MEL334: THERMAL ENGINEERING LAB-II MANUAL

SIXTH SEMESTER MECHANICAL ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

VIMAL JYOTHI ENGINEERING COLLEGE

Approved by AICTE &

Affiliated to ABDUL KALAM Technological University

Under the Archdiocese of Thalassery

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MEL334: THERMAL ENGINEERING LAB-II MANUAL

SIXTH SEMESTER MECHANICAL ENGINEERING

Name of the Student..

Semester & Branch ....

Roll No...

PRN No...

University Reg. No ....

CERTIFICATE

Certified that this is a bonafide record of the work done in the Mechanical Engineering Laboratory of Vimal Jyothi Engineering College, Chemperi, Kannur

by

Mr./Ms. ....

Under the guidance of Mr./ Ms.. during the year..

Date:

Place:

Staff in charge *Internal Examiner* *Head of the Department*

VIMAL JYOTHI ENGINEERING COLLEGE

JYOTHI NAGAR, CHEMPERI, KANNUR-670632

Vision

To bloom into a Center of Excellence for Technical Education and a pace-setter in rural India with its quality processes and procedures, interwoven with freedom of flexibility, moulding professionals of superior quality, dedicated to the progress and development of Humanity.

Mission

To prepare the students to see beyond geographical limit and belong to a new age of acquisition and application of technology to meet the challenges of the changing world. Inspired and guided by gospel values, we contribute to the socioeconomic welfare of the country with due concern to the marginalized.

Quality Policy

VJEC is committed to provide quality education in engineering and technology, to transform the youth into committed technical personal for the social and economic wellbeing of the nation with integral development of the personality and character building.

Motto

"Where Perfection is the Tradition"

DEPARTMENT OF MECHANICAL ENGINEERING

Vision

To become a center of excellence in Mechanical Engineering, producing innovative and creative mechanical engineers to meet the global challenges.

Mission

1. To provide a platform to the students towards attaining quality education in Mechanical Engineering.
2. To educate students about professional & ethical responsibilities and train them to build leadership and entrepreneurship qualities for their career development.
3. To create opportunities and guide students in acquiring career oriented jobs in the field of Mechanical Engineering

Program Educational Objectives (PEO's)

1. Graduates will be able to pursue successful professional career in Mechanical Engineering with sound technical and managerial capabilities.
2. Graduates will have skills and knowledge to formulate, analyze and solve problems in mechanical engineering to meet global challenges.
3. Graduates will be capable of pursuing mechanical engineering profession with good communication skills, leadership qualities, team spirit and professional ethics to meet the needs of the society.
4. Graduates will sustain an appetite for continuous learning by pursuing higher education and research in the allied areas of science and technology.

Program Outcomes (PO's)

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: 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.

PO3: 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

PO4: 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

PO5: 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

PO6: 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.

PO7: 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.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice

PO9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: 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

PO11: 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.

PO12: 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 Outcomes (PSPO's)

1. An ability to use computer aided modelling and simulation tools to provide solutions to mechanical engineering problems.
2. An ability to develop and implement a process in a well-planned manner leading to a demonstrable product.

Course Outcomes

Course Name: THERMAL ENGINEERING LAB-II

CO	After the completion of the course the student will be able to	POs
1	Evaluate thermal properties of materials in conduction, convection and radiation	PO1.PO3,PO4,PO7, PO9,PO10,PO12
2	Analyze the performance of heat exchangers	PO1.PO3,PO4,PO7, PO9,PO10,PO12
3	Illustrate the operational performances of refrigeration and air conditioning systems	PO1.PO3,PO4,PO7, PO9,PO10,PO12
4	Perform calibration of thermocouples and pressure gauges	PO1.PO3,PO4,PO7, PO9,PO10,PO12

COURSE NAME: MEL 334 THERMAL ENGINEERING LAB-II.

CO-PO MAPPING

CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSPO 1	PSPO 2
MEL334 CO.1	**3**	**-**	**2**	**3**	**-**	**-**	**2**	**-**	**3**	**2**	**-**	**2**	**-**	**-**
MEL334 CO.2	**3**	**-**	**2**	**3**	**-**	**-**	**2**	**-**	**3**	**2**	**-**	**2**	**-**	**2**
MEL334 CO.3	**3**	**-**	**2**	**3**	**-**	**-**	**2**	**-**	**3**	**2**	**-**	**2**	**-**	**2**
MEL334 CO.4	**3**	**-**	**2**	**3**	**-**	**-**	**2**	**-**	**3**	**2**	**-**	**2**	**-**	**-**

Note:

Enter correlation levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

Course code: MEL 334

Course Name: THERMAL ENGINEERING LAB-II

L-T-P & Credits: 0-0-3 & 2

LIST OF EXPERIMENTS

1. Determination of LMTD and effectiveness of parallel flow, Counter flow and cross flow heat exchangers
2. Performance studies on a shell and tube heat exchanger
3. Development of heat transfer correlation for heat exchangers/condenser using modified Wilson Plot Method
4. Determination of heat transfer coefficients in free convection
5. Determination of heat transfer coefficients in forced convection
6. Determination of thermal conductivity of solids (composite wall/metal rod)
7. Determination of thermal conductivity of powder
8. Determination of thermal conductivity of liquids
9. Measurement of unsteady state conduction heat transfer
10. Determination of emissivity of a specimen
11. Determination of Stefan Boltzman constant
12. Measurement of solar radiation
13. Experimental study of dropwise and filmwise condensation
14. Experiments on boiling heat transfer
15. Study and performance test on refrigeration (Refrigeration Test rig)
16. Study and performance test on air conditioning equipment (Air Conditioning test rig)
17. Performance study on heat pipe
18. Calibration of Thermocouples
19. Calibration of Pressure gauge

Note: Lab experiments may be given considering 12 sessions of 3 hours each. Minimum 12 experiments to be performed.

