

Course Outcome 2 (CO 2)

1. Does the use of insulation (outside a heated cylindrical tube) always result in a decrease in heat loss? Justify your answer.
2. What are the differences between forced and free convection?
3. What are the factors that affect the magnitude of convective heat transfer coefficient for: (i) Free convection and (ii) Forced convection for flow in a pipe
4. Can the overall heat transfer coefficient (U) for heat flow from a composite slab to (with convection and conduction taking place) be greater than the convective heat transfer coefficient (h)? Explain.
5. When does one use (i) Fourier number (ii) Nusselt Number (iii) Stanton Number ?
7. Explain why the temperature boundary layer grows much more rapidly than the velocity boundary layer in liquid metals.
8. What is the physical significance of the Schmidt number (S_c)? What is the heat transfer equivalent of this number? What does $S_c = 1$ signify?
6. What is a (i) gray surface (ii) diffuse surface?

Course Outcome 3 (CO 3):

1. The outside air at 31°C dry bulb temperature and 18.5°C wet bulb temperature enters a cooling coil at the rate of 40 m^3 /min. the effective surface temperature of the cooling coil is 4.5°C and its cooling capacity is 12.5kW of refrigeration. Find (a) dry bulb temperatures of the air leaving the coil, (b) enthalpy of air leaving the coil, (c) by pass factor of the coil.
2. Explain the following terms in brief. DBT, WBT, DPT
3. Explain the effect of Sub-cooling and Super-heating of on the performance of a simple vapour compression refrigeration system.

Course Outcome 4 (CO 4):

1. What are the primary heat transport limitations of a heat pipe?
2. What is the major heat transfer mechanism in a heat pipe?
3. What are the major operation limits of a heat pipe
4. A heat pipe with copper shell, copper wick and water as the working fluid is transferring 100W thermal power at steady-state operating conditions. The heat pipe dimensions are as follows: evaporator length = 0.1 m, condenser length = 0.1 m, adiabatic section length = 0.1

m and an outer diameter = 0.01 m. The average evaporator and condenser section temperatures of the heat pipe are measured as 105C and 95C respectively, calculate (a) the thermal resistance and (b) the effective thermal conductivity of the heat pipe.
5. What is a thermosyphon heat pipe? Comment on the thermal conductivity of a typical thermosyphon heat pipe?

Course Outcome 5 (CO 5):
1. Name three types of thermocouples with their respective composition and polarity. 2. What do you mean by: (i) cold junction compensation (ii) linearization?
3. What are the measuring ranges of different types of thermocouples?
4. What is a thermopile?
5. What is the difference between a RTD and PRT sensor?
6. What is automatic cold junction compensation?
7. What are the application advantages of a dead weight tester and a gauge comparator?
8. Write the types of Bourdon tubes? Explain the purpose of different Bourdon tubes.

Course Outcome 6 (CO 6):
1. What do you mean by static and dynamic balance of machinery
2. What do you mean by whirling of shaft?
3. What are the factors that affect the critical speed of a shaft?
4. What is (i) swaying couple (ii) Tractive force?

Course Outcome 7 (CO 7):
1. What is meant by free vibration and forced vibrations?
2. What is the significance of the node point in the case of vibration?
3. What do you mean by damping coefficient?
4. Define damping ratio (i) Damping ratio (ii) Logarithmic decrement
5. What is meant by dynamic magnifier or magnification factor?
6. Specify the importance of vibration isolation?
7. What is the condition to be satisfied for complete balance of in-line engine?
8. What are the effects of an unbalanced primary force along the line of stroke of two cylinder locomotive?

Course Outcome 8 (CO 8):
1. What is gyroscopic couple?
2. What is meant by active and reactive gyroscopic couple?
3. What is the effect of gyroscopic couple on a two wheeled vehicle while taking a turn?
4. Describe the right-hand rule to find the direction of angular velocity, momentum, and torque in a gyroscope.
5. What is meant by isochronous governor?
6. What is meant by hunting in a governor?

LIST OF EXPERIMENTS
Hear transfer
1. Determination of LMTD and effectiveness of parallel flow, counter flow and cross flow heat exchangers (double pipe heat exchanger).
2. Determination of heat transfer coefficients in free convection (free convection apparatus).

3. Determination of heat transfer coefficients in forced convection (forced convection apparatus).
4. Determination of thermal conductivity of solids (composite wall).
5. Determination of thermal conductivity of powder.
6. Determination of thermal conductivity of liquids.
7. Determination of emissivity of a specimen (emissivity apparatus).
8. Determination of Stefan Boltzman constant (Stefan Boltzmann apparatus).
9. Study and performance test on refrigeration (refrigeration test rig).
10. Study and performance test air conditioning equipments (air conditioning test rig).
11. Performance study on heat pipe (heat pipe).
12. Calibration of thermocouples.
13. Calibration of pressure gauge.

Dynamics

14. Whirling of shaft.
15. Gyroscope.
16. Universal governor apparatus.
17. Free vibration analysis.
18. Forced vibration analysis.

Note: Minimum 9 experiments in heat transfer and 3 experiments in dynamics are mandatory

Reference Books:

1. Y. A. Cengel, A. J. Ghajar, Heat and Mass Transfer: Fundamentals and Applications, 5th Ed., McGraw Hill, 2015.
2. J. P. Holman, S. Bhattacharyya, Heat Transfer, 10th Ed., McGraw Hill, 2011.
3. Frank P. Incropera, David P. Dewitt, T. L. Bergman, A. S. Lavine, Incropera's Principle of Heat and Mass Transfer, Wiley, 2018.
4. R. C. Sachdeva, Fundamentals of Engineering Heat and Mass Transfer, 5th Ed., New Age International Publishers, 2017.
5. R. K. Rajput, Heat and mass transfer, 7th Ed., S. Chand & Co., 2018.
6. C. P. Kothandaraman, Fundamentals of Heat and Mass Transfer, 4th Ed., New Age International, 2012.
7. R. J. Dossat, T. J. Horan, Principles of Refrigeration, 5th Ed., Pearson Education, 2001
8. W. F. Stoecker, J. W. Jones, Refrigeration and Air-Conditioning, 2nd Ed., McGraw-Hill Education, 2009.
9. C. P. Arora, Refrigeration and Air Conditioning, 3rd Ed., McGraw Hill Education, 2017.
10. W. T. Thompson, M. D. Dahleh, C. Padmanabhan, Theory of vibration with applications, 5th Ed., Pearson, 2008.
11. D. H. Myskza, Machines and Mechanisms Applied Kinematic Analysis, 4th Ed., Pearson Education, 2012.
12. V. P. Singh, Theory of Machines, 6th Ed., Dhanpat Rai & Co., 2017.
13. J. J. Uicker Jr., G. R. Pennock, J. E. Shigley, Theory of Machines and Mechanisms, 4th Ed., Oxford University Press, 2014.
14. C. E. Wilson, J. P. Sadler, Kinematics and Dynamics of Machinery, 3rd Ed., Pearson Education, 2003.

15. S. S. Rattan, Theory of Machines, McGraw Hill, 2017.
16. P. L. Ballaney, Theory of Machines and Mechanisms, 25th Ed., Khanna Publishers, 2015.
17. A. Ghosh, A. K. Malik, Theory of Mechanisms and Machines, Affiliated East West Press, 2008.
18. A. R. Holowenko, Dynamics of Machinery, John Wiley, 1955.

INDEX

Final Open Ended Projects / Design Experiments Done
1)Critical Heat Flux Apparatus

VERIFICATION BY HOD

INTERNAL EXAMINER **EXTERNAL EXAMINER**

EXPERIMENT N0: 1

PARALLEL FLOW AND COUNTER FLOW HEAT EXCHANGER

AIM

To calculate heat transfer rate, overall heat transfer coefficient and LMTD for the given parallel and counter flow heat exchanger.

APPARATUS

The apparatus consists of a tube in tube type concentric tube heat exchanger. The hot fluid is hot water which is obtained from an electric geyser and it flows through the inner tube while the cold fluid is cold water flowing through the annuls.

The hot water flows always in one direction and a flow rate of which is controlled by means of a valve. The cold water can be admitted at one of the end enabling the heat exchanger to run as a parallel flow apparatus or a counter flow apparatus. This is done by valve operations.

The main object of this experiment is to study and compare the:

1. Temperature distributions in parallel flow and counter flow heat exchanger.
2. Heat transfer rates in the two runs.
3. Overall heat transfer coefficient in parallel and counter flow runs.
4. To obtain the effectiveness of the given heat exchangers.

The experiment is conducted by keeping the identical flow rates while running the unit as a parallel flow exchanger and counter flow exchanger.

The temperature is measured by mercury in glass thermometers and the flow rates by a graduated measuring flask and stopwatch. The readings are recorded when steady state is reached.

THEORY

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

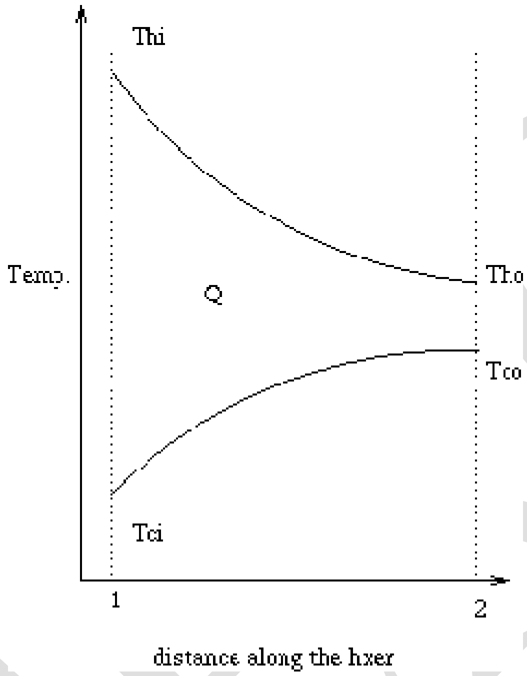
Heat exchangers are classified in three categories:

1. Transfer type
2. Storage type
3. Direct contact type

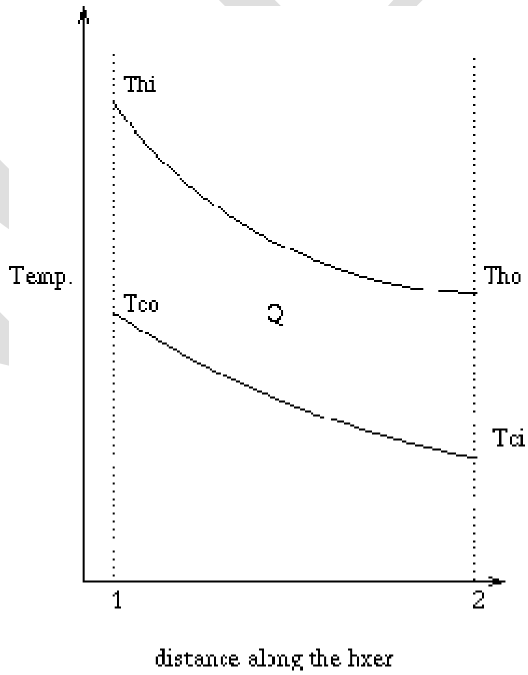
A transfer type of heat exchanger is one in which both fluids pass simultaneously through the device and heat is transferred through separating walls. In practice most of the heat exchangers used are transfer type ones.

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

1. Parallel flow: In which fluid flow in the same direction.



2. Counter flow: In which they flow in opposed direction.



3. Cross flow: In which they flow at right angles to each other.

A simple example of transfer type of heat exchanger can be in the form of a tube in type arrangement. One fluid flowing through the inner tube and the other fluid flowing through the surrounding tube. The heat transfer takes place across the walls of the inner tube.

SPECIFICATIONS

1. Inner tube

   Material- GI, Inner tube dia.-8.5mm, Outer tube dia.-14mm
2. Outer tube

   Material – GI, Inner tube dia.-27.5mm, Outer tube dia.-33.5mm
3. Length of the heat exchanger = 2m
4. Measuring flask = 0-1000cc
5. Stop watch
6. Geyser: single phase type to obtain hot water supply

EXPERIMENTAL PROCEDURE

1. Start the flow on hot water side.
2. Start the flow through annulus and run the exchanger either as parallel flow unit.
3. Put on the geyser.
4. Adjust the flow rate on hot water side.
5. Adjust the flow rate on cold water side.
6. Keeping the flow rate same, wait till the steady state conditions are reached.
7. Record the temperatures on hot water and cold water side and also flow rate accurately.
8. Repeat the experiment with counter flow under identical flow conditions.

OBSERVATION TABLE

Sl. No.	T_{hi}	T_{ho}	T_{ci}	T_{co}	Time collect of hot water, t_h (sec)	Time collect of cold water, t_c (sec)	Heat lost by cold fluid, q_c (kW)	LMTD in K	Overall heat transfer coefficient U (W/m^{2}K)	Effectiveness (ε)
1										
2										

Where T_{hi} is temperature of hot water at inlet, T_{ho} is temperature of hot water at outlet, T_{ci} is temperature of cold water at inlet and T_{co} is temperature of cold water at outlet.
Note: While changing the direction of flow T_{ci} of parallel is becoming T_{co} in counter flow.

CALCULATIONS

1. Average heat transfer rate 'q' is calculated

   as q_h = heat transfer rate from hot water

   $= m_h c_{ph} (T_{hi}-T_{ho})$

   q_c = heat transfer rate to the cold water

   $= m_c c_{pc} (T_{co}-T_{ci})$

$$q = \frac{q_h+q_c}{2} \quad \text{(KW)}$$

   Assume $c_{ph} = c_{pc} = 4.179$ kJ/kgK

2. LMTD: Logarithmic mean temperature difference. The temperature distribution ini the two runs is plotted.

   The LMTD can be calculated as

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

   In parallel flow heat exchanger $\Delta T_i = T_{hi}-T_{ci}$

   $\Delta T_o = T_{ho}-T_{co}$

   In Counter flow heat exchangers $\Delta T_i = T_{hi}-T_{co}$

   $\Delta T_o = T_{ho}-T_{ci}$

3. Overall heat transfer coefficient can be calculated by using

$$q = UA\Delta T_m$$

$$U = q/A\Delta T_m$$

   Where A = outside area of inner tube = πDL

4. Compare the value of ΔT_m and q in the parallel flow and counter flow runs.

   Note that if experiment is conducted very carefully them the superiority of counter flow arrangement in terms of higher value of ΔT_m and excess value of q for same flow rates condition can be revealed. The value of overall heat transfer coefficient U is more or less same for both the runs.

5. The effectiveness of the heat exchanger can be calculated by using the expression:

Effectiveness (ε) = Actual heat transfer/ Max possible heat transfer.

If ch < cc where ch = mhcph and cc = mccpc

If $c_c < c_h$

$\varepsilon = (T_{hi}-T_{ho})/(T_{hi}-T_{ci})$

$\varepsilon = (T_{co}-T_{ci})/(T_{hi}-T_{ci})$

RESULT

INFERENCE

EXPERIMENT N0: 2

HEAT TRANSFER BY NATURAL CONVECTION

AIM

To find out heat transfer coefficient and heat transfer rate from vertical cylinder in natural convection.

APPARATUS

The apparatus consists of stainless tube fitted in a rectangular duct in a vertical position. The duct is open at the top and bottom, forms an enclosure, and serves the purpose of undisturbed surrounding. One side of the duct is made up of acrylic sheet for visualization. An electric heating element is kept in the vertical tube which in turns 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. The surface is polished to minimize the radiation losses.