INDEX

Sl. No.	Date	Name of Experiment	Page No.	Marks		Sign.
				Experiment	Viva	
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
Average Mark						

Date: **Exp No: 1**

DETERMINATION OF LMTD AND EFFECTIVENESS OF PARALLEL & COUNTER FLOW HEAT EXCHANGERS

AIM:

To determine the LMTD and effectiveness of double pipe parallel, counter flow heat exchanger.

MATERIALS REQUIRED:

Parallel, counter flow heat exchanger, stop watch, measuring tank and thermometer.

THEORY:

Heat exchanger is an apparatus which can transfer heat from one fluid to another. The overall heat transfer coefficient is given by:

$$U_0 = \frac{Q}{A_0(\mathrm{LMTD})}$$

Were, Q = Rate of heat transfer

A_0 = Outer area of inner tube

LMTD = Logarithmic Mean Temperature Difference.

LMTD (for parallel flow) $= \dfrac{(T_{hi}-T_{ci})-(T_{ho}-T_{co})}{\ln(\frac{(T_{hi}-T_{ci})}{(T_{ho}-T_{co})}}$

LMTD (for counter flow) $= \dfrac{(T_{hi}-T_{co})-(T_{ho}-T_{ci})}{\ln(\frac{(T_{hi}-T_{co})}{(T_{ho}-T_{ci})}}$

Where, T_{hi} =temperature of hot fluid inlet (K).

T_{ho} – temperature of hot fluid outlet (K).

T_{ci} – temperature of cold fluid inlet (K).

T_{co} – temperature of cold fluid outlet (K).

Rate of Heat Transfer, $Q = m_h C_{ph}(T_{hi} - T_{ho}) = m_c C_{pc}(T_{co} - T_{ci})$

Where, m_h is the mass flow rate of hot water and m_c is the mass flow rate of cold water respectively.

C_{ph} is the Specific heat of hot water and C_{pc} is the Specific heat of cold water respectively.

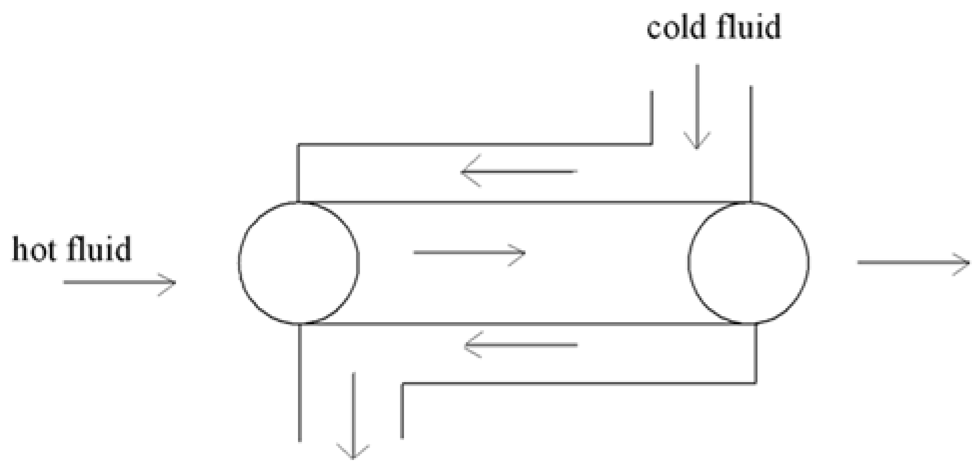

Fig:1-Counter flow heat exchanger

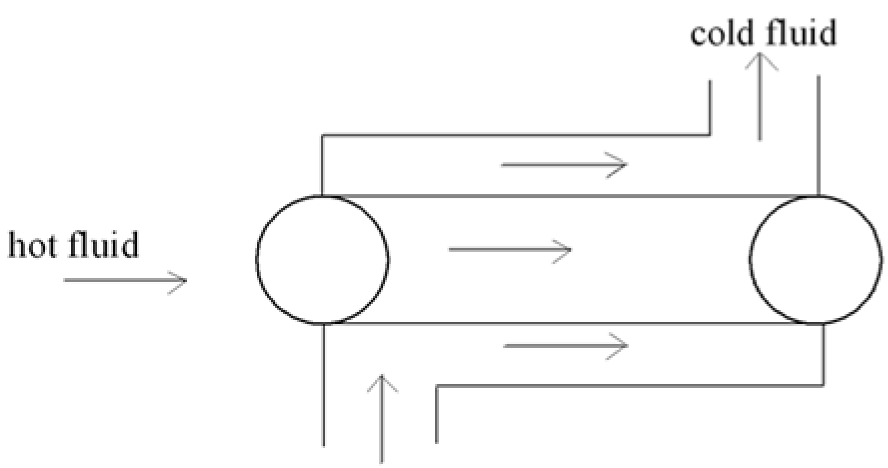

Fig:2-Parallel flow heat exchanger

Effectiveness, $\varepsilon = \frac{Actual\ Heat\ Transfered}{Maximum\ Heat\ Transfered}$

$Q_{max} = (mC_p)_{min}\, \Delta T_{max} = (mC_{p\ min})\ (T_{hi} - T_{ci})$

Or, $\varepsilon = \frac{(mC_p)\ (T_{hi} - T_{ho})}{(mC_p)min\ (T_{hi} - T_{ci})}$

PROCEDURE:

For Parallel Flow

1. Water is allowed to flow through the heat exchanger by opening the appropriate valves. Hot water is allowed to flow through the inner valve tubes. The flow is adjusted to the required amount by adjusting the valves through which the cold water passes.
2. Cold water is passed through the outer tube. A thermometer is used to measure the temperatures at hot water inlet, hot water outlet, cold water inlet and cold water outlet.
3. The readings are noted down at steady states and the outlets from hot and cold waters are collected in the collecting tank separately.
4. Time for 5 or 10 cm rise of cold water in the collecting tank is noted.
5. The rate of flow of hot water is changed and various readings are noted.

For Counter Flow

1. Check the water level in the heater tank. Put on the heater and wait for half an hour
2. Start the flow of the cold water circuit by drawing water from the tap. Set the flow rate to 40 l/hr and start the pump so that the water the water starts flowing the hot circuit. Set the flow rate to 100 l/hr.
3. Wait until thermal equilibrium is reached i.e; when the temperature fluctuate less than 10C per minute. For this purpose, it is sufficient to observe the outlet temperatures i.e; Tc2 and Th2.
4. Once the thermal stability is reached, take the following readings: inlet temperature, outlet temperature and intermediate temperature both in the cold and hot water circuit, flow rate of the cold water and the hot water circuit, flow rate of the hot water and the cold water.
5. Put off the water pump and heater. Allow the cold water to flow for 10 minutes before the cold water flow is stopped

OBSERVATIONS:

Sl. No.	T_{hi} (K)	T_{ho} (K)	T_{ci} (K)	T_{co} (K)	Time for ….cm rise of hot water (s)	Time for ….cm rise of cold water (s)	C_{ph} (Kj/kg.K)	C_{pc} (Kj/kg.K)	P_h (kg/m^3)	P_c (kg/m^3)	m_h	m_c
1												
2												

Sl. No	$m_h\, C_{ph}$	$m_c\, C_{pc}$	Q	ΔT_{max}	U_0	$\varepsilon = \frac{Q}{Q_{max}}$
1						
2						

CALCULATIONS:

RESULT:

INFERENCE:

VIVA QUESTIONS

1. Explain LMTD
2. What is NTU and give the effectiveness equation using NTU method?
3. Differentiate between parallel and counter flow heat exchangers.
4. What are cross flow heat exchangers?
5. What do you understand by steady state regarding heat transfer?

ASSESSMENT RUBRICS

Category	Score	5	4	3	2	1
Conduct of experiment / Procedure & Timely Completion **(5 Marks)**		Procedure is followed correctly and experiment conducted in an outstanding manner	Procedure is followed and experiment conducted in an excellent manner	Procedure is followed and experiment conducted with difficulty but conducted in good manner.	Procedure is not followed properly and experiment conducted with difficulty.	Procedure is not followed properly and experiment not conducted properly
Observations & Readings **(5 Marks)**		The readings/observation are taken accurately and tabulated neatly.	The readings/observation are taken and tabulated	The readings/observation are taken with few errors and tabulated	The readings/observation are taken with inaccuracy and not tabulated correctly	The readings/observation taken with errors and not tabulated
Calculations **(5 Marks)**		Formulas used correctly and steps to solutions are very accurate with correct units	Formulas used correctly and steps and solution has no errors	Formulas used, with some error in calculations.	Formulas are used, some error in calculations units incorrect.	Majority of the calculations are incorrect and solutions have errors.
Results (5 Marks)		Determined results from the observations. Units are specified. Inference is completed	Results are in a range. Units are mentioned &Inference is completed	Results are in a range. Units are mentioned & Inference is not completed	Results are not in a range. Units are mentioned & Inference is not completed	Results are not in a range. Units are not mentioned & Inference is not completed
Graphs and Sketches (5 Marks)		Graphs and sketches are neat and clear and all points plotted very accurately	Graphs and sketches made and all points plotted accurately	Graphs and sketches made and all points plotted with few errors	Graphs and sketches are difficult to understand	In correct values/reading not proper

Score out of 25						
Viva **5 Marks**		Have good knowledge, communicates clearly and fluently	Answers are correct, have overall idea	Some answers are correct	A few answers are communicated clearly or correctly	Unable to communicate/ unaware of most of the ideas
Attendance **15 Marks**						
Total marks out of 45				**Signature of the faculty**		

Date: **Exp No: 2**

DETERMINATION OF HEAT TRANSFER COEFFICIENTS IN FREE CONVECTION

AIM:

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

THEORY:

Natural convection heat transfer takes place by movement of fluid particles on 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 rate of heat transfer is given by Newton's law of cooling

$Q=hA\Delta T$, where h is the convective heat transfer coefficient and value of h depend upon the fluid properties, type of flow and geometry of surface.

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 $=hL/k$

Gr = Grashof number $=[L^3\beta g(T_s-T_a)]/\nu^2$

Pr = Prandtl number $= \mu c_p/k$

β = Coefficient of Volumetric expansion

For ideal gases $\beta= 1/T_f$

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

k =thermal conductivity of air

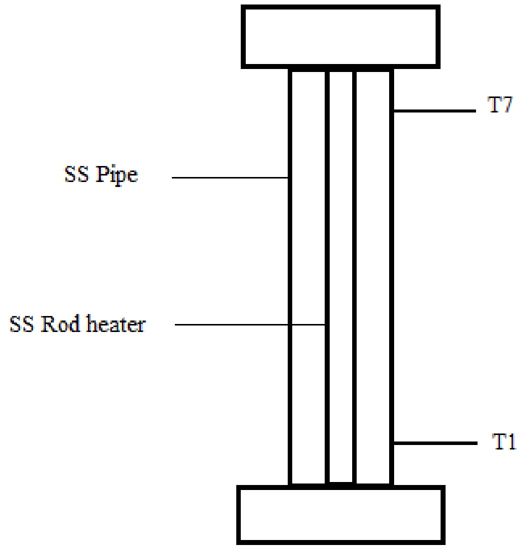

Fig 1: Free convection apparatus

SPECIFICATIONS:

Specimen:

Size of the Specimen:

Heater:

Thermocouples used:

Ammeter:

Voltmeter :

Dimmerstat for heating coil:

Enclosure with acrylic door:

APPARATUS:

The apparatus consists of a stainless steel tube fitted in a rectangular duct in a vertical position. 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 of acrylic sheet for visualization. A heating element is kept in the vertical tube, which heats the tube surface. The heat is lost from the tube to the surrounding air by natural convection. Digital temperature indicator measures the temperature at different points with the help of seven temperature sensors, including one for measuring surrounding temperature. The heat input to the heater is measured by Digital Ammeter and Digital Voltmeter and can be varied by a dimmer stat.