SPECIFICATIONS

1. Specimen : Stainless steel tube
2. Size of the specimen: ID 38mm, OD 44mm, 500mm length
3. No of thermocouples = 7 and as marked on the temperature indicator switch
4. Thermocouple no.8 read the ambient temperature and is kept in the duct.
5. Ammeter: Digital type, 0-2 A, AC
6. Voltmeter: Digital type, 0-300V, AC
7. Dimmer stat for heating coil: 0-230V, 2A, AC power

THEORY

Natural convection heat transfer takes place by movement of fluid particles within to solid surface caused by density difference between the fluid particles on account of difference in temperature. Hence there is no external agency facing fluid over the surface. It has been observed that the fluid adjacent to the surface gets heated, resulting in thermal expansion of the fluid and reduction in its density. Subsequently a buoyancy force acts on the fluid causing it to flow up the surface. Here the flow velocity is developed due to difference in temperature between fluid particles.

The following empirical correlations may be used to find out the heat transfer coefficient for vertical cylinder in natural convection.

$Nu = 0.53 (Gr.Pr)^{1/4}$ for $Gr.Pr < 10^5$

$Nu = 0.56 (Gr.Pr)^{1/4}$ for $10^5 < Gr.Pr < 10^8$

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

Where, Nu = Nusselt number $= \frac{hL}{k}$

Gr = Grashof number $= \frac{L^3 \beta g (T_s - T_a)}{\nu^2}$

Pr = Prandtl number $= \frac{\mu C_p}{k}$

β = Volumetric coefficient of thermal expansion

For ideal gases β $= \frac{1}{T_f}$

Where 'T_f' is the absolute film temperature at which the properties are taken.

PROCEDURE

1. Put on the supply and adjust the dimmerstat to obtain the require heat imput. (Say 40W, 60W and 70W).
2. Wait till the steady state is reached, which is confirmed from temperature reading (T_1 to T_7).
3. Measure surface temperature at the various points to T_1 to T_7.
4. Note the ambient temperature T_8.
5. Repeat the experiment at different heat inputs.
6. When experiment is over, switch off heater first.

OBSERVATIONS

O.D.Cylinder = 44mm

Length of cylinder = 500mm

Input to heater = VI =---------------- W

Where, V = Voltage and I = Current

PRECAUTIONS

Do's:

1. Before switching ON the unit, make sure that the variac is in Zero position.
2. Operate thermocouple selector switch (TSS) gently.
3. Operate the unit minimum twice a week.
4. Fill up the water in the small water container before starting the experiment.

5. Adjust water flow rate before start the experiment.
6. Change container water regularly.
7. Increase the voltage

slowly. Don'ts:

1. Do not go above 150volts power input to heater.
2. Do not operate the equipment if line voltage is less than 200volts.

TABULAR COLUMN

Sl. No.	V Volts	I Amps	VI Watts	Thermocouple readings ^{0}C							
				T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8 Chamber
1											
2											

CALCULATIONS

1. $T_s = \frac{T_1+T_2+T_3+T_4+T_5+T_6+T_7}{7} + 273.15$ K
2. T_a = Surrounding ambient temperature = T_8 + 273.15 K
3. Obtain the properties of air at a mean temperature of $T_m = \frac{T_s+T_a}{2}$ K
4. Volumetric coefficient of thermal expansion $\beta = \frac{1}{T_m}$
5. Grashof number, $Gr = \frac{L^3\beta g(T_s-T_a)}{\nu^2}$

   Where, ν = kinematic viscosity
6. Rayleigh Number Ra = Gr.Pr
7. Nusselt Number $Nu = \frac{hL}{k}$

   The following correlations are used to find Nusselt Number

   $Nu = 0.53\,(Gr.Pr)^{1/4}$ for $Gr.Pr < 10^5$

   $Nu = 0.56\,(Gr.Pr)^{1/4}$ for $10^5 < Gr.Pr < 10^8$

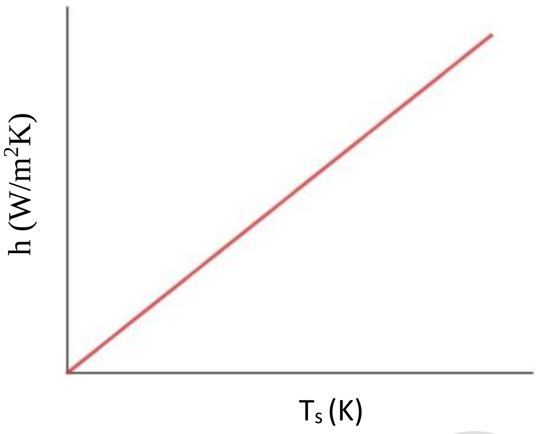
   $Nu = 0.13\,(Gr.Pr)^{1/3}$ for $10^8 < Gr.Pr < 10^{12}$
8. Free convective heat transfer coefficient $h = \frac{Nu\,k}{L}$ W/m^{2}K
9. Heat transfer rate by convection $Q_c = hA(T_s-T_a)$

$Q_c = h\pi dL(T_s - T_a)$ Watt

10. Heat inputs to the coil $Q_i = V \times I$ Watt

RESULT

The heat transfer coefficient and heat transfer rate from vertical cylinder by natural convection are determined. Also the graph h vs T_s is plotted.



INFERENCE

The heat transfer coefficient is having a maximum value at the beginning as expect because of the just starting of the boundary layer and it decreases as the expected in upward direction due to thickening of layer and which is laminar one. This trend is maintained up to half of the length and beyond that there is little variation in the value of local heat transfer coefficient because of the transition and turbulent boundary layers. The last point shows somewhat increase in the value of h, which is attributed to end loss causing a temperature drop.

The comparison of average heat transfer coefficient is also made with predicted values are somewhat less than experimental values due to the heat loss by radiation.

EXPERIMENT N0: 3

HEAT TRANSFER IN FORCED CONVECTION

AIM

To determine the heat transfer coefficient at the inner surface of a tube and to compare it with the same obtained from empirical relations.

DESCRIPTION

The apparatus consists of a 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 measure 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 id provided to measure temperature of pipe wall in the test section and inlet and exit temperatures of air through the test section. Airflow is measured with the help of orifice meter and the water manometer fitted on the board.

SPECIFICATIONS

Specimen	: Copper Tube
Size of specimen	: ID 25mm x 400mm long
Heater	: Externally heated, Nichrome wire band heater
Ammeter	: Digital type, 0-20A, AC
Voltmeter	: Digital type, 0-300V, AC
Dimmer stat for heating coil : 0-230V, 2A Thermocouple used	
	: 7 nos
Centrifugal Blower	: Single phase 230V, 50Hz, 13000rpm
Manometer	: U tube with mercury as working fluid
Orifice diameter, d_o	: 20mm
GI pipe diameter, d_p	: 40mm

PRECAUTIONS

1. Keep the dimmer stat at zero position before switch on power supply.
2. Start the blower unit.
3. Increase the voltage gradually

4. Do not stop the blower in between the testing period.
5. Do not disturb thermocouples while testing.
6. Operate selector switch of the temperature indicator gently.
7. Do not exceed 200 watts.

PROCEDURE

1. Start the blower and adjust the flow by means of value 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 wattmeter or voltmeter and ammeter.
3. Take reading of all the six thermocouples at an interval of 10 minutes until the steady state is reached.
4. Wait for the steady state and take the readings of all six thermocouples at steady state.
5. Note down the heater input.
6. Repeat the experiment for different heat input and flow rates.