PRECAUTIONS:

1. Never switch on the main power supply before ensuring that all on / off switches give on the panel are at off position.

2. Never run the apparatus if power supply is less than 180 or above 200 Volts.

3. Make sure that convection should conduct in closed container.

4. Before switch on the main supply observer that the dimmer is in zero position.

PROCEDURE:

1. Ensure that all ON/OFF switches given on the panel are at OFF position.
2. Ensure that dimmerstat knob is at zero position, provided on the panel.
3. Now switch on the main power supply (220 V AC, 50 Hz).
4. Switch on the panel with the help of mains ON/OFF switch given on the panel.
5. Fix the power input to the heater with the help of dimmerstat by setting the voltmeter reading to some value say 50V.
6. After steady state is reached, take thermocouple, voltmeter & ammeter readings.
7. When experiment is over, switch off heater first.
8. Adjust dimmerstat to zero position.

Sl. No	Heat input(W)			Temperature on the surface of pipe(°C)							Avg Temperature Ts(°C)	Ambient temperature T_∞(°C)	h_{exp} (W/m^2°C)	h_{th}(W/m^2°C)
	V(V)	I (A)	VI	T_1	T_2	T_3	T_4	T_5	T_6	T_7				

CALCULATIONS:

1. Temperature of vertical cylinder wall $T_s=[(T_1+T_2+T_3+T_4+T_5+T_6+T_7)]/7$

2. Surrounding ambient temperature $=T_\infty$

3. Obtain the properties of air at a mean temperature of $T_f = (T_s+ T_\infty)/2$

4. Volumetric coefficient of thermal expansion $\beta =1/T_f$

5. Rayleigh Number Ra = Gr.Pr

6. Grashoff Number = $[L^3\beta g(T_s-T_\infty)]/ \nu^2$

Where,
Pr= Prandtl number (from Data book at T_f)
ν =kinematic viscosity……….. m^2/sec (from Data book at T_f)

7. Nusselt Number Nu = 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=Nu.k/L W/m² K, which is theoretical value of h

9. Heat transfer rate by convection

$Q_c = h A (Ts – T\infty)$

$Q_c = h \pi d L (Ts – T\infty)$ watt

$$h = \frac{Q_c}{\pi d L(T_s - T_\infty)}$$

which is experimental value of h

10. Heat Input to the coil Q_c= V x I watts

SAMPLE CALCULATION:

RESULT:

INFERENCE:

VIVA QUESTIONS:

1) How does Rayleigh number differ from Grashof number?
2) What is the physical significance of the Nusselt number?
3) Define hydrodynamic entry length for flow in a tube. Is the entry length longer in laminar or turbulent flow?
4) What is a lumped system?
5) What do you understand by the terms fully developed velocity and temperature profile regions in internal flow?

ASSESSMENT RUBRICS

Category	Score	5	4	3	2	1
Conduct of experiment / Procedure & Timely Completion (5 Marks)		Procedure is followed correctly and experiment conducted in an outstanding manner	Procedure is followed and experiment conducted in an excellent manner	Procedure is followed and experiment conducted with difficulty but conducted in good manner.	Procedure is not followed properly and experiment conducted with difficulty.	Procedure is not followed properly and experiment not conducted properly
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Score out of 25						
Viva 5 Marks		Have good knowledge, communicates clearly and fluently	Answers are correct, have overall idea	Some answers are correct	A few answers are communicated clearly or correctly	Unable to communicate/ unaware of most of the ideas
Attendance 15 Marks						
Total marks out of 45				**Signature of the faculty**		

Date: **Exp No: 3**

DETERMINATION OF HEAT TRANSFER COEFFICIENTS IN FORCED CONVECTION (FORCED CONVECTION APPARATUS)

AIM:

To determine the theoretical and experimental value of convective heat transfer coefficient for a horizontal pipe through which air flows under forced convection.

THEORY:

Convective heat transfer between a fluid and a solid surface takes place by the movement of fluid particles relative to the surface. If the movement of fluid particles is caused by means of external agency such as pump or blower that forces fluid over the surface, then the process of heat transfer is called forced convection.

In convectional heat transfer, there are two flow regions namely laminar & turbulent. The non-dimensional number called Reynolds number is used as the criterion to determine change from laminar to turbulent flow. For smaller value of Reynolds number viscous forces are dominant and the flow is laminar and for larger value of Reynolds numbers the inertia forces become dominant and the flow is turbulent. Dittus –Boelter correlation for fully developed turbulent flow in circular pipes is,

$Nu = 0.023 (Re)^{0.8}(Pr)^{n}$ (from data book)

Where

$n = 0.4$ for heating of fluid

$n = 0.3$ for cooling of fluid

Nusselt number= $Nu = hd/k$

Re = Reynolds Number = Vd/ν = inertia force/viscous force

Pr = Prandtl Number = $\mu c_p/k$

DESCRIPTION OF THE APPARATUS:

The apparatus consists of a blower to supply air. The air from the blower passes through a flow passage, heater and then to the test section. Air flow is measured by an orifice meter placed near the test section. A heater placed around the tube heats the air, heat input is controlled by a dimmer stat. Temperature of the air at inlet and at outlet is measured using thermocouples embedded in walls at the different distances from the entrance. Test section is enclosed in a water jacket where the circulating

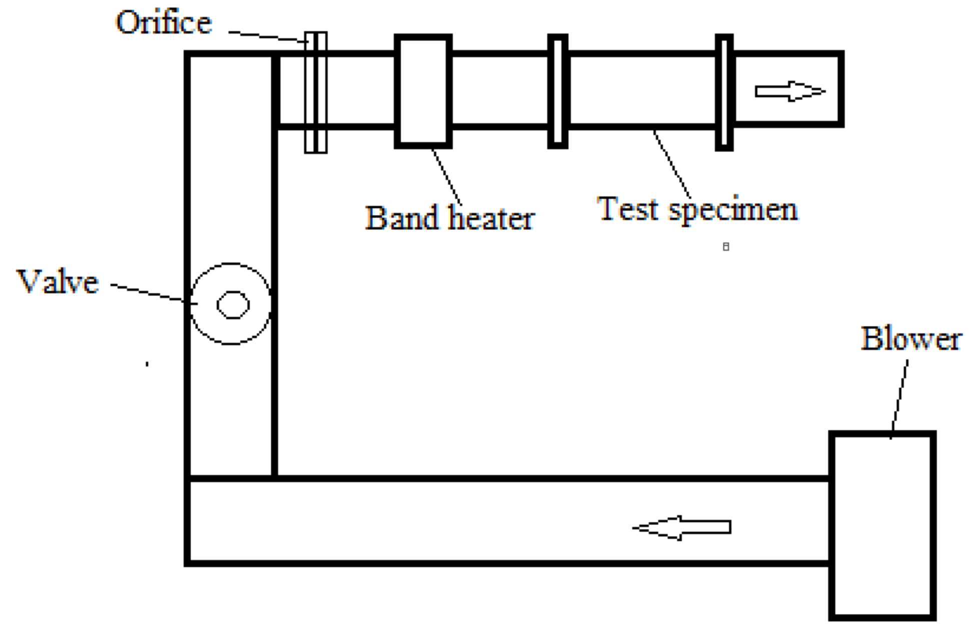


Fig 1: Forced convection apparatus

water removes air. Water flow rate is measured by using the measuring jar. A bypass on the air system enable test to be conducted at different Reynolds number.

SPECIFICATIONS:

Specimen:

Size of the Specimen:

Heater:

Ammeter:

Voltmeter:

Dimmerstat for heating Coil:

Thermocouple Used:

Centrifugal Blower:

Manometer:

Orifice diameter, ‘d_2’:

G. I pipe diameter, ‘d_1’:

Coefficient of discharge:

Length of the tube:

PRECAUTIONS:

1. Never switch ON main power supply before ensuring that all on/off switches given on the panel are at off position

2. Never run the apparatus if power supply is less than 180 or above 210 volts.

PROCEDURE:

1. Start the blower after keeping the valve fully open.

2. Put on the heater and adjust the voltage to a desired value and maintain it as constant.

3. Start the water circulation.

4. Allow the system to stabilize and reach a steady state.

OBSERVATION TABLE:

Sl. No	Heater input Q (Watts)			Diff. in Mano meter reading (mm Hg)	Air temp. °C		Tube surface Temperature °C				
	V volt	I amp	V I		Inlet T_1	Outlet T_7	T_2	T_3	T_4	T_5	T_6

SAMPLE CALCULATION:

5. Note down all the temperatures T_1 to T_7, voltmeter and ammeter readings, and manometer readings.

6. Repeat the experiment for different heat input and flow rates.

MODEL CALCULATIONS:

1. Properties of air are taken at temperature $T_f=(T_S+T_\infty)/2$
Average surface temperature of the tube $T_S=[(T_2+T_3+T_4+T_5+T_6)/5]$
Mean temperature of air $T_\infty=(T_1+T_7)/2$

2. Discharge of the air in the tube

$$Q=C_d\times a\times\sqrt{(2gH_{air})}$$

Where
C_d=Coefficient of discharge
a = area of orifice = $(\pi/4)d^2$
Where d is diameter of the orifice
H_{air}= head of air in m
$H_{air}=(\rho_{Hg}\times h_{Hg})/\rho_a$
Where ρ_{Hg}= density of mercury
ρ_a= density of air
h_g= head in m of mercury

3. Reynolds Number $Re= v_a d_1/\nu$
Where ν=kinematic viscosity, from data book at T_f
v_a= velocity of flow of air =Q/A
Where Q= discharge
A=cross sectional area of tube = $(\pi/4)\times D^2$

Where D = inside diameter of tube

Nusselt number $Nu = 0.023\,(Re)^{0.8}(Pr)^{0.3}$
(Pr= Prandtl number from data book at Tf)

4. Nusselt number Nu = hD/k

Forced convective heat transfer co-efficient $h_{th}=Nu.k/D$ W/m² K
Which is the theoretical value of h
k= thermal conductivity of air from data book, at T_f

From Newton's Law of Cooling:

1. Rate of heat transfer $Q=hA(T_\infty-T_s)$

Heat loss by air = heat transferred across section surface
$Q = m_a c_p(T_{inlet}- T_{outlet})$
Mass flow rate of air, m_a=density of air ×discharge
c_p=specific heat of air
Surface area of the pipe $A_s= \pi DL$

Therefore, $h_{exp}=Q/[A_s(T_\infty-T_s)]$
Which is the experimental value of heat transfer coefficient

RESULT:

INFERENCE:

VIVA QUESTIONS:

1) How is thermal entry length defined for flow in a tube?

2) Define overall heat transfer coefficient.

3) How is natural convection different from forced convection?

4) Define and state the physical interpretation of the Biot number.

5) What is the Fourier number?