OBSERVATIONS

1. Diameter of the test pipe, D = ------------------------ mm
2. Length of the test section, L =--------------------------cm
3. Diameter of the orifice, d = ------------------------ cm

Sl. No.	Heater input		Q=Heat supplied	Tube surface temp in ^{0}C						Air temp ^{0}C	Diff in Manometer reading h_m in mm
	V	I		T_1	T_2	T_3	T_4	T_5	T_6		
1											
2											

CALCULATIONS

Average heat transfer coefficient, $h_a = \frac{q_a}{A(T_s - T_a)}$

Where, q_a = Heat rate at which the air is getting heated.

A = Test section area

T_a = Average temperature of air = $(T_1+T_6)/2$

T_s = Average surface temperature = $(T_2+T_3+T_4+T_5)/4$

The rate at which air getting heated is calculated as follows:

$$q = m.c_p.\Delta T$$

Where, m = Mass flow rate of air

c_p = Specific heat of air

ΔT = Temperature rise in air $(T_6 - T_1)$

w = Density of air to be evaluated at $(T_1+T_6)/2$

Q = Volume flow rate

$$= c_d.\pi/4.d^2 \sqrt{2g \frac{\rho_w}{\rho_a} H}$$

Where, c_d = Coefficient of discharge

H = Difference of water level in manometer

ρ_w = Density of water in kg/m^3

ρ_a = Density of air in kg/m^3

d = Diameter of orifice

Using the procedure obtain the values of 'h_a' for different air flow rates.

Reynolds Number, $Re = VD/\nu$

Where, V = Velocity of air

N = Kinematic viscosity to be measured at avg of bulk mean temp $(T_1+T_6)/2$

Nusselt Number, $Nu = h_aD/k$

Where, k = Thermal conductivity of air at $(T_1+T_6)/2$

Plot the values of Nu and Re on a log-log plot for the experiment readings.

$$Nu = 0.023[Re]^{0.8}[Pr]^{0.4}$$

The appropriate correlation for turbulent flow through closed conduits is the Dittus-Boelter Correlation.

Plot this correlation on the same plot and compare the two. All properties are to be evaluated at the average of bulk mean temperatures of air.

RESULT

INFERENCE

EXPERIMENT N0: 4

HEAT TRANSFER THROUGH COMPOSITE WALLS (THERMAL CONDUCTIVITY)

AIM

To determines the thermal conductivities and thermal resistances of the given specimens. To plots the temperature distribution across the specimens.

DESCRIPTION

The apparatus consists of central heater sandwiched between two aluminium plates. Three types of slabs are provided on both sides of heater, which forms a composite structure. A small hand press frame is provided to ensure the perfect contact between the slabs. A dimmerstat is provided for varying the input to the heater and measurement of input is carried out by a voltmeter, ammeter. Thermocouples are embedded between interfaces of the slabs, to read the temperatures at the surface.

The experiment can be conducted at various values of input and calculation can be made accordingly.

SPECIFICATIONS

Slab Size

1. Mild Steel - 30cmΦ x 25mm thick
2. Hylan - 30cmΦ x 10mm thick
3. Wood - 30cmΦ x 15mm thick

Heater

Nichrome heater wounds on mica former and insulator. With control unit capacity 300watt maximum.

Heater control unit	: 0-230V, 0-2A single phase dimmerstat (1 nos)
Voltmeter	: 0-200V
Ammeter	: 0-2 A
Thermocouple	: 0 – 300^0C
Service required	: AC single phase 230V electric supply

PRECAUTIONS

1. Keep dimmerstat to zero position before start.
2. Increase the voltage slowly.
3. Keep all the assembly undisturbed.

4. Remove air gap between plates slowly by moving hand press gently.
5. When removing the plates do not disturb the thermocouples.
6. Do not increase voltage above 120V.
7. Operate selector switch of temperature indicator slowly.

PROCEDURE

Arrange the plates in proper fashion (symmetrical) on both sides of the heater plates.

1. See that plates are symmetrically arranged on both sides of the heater plates.
2. Operate the hand press properly to insure perfect contact between the plates.
3. Close the box by cover sheet to achieve steady environmental conditions.
4. Start the supply of heater. By varying the dimmerstat and adjust the input at the desired value (range 30-70watts).
5. Take reading of all the thermocouples at an interval of 10 minutes until the steady state is reached.
6. Note down the steady state readings in observation table.

OBSERVATION

1. Wall thickness
   (a) Wood = 15mm
   (b) Mild steel = 22mm
   (c) Hylem = 10mm
2. The values of thermal conductivity for the materials used in the present experiment as given in the literature are as following.
   (a) Wood = 0.18
   (b) Steel = 37.2
   (c) Hylem = 0.2

Sl. No.	V Volts	I Amps	Heat supplied (W)	Thermocouple readings ^{0}C							
				T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
1											
2											
3											

Main readings: $T_A = (T_1 + T_2)/2$

$T_B = (T_3 + T_4)/2$ T_C

$= (T_5 + T_6)/2$ $T_D =$

$(T_7 + T_8)/2$

CALCULATIONS

Heat supplied rate, Q = VI =-------------- W

We will first assumed that the slab is large in radial direction thus the heat transfer can be assumed to be axial in the central portion. According to this assumption the thermocouples are fixed at close to the centre of plates.

$$\text{Heat flux, } q = \frac{Q \times 4}{2\pi \times D^2}$$

Where, D = diameter of the plates.

To check thermal resistance law for composite slab.

1. We will find first thermal resistance of each slab indicidually.

$R_{MS} = (T_A - T_B)/q$

$R_{hylam} = (T_A - T_B)/q$

$R_{Wood} = (T_A - T_B)/q$

$R_{total} = R_{MS} + R_{hylam} + R_{Wood}$

2. Thermal resistance of composite slab based on assumed values of thermal conductivities can be found as

$$R_{total} = \frac{b_1}{k_1} + \frac{b_2}{k_2} + \frac{b_3}{k_3} + \dots\dots\dots\dots$$

Where b_1, b_2 and b_3 are thickness of MS, Hylam and wood respectively in meters. k_1, k_2 and k_3 are thermal conductivities of MS, Hylam and wood in kcal/mhrK.

3. Individual thermal resistance values as obtained from experimental observations in (1) and from calculations in (2) are to be compared.

4. Assumed thermal conductivity values can be compared to their experimental determination. It should be noted that this is only approximate and comparison only in terms of order of magnitude is desirable.

$$k_{MS} = \frac{q \times b_1}{T_A - T_B}$$

$$k_{hylam} = \frac{q \times b_2}{T_B - T_C}$$

$$k_{wood} = \frac{q \times b_3}{T_C - T_D}$$

RESULT

1. Thermal Conductivities
   a. MS = --------------
   b. Hylam = --------------
   c. Wood = --------------
2. Thermal Resistances
   a. MS = --------------
   b. Hylam = --------------
   c. Wood = --------------

INFEREENCE

EXPERIMENT N0: 5

THERMAL CONDUCTIVITY OF LIQUID

AIM

To finds the thermal conductivity of liquids.

THEORY

The heat transferred to conduction through the liquids $Q = kA\frac{\Delta T}{\Delta x}$

Where,

A: Area of test substance, normal to direction of heat flow.

ΔT: It is the temperature across the bottom and top surface of liquids

Δx: Thickness of the liquid layer

k: Thermal conductivity of test section

The heat transferred through the liquids $q_w = m_w c_p (T_{out} - T_{in})$

m_w: Mass flow rate of water in kg/hr

c_p: Specific heat of water

PROCEDURE

1. Keep the unit near 230V, 5A power source.
2. Till the water in the provided SS container which is kept above one table panel connect one rubber tubes to inlet and outlet tube to one control value provided at one bottom.
3. Plug-in the main power source to one power source of put on the MCB provided on the panel one digital instrument zero in voltmeter and ammeter.
4. Fill the liquid into the test section.
5. Rotate the variac in clockwise undergoes to any desired heat output to about 100-150V respectively.
6. Note down following readings:
   a. Voltage
   b. Current
   c. Temperature from T_1 to T_4
   d. Flow rate
7. Calculate normal conductivity of liquid by

$$k = \frac{Q\Delta x}{A\Delta T}$$

where, Q = V x I x 0.86

OBSERVATION

Sl. No.	Voltage (V)	Current (A)	Water flow rate (kg/s)	Thermocouple readings (^{0}C)			
				T_1	T_2	T_3	T_4
1							
2							

RESULT

Thermal conductivity of liquids, k_1 = -------------- W/mK

K_2 = ---------------- W/mK

INFERENCE

EXPERIMENT N0: 6

EMISSIVITY MEASUREMENT OF RADIATING SURFACES

AIM

To determine the emissivity of gray surface

THEORY

Any hot body maintained by a constant heat source, loses heat to surroundings by conduction, convection and radiation. If two bodies made of same geometry are heated under identical conditions, the heat loss by conduction and convection can be assumed same for both the bodies, when the difference in temperatures between these two bodies is not high. In such a case, when one body is black and the other body is gray from values different surface temperatures of the two bodies maintained by a constant power source emissivity can be calculated. The heat loss by radiation depends on:

Characteristics of the material

Geometry of the surface

Temperature of surface

The heat loss by radiation when one body is completely enclosed by the other body is given by

$$Q = \frac{\sigma A_1 (T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{A_1}{A_2}\left[\frac{1}{\varepsilon_2} - 1\right]}$$

If a body is losing heat to the surrounding atmosphere, then the area of atmosphere A_2 is very greater than the area of body A_1. Thus if anybody is losing heat by radiation to the surrounding atmosphere above equation takes the form.

$$Q = \sigma A_1 \varepsilon (T_1^4 - T_2^4)$$

Where, σ = Stefan Boltzman constant = 5.6697×10^{-8} W/m^2K^4 A_1

= Surface area in m^2

ε = Emissivity

T_1 = Surface temperature of the body in K

T_2 = Surrounding atmospheric temperature in K

Let us consider a black body and a gray body with identical geometry being heated under identical conditions, assuming conduction and convention heat loss to remain the same. Let Q_b and Q_g be the heat supplied to black and gray bodies respectively.

If heat input to both the bodies are same,

$$Q_b = Q_g$$

Assuming the heat loss by conduction and convection from bodies to remains same.

Heat loss by radiation by the black body = Heat loss by radiation by the gray body

$$\sigma \times A_b \times \varepsilon_b \times (T_b^4 - T_a^4) = \sigma \times A_g \times \varepsilon_g \times (T_g^4 - T_a^4)$$

As geometry of two bodies are identical, $A = A_g = A_b$ and $\varepsilon_b = 1$ for black body.

Therefore, $$\varepsilon_g = \frac{T_b^4 - T_a^4}{T_g^4 - T_a^4}$$

Where,

Suffix 'b' stands for black body

Suffix 'g' stands for gray body

Suffix 'a' stands for ambient

DESCRIPTION

The experimental set up consists of two circular brass plates of identical dimensions. One of the plates is made black by applying a thick layer of lamp black while the other plate whose emissivity is to be measure is a gray body. Heating coils are provided at the bottom of the plates. The plates are mounted on asbestos cement sheet and kept in an enclosure to provide undisturbed natural convection condition. Three thermocouples are mounted on each to measure the average temperature. One thermocouple is in the chamber to measure the ambient temperature or chamber air temperature. The heat input can be varied with the help of various dimmerstats for both the plates, which can be measured using digital volt and ammeter.

SPECIFICATIONS

Specimen material	: Brass
Specimen size	: Φ150mm, 6mm, thickness (gray and black body)
Voltmeter	: Digital type, 0-300V
Ammeter	: Digital type, 0-3A
Dimmerstat	: 0 – 240V,2A
Temperature Indicator	: Digital type, 0 – 300^{0}C, K type
Thermocouple used	: 7 nos.

Heater : sand witched type Nichrome heater, 400W

PROCEDURE

1. Switch on the electric mains.
2. Operate the dimmer stat very slowly and give same power input to both the heater say 50V by using operating can switches provided.
3. When steady state is reached is reached note down the temperatures T_1 to T_7 by rotating the temperature selection switch.
4. Also noted down the volt and ammeter reading.
5. Repeat the experiment for different heat inputs.

OBSERVATION

Sl. No.	Heater input			Temp of black body ^0C			Temp of gray surface ^0C			Chamber Temp ^0C
	V	I	V x I	T_1	T_2	T_3	T_4	T_5	T_6	T_7
1										
2										

CALCULATIONS

1 Temperature of the black body $T_b = \frac{T_1+T_2+T_3}{3} + 273.15$ K

2 Temperature of the gray body, $T_g = \frac{T_4+T_5+T_6}{3} + 273.15$ K

3 Ambient temperature, $T_a = (T_7 + 273.15)$ K

4 Heat input to the coils Q = V x I watt

5 Emissivity of gray body, $\varepsilon_g = \frac{T_b^4 - T_a^4}{T_g^4 - T_a^4}$

RESULT

INFERENCE

EXPERIMENT N0: 7

STEFAN BOLTZMAN CONSTANT FOR RADIATION HEAT TRANSFER

AIM

To determine the value of Stefan Boltzman constant for radiation heat transfer.

THEORY

Stefan Boltzman law states that the total emissive power of a perfect black body is proportional to fourth power of the absolute temperature of black body surface.

$$E_b = \sigma T^4$$

Where, σ = Stefan Boltzman constant = 5.667 x 10^{-8} W/m^2K^4

DESCRIPTION

The apparatus consists of a flanged copper hemisphere fixed on a flat non- conducting plate. A test disc made of copper is fixed to the plate. Thus the test disc is completely enclosed by the hemisphere. The outer surface of the hemisphere is enclosed in a vertical water jacket used to heat the hemisphere to a suitable constant temperature. Three Cr-Al thermocouples are attached at four strategic places on the surface of the hemisphere to obtain the temperatures. The disc is mounted on an ebonite rod which is fitted in a hole drilled at the center of the base plate. Another Cr-Al thermocouple is fixed to the disc to record its temperature. Fill the water in the SS water container with immersion heater kept on top of the panel.

SPECIFICATIONS

Specimen material	: Copper
Size of the disc	: Φ20mm x 2mm thickness
Base plate	: Φ250mm x 12mm thickness (hylan)
Heater	: 1.5kW capacity, immersion type
Copper Bowl	: Φ200mm
Digital temperature indicator	: 0-199.9^{0}C
Thermocouples used	: 3 nos. on hemisphere
Stop watch	: Digital type
Overhead tank	: SS, approx. 10 litre capacity
Water jacket	: Φ250mm, SS
Mass of specimen, 'm'	: 5g

PROCEDURE

1. Remove the test disc before starting the experiment.
2. Heat the water in the SS containter to its boiling point.
3. Allow the boiling water into the container kept at the bottom containing copper hemisphere until it is full. Allow sufficient time to attain thermal equilibrium.
4. Insert the test disc fixed on the ebonite rod sleeve completely inside and lock it. Start the stop clock simultaneously.
5. Note down the temperature of the test disc at an interval of about 15sec for about 15 to 20 minutes.