ASSESSMENT RUBRICS

Category	Score	5	4	3	2	1
Conduct of experiment / Procedure & Timely Completion (5 Marks)		Procedure is followed correctly and experiment conducted in an outstanding manner	Procedure is followed and experiment conducted in an excellent manner	Procedure is followed and experiment conducted with difficulty but conducted in good manner.	Procedure is not followed properly and experiment conducted with difficulty.	Procedure is not followed properly and experiment not conducted properly
Observations & Readings (5 Marks)		The readings/observation are taken accurately and tabulated neatly.	The readings/observation are taken and tabulated	The readings/observation are taken with few errors and tabulated	The readings/observation are taken with inaccuracy and not tabulated correctly	The readings/observation taken with errors and not tabulated
Calculations (5 Marks)		Formulas used correctly and steps to solutions are very accurate with correct units	Formulas used correctly and steps and solution has no errors	Formulas used, with some error in calculations.	Formulas are used, some error in calculations units incorrect.	Majority of the calculations are incorrect and solutions have errors.
Results (5 Marks)		Determined results from the observations. Units are specified. Inference is completed	Results are in a range. Units are mentioned &Inference is completed	Results are in a range. Units are mentioned & Inference is not completed	Results are not in a range. Units are mentioned & Inference is not completed	Results are not in a range. Units are not mentioned & Inference is not completed
Graphs and Sketches (5 Marks)		Graphs and sketches are neat and clear and all points plotted very accurately	Graphs and sketches made and all points plotted accurately	Graphs and sketches made and all points plotted with few errors	Graphs and sketches are difficult to understand	In correct values/reading not proper

Score out of 25						
Viva 5 Marks		Have good knowledge, communicates clearly and fluently	Answers are correct, have overall idea	Some answers are correct	A few answers are communicated clearly or correctly	Unable to communicate/ unaware of most of the ideas
Attendance 15 Marks						
Total marks out of 45				**Signature of the faculty**		

Date: **Exp No: 4**

DETERMINATION OF THERMAL CONDUCTIVITY OF SOLIDS (METAL ROD/BAR)

AIM:

To determine the thermal conductivity of given metal rod.

THEORY:

Thermal conductivity is a property of the material and may be defined as the amount of heat conducted per unit time through unit area, when a temperature difference of unit degree is maintained across unit thickness.

From Fourier's law of heat conduction

$$Q = -\mathrm{k}\mathrm{A}\frac{\mathrm{dT}}{\mathrm{dx}}$$

Where,

Q = Rate of heat conducted, W

A = Area of heat transfer, m^2

k = Thermal conductivity of the material, W/m-K

$\frac{\mathrm{dT}}{\mathrm{dx}}$ = Temperature gradient

DESCRIPTION OF THE APPARATUS:

It consists of brass rod of diameter d and length l. About half the rod (center position) is embedded in a metallic shell rammed with asbestos powder. The end of rod is fixed on electric heater with dimmer stat supplying with heat. Five thermocouples are uniformly mounted on the bar and two thermocouples are provided on water line. The temperature can be measured on a digital temperature indication with the help of thermocouple selection switch.

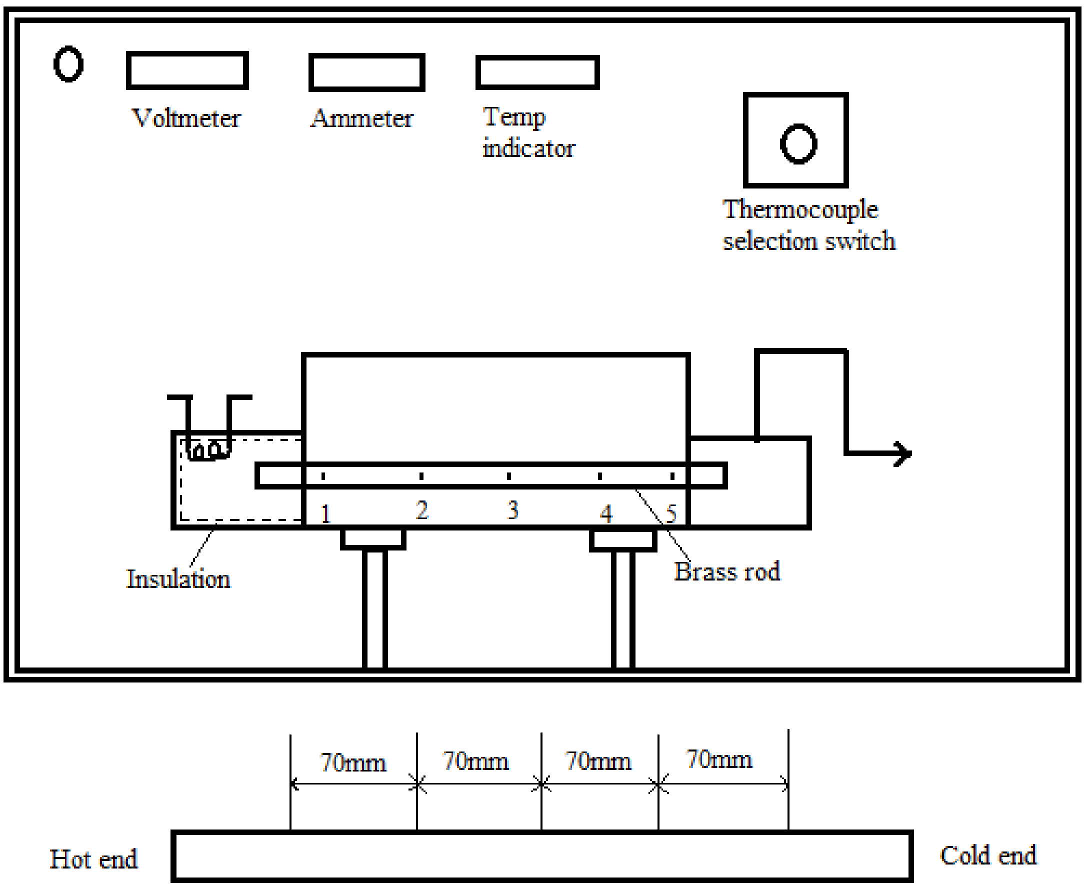


Fig: Apparatus and distance showing the arrangements of thermocouple

SPECIFICATIONS:

Specimen material:

Size of the Specimen:

Cylindrical shell:

Voltmeter:

Ammeter:

Dimmer for heating Coil:

Heater:

Thermocouple used:

Temperature indicator:

PRODEDURE:

1) Power supply is given to the apparatus.
2) Give heat input to the heater by slowly rotating the dimmer and adjust the voltage.
3) Start the cooling water supply through the jacket and adjust its flow rate so that the heat is taken away from the specimen constantly.
4) Allow sufficient time for the apparatus to reach steady state.
5) Take readings of voltmeter and ammeter.
6) Note the temperatures along the length of the specimen rod at five different locations.
7) Note down the inlet & outlet temperatures of cooling water and measure the flow rate of water.
8) Repeat the experiment for different heat inputs.

OBSERVATION TABLE:

Sl. No	Voltage V (V)	Current I(A)	Heat input(W)	Metal rod thermocouple reading (°C)					Water temperature (°C)		Volume flow rate of water (m^3/s)	Mass flow rate of water (kg/s)
				T_1	T_2	T_3	T_4	T_5	Inlet T_{10}	Outlet T_{11}		

SAMPLE CALCULATION:

CALCULATION:

Plot the variation of temperature along the length of the rod. From the graph, obtain dT/dx, which is the slope of the straight line passing through/near to the points in the graph. Assuming no heat loss, heat conducted through the rod = heat carried away by the cooling water

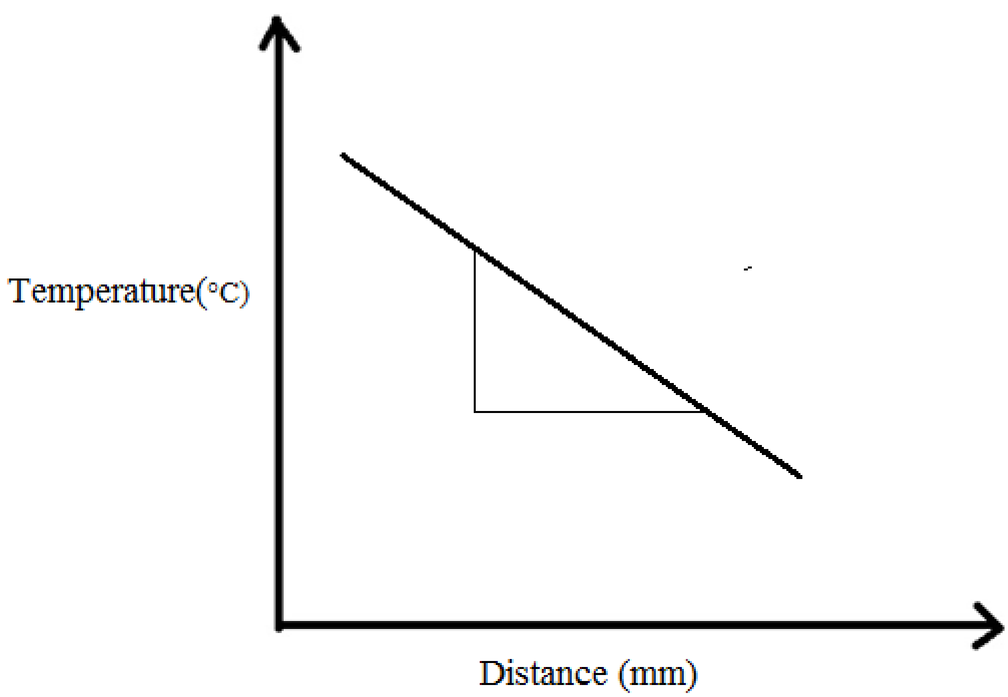
$$kA\,(dT/dx) = m_f\, c_p (T_{11} - T_{10})$$

Where, ‘k’ = thermal conductivity of metal rod, (W/m-K)
‘A’ = Cross sectional area of metal rod (m^2) = $\pi d^2/4$
‘d’ = diameter of the specimen
‘C_p’ = Specific heat of water = 4.187 kJ/kg-K
t= Time for 100ml rise of water in seconds
m_f = Mass flow rate of water(in kg/s)=density of water × Volume of water(in m^3)/ t

Thus, the thermal conductivity ‘k’ of metal rod can be evaluated.

$$k = \frac{m_f c_p (T_{11} - T_{10})}{A \frac{dT}{dX}}$$

SAMPLE GRAPH:



PRECAUTIONS:

1. Keep the dimmer stat to zero before starting the experiment.

2. Take readings at study state condition only.

3. Use the selector switch knob and dimmer knob gently.

RESULT:

INFERENCE:

VIVA QUESTIONS:

1) Discuss about the importance of insulating material in heat transfer.
2) Explain the concept of critical radius of insulation and its significance.
3) What do you mean by transient heat conduction?
4) Distinguish between conduction and convection heat transfer
5) Distinguish between fin efficiency and effectiveness

ASSESSMENT RUBRICS

Category	Score	5	4	3	2	1
Conduct of experiment / Procedure & Timely Completion **(5 Marks)**		Procedure is followed correctly and experiment conducted in an outstanding manner	Procedure is followed and experiment conducted in an excellent manner	Procedure is followed and experiment conducted with difficulty but conducted in good manner.	Procedure is not followed properly and experiment conducted with difficulty.	Procedure is not followed properly and experiment not conducted properly
Observations & Readings **(5 Marks)**		The readings/observation are taken accurately and tabulated neatly.	The readings/observation are taken and tabulated	The readings/observation are taken with few errors and tabulated	The readings/observation are taken with inaccuracy and not tabulated correctly	The readings/observation taken with errors and not tabulated
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Attendance **15 Marks**						
Total marks out of 45				**Signature of the faculty**		

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Date: **Exp No: 5**

THERMAL CONDUCTIVITY OF INSULATING POWDER

AIM:

To determine the thermal conductivity of insulating powder at various heat inputs.