OBSERVATION

Thermocouple	Temperature of the copper hemisphere ^{0}C
T_1	
T_2	
T_3	

Temperature – Time response of test disc

Time ‘t’ sec	Temperature T_4 ^{0}C

CALCULATIONS

1. Plot the graph of temperature of the disc vs time to obtain the slope (dT/dt) of the line, which passes through/ nearer to all points.
2. Average temperature of the hemisphere

$$Ta_{vg.} = \frac{T_1+T_2+T_3}{3}$$

3. T_d = Average temperature of the disc in K
4. Rate of change of heat capacity of the disc = $mc_p\frac{dT}{dt}$
5. Net energy radiated on the disc = $\sigma A_d(T^4_{avg} - T^4_d)$

   where, A_d = area of the disc in m^2 ,d = 20mm

c_p = specific heat capacity of copper = 0.38 kJ/kgK

m = Mass of the copper disc = 5.5g

Rate of change of heat capacity of the disc = Net energy radiated on the disc

$$mc_p\frac{dT}{dt} = \sigma A_d(T^4_{avg} - T^4_d)$$

Thus 'σ' can be evaluated as shown

$$\sigma = \frac{mc_p\frac{dT}{dt}}{A_d(T^4_{avg} - T^4_d)}$$

RESULT

The value of Stefan Boltzman constant = -------------- W/m^2K^4

INFERENCE

EXPERIMENT N0: 8

STUDY ON REFRIGERATION

AIM

To calculates the actual COP and the theoretical COP for any two openings of expansion device (Full opening, 75% opening, 50% opening).

APPARATUS

The component of vapour compression refrigeration systems are compressor, condenser, expansion devices and the evaporator.

Compressor

A 1/3 HP hermetically sealed compressor is used. The specifications are:

No. Of Cylinders	: One
Bore	: 25.4mm
Stroke	: 22.3mm
Speed	: 2850rpm
Displacement per revolutions	: 11.26 cm^3
Displacement per hour	: 1.92 m^3
Clearance volume	: 6%

Condenser

A finned tube air-cooled condenser is used. Tubes are made of copper and fins are of aluminium. Purpose is to liquefy the temperature close to the ambient. Forced airflow normal to tube is achieved by using a 300mm sweep fan rotating at 1440rpm. The blow through type of fan is mounted behind condenser.

Expansion Devices

The panel unit is provided with both thermostatic expansion valve and capillary tube.

Evaporator

The evaporator (chiller) made of copper coil, placed in a insulated stainless steel vessel with fiber glass coated interior, housed in a wooden chamber.

Refrigerant

The panel uses refrigerant R-134a commercially known as Freon. The refrigerant has a normal boiling point of -30^{0}C of condensing pressure of 10bar at 40^{0}C. It is non toxic, non flammable and non explosive fluid and is considered to be a safe refrigerant.

Other Accessories

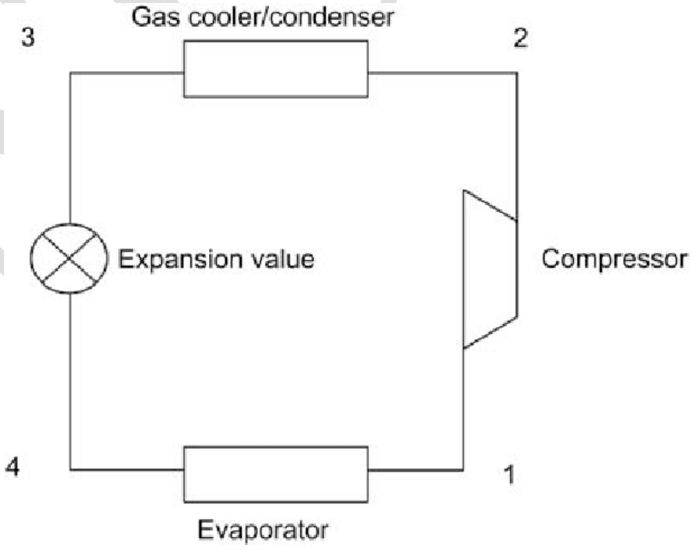
For purpose of charging, a valve is providing on charge line of compressor. A filter driver is mounted in high pressure liquid line to remove moisture and dirt. The flow rate of refrigerant can be measured in litre/hour using rotameter type of flow measuring device. A charging cylinder is incorporated in circuit to enable control of quantity of refrigerant in the system.

Safety and Control Devices

The high pressure is set at about 1bar. When unit is shutdown, either solenoid valve or valve ahead of capillary is to be closed. Flooding of evaporator by the leaking refrigerant is prevented by using solenoid valve. A thermostat cut out is mounted on the unit to demonstrate operation of air conditioning unit used to maintain a given space temperature. This is an on-off device which stops unit when the desired temperature is reached and starts it again when space temperature increased.

THEORY

The rate of heat absorbed in the cycle from the space to be cooled is called the refrigerating effect. Unit of refrigeration is expressed as ton of refrigeration. The heat absorbed in the system from the body or space to be cooled, equivalent to the latent heat of fusion of one ton of ice, at 0^0C in 24 hours is called ton of refrigeration. Coefficient of performance of a refrigerating machine is defined as the ratio of refrigeration effect produced by it in a given time to the work supplied to it during same time.



The standard vapour compression cycle consists of following

1. Process 1-2 represents reversible adiabatic compression from saturated vapour to the condenser pressure or superheated vapour.
2. Process 2-3 represents reversible heat rejection at constant pressure, de preheating and condensation.
3. Process 3-4 represents irreversible constant enthalpic expansion from saturated liquid to the evaporator pressure.
4. Process 4-1 represents reversible heat addition at constant pressure (Evaporation to saturated vapour)

Actual COP = Refrigerating effect/ Work output

Refrigerating Effect (actual) = $mC_p\Delta T$

Work input = Ne x 3600/ (t x K)

Ne = No.of revolutions of energy meter disc

K = Energy meter constant = 750 rev/kwhr

t = Time

m = mass = 14kg

Theoretical COP = Refrigerating effect / Work done

$= (h_1-h_4)/(h_2-h_1)$

PROCEDURE

1. Fill the cooling chamber with water.
2. Fully open the expansion device.
3. Note the initial temperature of water and switch on the unit.
4. After say 30 minutes of refrigeration take temperature reading at inlet to the compressor (T_1), inlet to evaporator (T_5), outlet of compressor (T_2), outlet of expansion device (T_4) and outlet of condenser (T_3) and time taken for five revolutions of energy meter disc.
5. Repeat the above steps for different openings of expansion device.

OBSERVATIONS

Sl.No.	Initial Temp of water T_5	Temp of inlet of Comp. T_1	Temp of outlet of Comp T_2	Temp of outlet of conden T_3	Temp of outlet of expen. T_4	Final temp of water T_5	Pres of inlet of comp P_1 (psi)	Pres of outlet of comp P_2 (psi)	Actual refrigeration effect (kJ)	Time for 5 rev of e/m disc (sec)	Actual work done (kJ)	Actual COP	Enthalpy of vapour at inlet h_1 (kJ/kg)	Enthalpy of outlet of comp h_2	Enthalpy at inlet of evapo h_4	Theoretical COP
1																
2																
3																

CALCULATIONS

$$\text{Refrigeration effect} = \text{mass} \times c_p \times \Delta T$$

Mass = mass of water in chamber = 14kg

C_p = specific heat of water = 4.18 kJ/kg

T_1 = Inlet temp of compressor

T_4 = outlet temp of evaporator

ΔT = Difference b/w initial and final temp of water

$$\text{Actual COP} = \text{Refrigeration effect/ Work done}$$

Work done = (Ne x 3600)/(t x K)

$$\text{Theoretical COP} = (h_1 - h_4)/(h_2 - h_1)$$

Take h_1, h_2, h_4 from P-H chart for the corresponding pressure P_1, P_2 and temperature T_1, T_2, T_3.

RESULT

INFERENCE

EXPERIMENT N0: 9

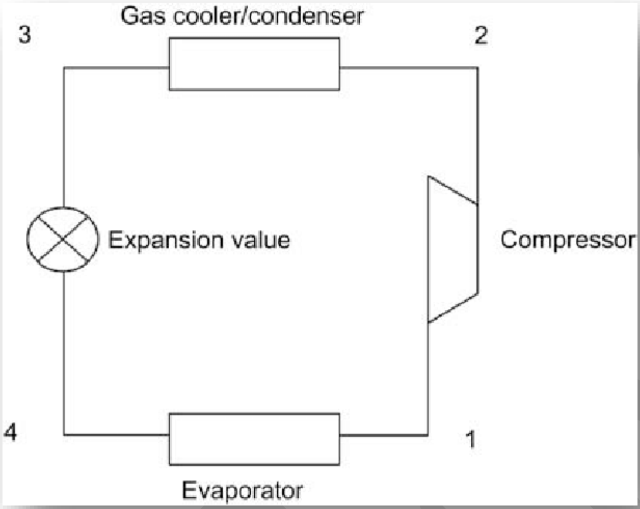
STUDY ON AIRCONDITIONER TRAINER

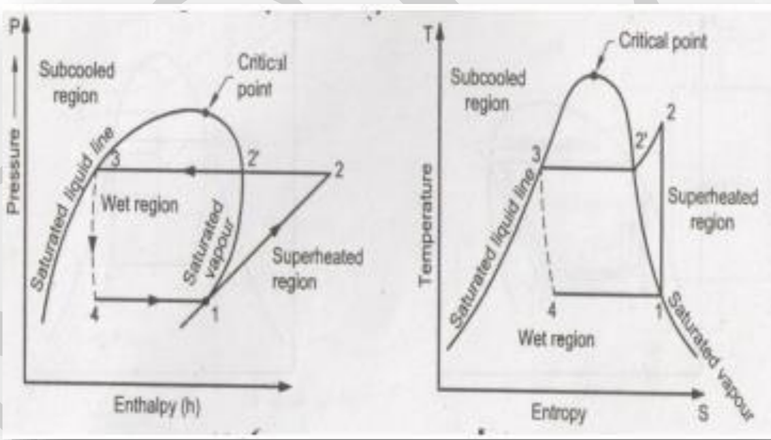
AIM

To conducts the performance test on air conditioner trainer.

THEORY

This system works on vapour compression refrigeration cycle.





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2. Process 2-3 represents reversible heat rejection at constant pressure, de preheating and condensation.
3. Process 3-4 represents irreversible constant enthalpic expansion from saturated liquid to the evaporator pressure.

4. Process 4-1 represents reversible heat addition at constant pressure (Evaporation to saturated vapour)

The refrigerants such as R-12, R-22, R-134a (commercially known as Freon) are used as working medium because of their properties which are required as refrigeration cycles.

OPERATING PROCEDURE

1. Plug in the mains card of the system.
2. Switch ON the DP switch so that the digital panel meters indicator corresponding readings.
3. Switch ON the condenser fan and blower (CF & EF)
4. Start the system by switching ON the thermostat by opening the corresponding valves depending on solenoid and thermostatic expansion valve or capillary expansion device.
5. Allow air flow through the air conditioning chamber and let it stabilize for few minutes.
6. Record T_1, T_2, T_3, T_4, T_5, P_1, P_2, V, I, T rotameter reading. Also note down wet and dry bulb temperature inlet and outlet.
7. Take 3 to 4 readings for every 10 minutes.
8. For humidification operation
   a. Fill the water through water inlet valve to the boiler about half to ¾ and close the valve.
   b. Switch on the boiler for about 45 to 60 minutes.
   c. When steam is formed close the glass tube valve and open steam inlet valve and allow it to flow about minutes. (say 10 minutes)
   d. Record wet and dry bulb temperature at inlet and outlet
9. For dehumidification operation
   a. Switch on the heater switches.
   b. Vary the electronic dimmer up to the corresponding indicator glows.
   c. Allow it for few minutes.
   d. Record wet and dry bulb temperature at inlet and outlet.
10. Then switch off heaters/ boiler, thermostat and after about 5 minutes switch off CF, EF and main.

Cooling with Dehumidification of Air

The removal of water vapour from the air is termed as dehumidification of air. This is only possible if the air is cooled below dew point temperature of air. By heating (heater 1) the inlet air by using electrical heaters the quantity of the water vapour presented in the inlet air will be reduced. This is essential for dehumidification. We can also remove some more amount of water vapour presented in the air after it passing through the cooling coil (evaporator) with the help of heater 2 (if needed).

Cooling with Humidification

Adding of water vapour to the air is termed as humidification. This can be obtained by adding steam to the air inlet of the cooling coil. When air is passed through a spray chamber, part of the water will be evaporated and is carried with the air, thus increasing the specific humidity. The heat required for the evaporator of water vapour carried with the air is taken from the air itself by decreasing the temperature of air and the total enthalpy of air remains constant.

Thermocouple Details

T_1 = Temperature of refrigerant at inlet of compressor

T_2 = Temperature of refrigerant at outlet of compressor

T_3 = Temperature of refrigerant at outlet of condenser

T_4 = Temperature of refrigerant at outlet of expansion device

T_5 = Ambient Temperature

WDB_1 = Wet and Dry bulb temperature of air at inlet of duct

WDB_2 = Wet and Dry bulb temperature of air at outlet of duct

CALCULATIONS

- Theoretical COP

$$COP = (h_1 – h_4)/(h_2 – h_1)$$

From R-22 p-h chart

h_1 = Enthalpy in kJ/kg, corresponding to P_1 & T_1

h_2 = Enthalpy in kJ/kg, corresponding to P_2 & T_2

h_4 = Enthalpy in kJ/kg, corresponding to P_2 & T_3

- Carnot COP

$$COP = (T_1)/(T_2-T_1)$$

T_1 = Temperature of refrigerant at inlet of compressor in K

T_2 = Temperature of refrigerant at outlet of compressor in K

- Actual COP

$$COP = Q/W = \frac{\text{Refrigeration effect}}{\text{Compressor input}}$$

$$Q \quad = m_a \times c_{pa} \times (T_i - T_o) \text{ kJ}$$

m_a = mass of air = velocity of air x area of anemometer x density of air

By using anemometer, find out velocity of air.

C_{pa} = Specific heat of air = 1.005 kJ/kgK

T_i = Air inlet temperature

T_o = Air outlet temperature from duct

Density of air = 1.197 kg/m^3

Mass of air = 0.2015 kg/s

$$W \quad = (VI)/1000 \text{ kW}$$

V = Volts from voltmeter

I = Current in A from ammeter

- Relative COP

COP rel. = Actual COP/Theoretical COP

- Mass of Refrigerant

$$M_{ref} = \rho_{ref} x V_{ref} \text{ kg}$$

$$V_{ref} = \frac{\text{Rotameter reading}}{1000 \times 3600} m^3 kg$$

ρ_{ref} at T_3 (condenser outlet temperature) from R-22 table (almost ambient)

ρ_{ref} =__________kg/m^3

m = ρ x V kg/s

- Air Conditioning Process

State: 1 Ambient WBT$_1$ =_________^{0}C

DBT$_1$ =_________^{0}C

State: 2 Air out from AC WBT_2 =____________ ^{0}C

DBT_2 =____________ ^{0}C

- Sensible cooling

$DBT_1 - DBT_2$ =____________________ °C

- Dehumidification

State points 1, 2 on psychometric chart (enclosed) using DBT_1, WBT_1, DBT_2, WBT_2 and thus we can find out corresponding values of specific humidity, enthalpy, relative humidity and specific volume.

H_1 =_______________kJ/kg of dry air

H_2 =_______________kJ/kg of dry air

Therefore,

Energy transfer (cooling) = $H_1 - H_2$ =________________kJ/kg of dry air

Relative humidity =_______________%

Specific volume =_______________m^3/kg

- Humidification

State points 1, 2 on psychometric chart (enclosed) using DBT_1, WBT_1, DBT_2, WBT_2 and thus we can find out corresponding values of specific humidity, enthalpy, relative humidity and specific volume.

H_1 =_______________kJ/kg of dry air

H_2 =_______________kJ/kg of dry air

Therefore,

Energy transfer (cooling) = $H_1 - H_2$ =________________kJ/kg of dry air

Relative humidity =_______________%

Specific volume =_______________m^3/kg

TABULAR COLUMN

Mode: Capillary Test: Cooling effect

P_1 Psi	P_2 Psi	V Volts	I A	T_1 ^{0}C	T_2 ^{0}C	T_3 ^{0}C	T_4 ^{0}C	T_5 ^{0}C	Rt lpm	EMR1 5 rev	Wet/Dry (inlet) ^{0}C	Wet/Dry (outlet) ^{0}C

Test: Dehumidification (heater 1 and 2 ON)

$WDB_1 = WDB_2$

=

Test: Humidification (Steam supply)

$WDB_1 = WDB_2$

=

Mode: Thermostatic Expansion Test: Cooling effect

P_1 Psi	P_2 Psi	V Volts	I A	T_1 ${}^0C$	T_2 ${}^0C$	T_3 ${}^0C$	T_4 ${}^0C$	T_5 ${}^0C$	Rt lpm	EMR1 5 rev	Wet/Dry (inlet) ${}^0C$	Wet/Dry (outlet) ${}^0C$

Test: Dehumidification (heater 1 and 2 ON)

$WDB_1 = WDB_2$

=

Test: Humidification (Steam supply)

$WDB_1 = WDB_2$

=

RESULT

INFERENCE

EXPERIMENT N0: 10

CALIBRATION OF THERMOCOUPLE

AIM

To calibrates the given thermocouple using given a digital temperature indicator.

THEORY

A thermocouple is a junction between two different metals that produces a voltage related to a temperature difference. Thermocouples are a widely used type of temperature sensor and can also be used to convert heat into electric power. Thermocouples measure the temperature difference between two points, not absolute temperature. In traditional applications, one of the junctions – the cold junction was maintained at a known (reference temperature, while the other end was attached to a probe.

Type of Sensors

Type K (chromel-alumel) is the most commonly general purpose thermocouple. It is inexpensive available in a wide variety of probes. They are available in the -200^{0}C to 1350^{0}C range.

Type J (iron – constantan is less popular than type K due to its limited range (-40^{0}C to 750^{0}C). The curie point of the iron (770^{0}C) causes an abrupt change to the characteristic and it is this that provides the upper temperature limit.

Type T (copper–constantan) thermocouples are suited for measurements in the -200^{0}C to 350^{0}C range. It is used as a differential measurement since only copper wire touches the probes.

PROCEDURE

Select the J/K/T thermocouples by selector switch. Connect the J/K/T thermocouple to the sensor socket provided at the front panel. Set the Min pot to read the ambient temperature in display. Insert the J/K/T thermocouple in the hot bath. The digital display will show the temperature obtaining at the hot bath directly. Note the reading in the tabular column.

OBSERVATIONS

Sl.No.	J Type Reading in ^{0}C	K Type Reading in ^{0}C	T Type Reading in ^{0}C	Thermometer Reading in ^{0}C
1				
2				

Calibration equations can be found out from the graph

Graph 1 : Thermometer reading vs J type reading

Graph 2 : Thermometer reading vs K type reading

Graph 3 : Thermometer reading vs T type reading

RESULT

INFERENCE

EXPERIMENT N0: 11

PRESSURE GAUGE CALIBRATION

AIM

To calibrates the given pressure gauge using given dead weights.

THEORY

Dead weight tester commonly used as a source of static pressure for calibration purpose, but which is basically a pressure producing and pressure measuring device. When the applied weight and piston area are known, the resulting pressure may be readily calculated.

PROCEDURE

Check whether there is any air bubbles entrapped in the oil reservoir. If there is air bubbles release that air by filling oil into the reservoir after releasing the nut near the place in which pressure gauge is fitting. Select the dead weights according to the range of pressure gauge given for calibration. Place the first dead weight and apply the load on the plunger. This pressure will act on the piston. Corresponding pressure will shown in the pressure gauge. Place the dead weight in the increasing order and corresponding pressure are to be noted. After loading to the maximum value, the dead weights are unloaded on by one and each time the pressure values are noted.

OBSERVATIONS

Sl.No.	True Pressure kg/cm^2	Indicated pressure kg/cm^2	
		Upward reading	Downward reading
1			
2			
3			

Calibration equations can be found out from the graph, where X-axis and Y axis represent time value and indicated value of the pressure respectively.

RESULT

INFERENCE

EXPERIMENT N0: 12

STUDY OF HEAT PIPE AND ITS DEMONSTRATION

AIM To studies the parts and working principle of a heat pipe.

INTRODUCTION

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

DESCRIPTION

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

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

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

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

PROCEDURE

1. Before using the demonstrator evacuate the heat pipe if necessary and fill about 50cc of distilled water. Fill equal amount of water in three condense tanks so that the pipe is submerged completely in water.
2. Start the supply
3. Give known steady input to all the three heaters with the help of a dimmer stat.
4. Check the input to three heaters with the help of selector switch and voltmeter and

ammeter.

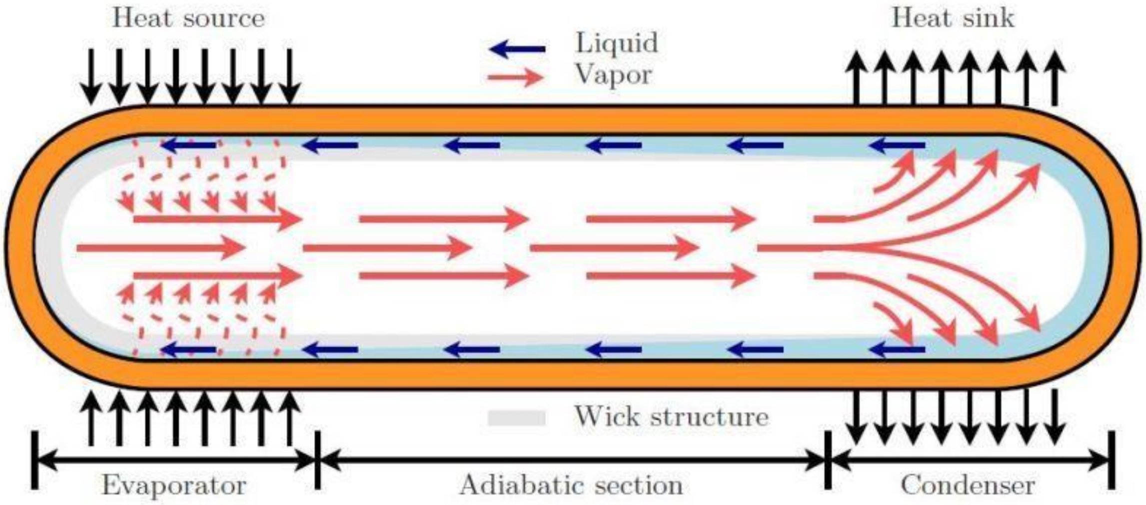
5. Allow an initial heating period of about 15 minutes for sharing up of the demonstrator.
6. Note down all the temperature along lengths of the pipes and also of the water in the tanks at the time interval of 110 minutes.
7. This procedure is to be followed for about 60 minutes to study the heat pipe demonstrator working.

SPECIFICATIONS

1. O.D. of stainless steel pipe : 30 mm
2. O.D. of heat pipe : 30 mm
3. O.D. of copper pipe : 30 mm
4. Length of pipes : 370 mm
5. Condenser tank : 135 mm X 100 mm X 100 mm
6. Condenser tank capacity : About 1 litre of water
7. Dimmer stat : 4 Amps
8. Ammeter selector : Standard
9. Heater : Band Heater
10. Temperature indicator : Digital Temperature indicator, 0-200^{0}C
11. Thermometers : -10 to 110^{0}C, 3 nos
12. Digital Voltmeter : 0 – 300 volts
13. Digital Ammeter : 0 – 2.5 Amps

EXPERIMENTS TO BE CARRIED OUT

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



CONCLUSIONS