THEORY:

Fourier law of heat conduction:

This law states that rate of heat flow through a surface is directly proportional to the area normal to the surface and the temperature gradient across the surface.

$$Q \propto A\frac{dT}{dx}$$

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

Negative sign indicates that the heat flows from higher temperature to the lower temperature. K is called the thermal conductivity. Thermal conductivity can be defined as the amount of heat that can flow per unit time across a unit cross sectional area when the temperature gradient is unity.

A Materials having lower thermal conductivity are called insulators. Examples for good conductors include all metals. While asbestos, magnesia, glass wool etc., are some the examples for insulators**.**
The radial heat conduction for single hollow sphere transferring heat from inside to outside is given by

$$Q = \frac{4k\pi r_i r_o(T_i - T_o)}{r_o - r_i}$$

Where,

Q = rate of heat transfer in watts = V X I

k = Thermal conductivity W/m-K

r_i = radius of inner sphere in meters

r_o = radius of outer sphere in meters

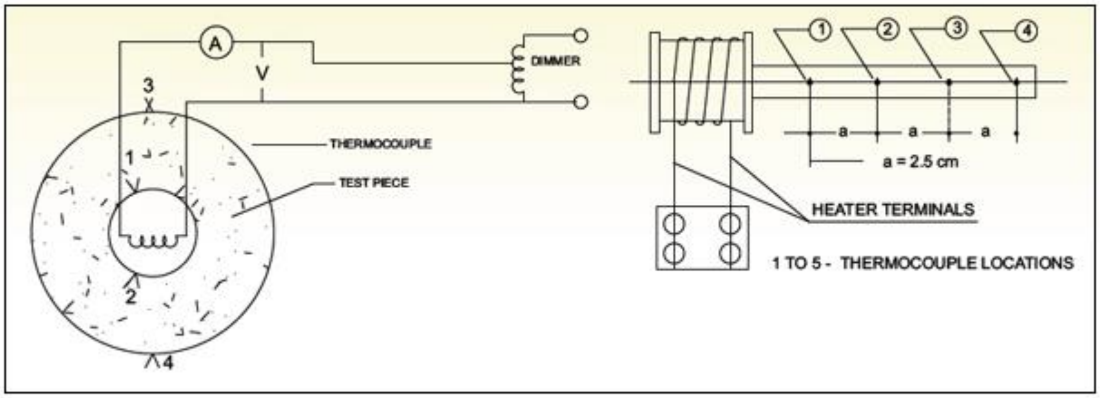

Fig 1: Insulating Powder test rig

T_i =Temperature of the inner sphere

T_o =Temperature of the outer sphere

DESCRIPTION OF APPARATUS:

The apparatus consists of two concentric copper spheres. Heating coils is provided in the inner sphere. The space between the inner and outer spheres are filled by the insulating powder whose thermal conductivity is to be determined. The power supply to the heating coils is adjusted by using dimmer stat. Chromel -Alumel thermocouples are used to record the temperatures. Thermocouples 1 to 6 are embedded on the surface of inner sphere and 7 to 12 are embedded on the outer shell surface.

SPECIFICATIONS:

1. Radius of inner sphere:
2. Radius of outer sphere:
3. Voltmeter:
4. Dimmer stat:
5. Temperature indicator:

PRECAUTIONS:

1. Keep the dimmer stat to zero before starting the experiment.
2. Take readings at study state condition only.
3. Use the selector switch knob and dimmer knob gently.

SL No	Heat input			Inner surface temperature (°C)						Outer surface temperature (°C)					
	V(V)	I(A)	Q(W)	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}

PROCEDURE:

1. Check all electrical connection and give AC input to units

2. Operate the dimmer stat slowly to increase the heat input to the heater and adjust the voltage to any desired voltage to say 50V

3. Maintain the same heat input until the temperature reaches a steady state. This can be checked by reading the temperature of thermocouple 1 to 12 till there is no change in their reading with time.

4. Note down the following readings provided in the Observation table.

5. Repeat the experiment for other heat inputs.

CALCULATIONS:

Heat generated Q=VI

$T_i = (T_1+T_2+T_3+T_4+T_5+T_6)/6$ °C

$T_o = (T_7+T_8+T_9+T_{10}+T_{11}+T_{12})/6$ °C

$$Q = \frac{4k\pi r_i r_o (T_i - T_o)}{r_o - r_i}$$

$$k = \frac{Q(r_o - r_i)}{4\pi r_i r_o (T_i - T_o)} \text{ W/mK}$$

SAMPLE CALCULATION:

RESULT:

INFERENCE:

VIVA QUESTIONS:

1) Define Thermal conductivity
2) What is the difference between thermal conductivity and thermal conductance?
3) Differentiate between thermodynamics and Heat transfer.
4) Distinguish between steady state conduction and unsteady state conduction.
5) State some practical applications of transient heat transfer analysis

ASSESSMENT RUBRICS

Category	Score	5	4	3	2	1
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Score out of 25						
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Attendance 15 Marks						
Total marks out of 45				**Signature of the faculty**		

Date: **Exp No: 6**

DETERMINATION OF EMISSIVITY OF A SPECIMEN

(EMISSIVITY APPARATUS)

AIM:

To determine the emissivity of given test plate 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 & the other body is gray from the values of different surface temperatures of the two bodies maintained by a constant power source emissivity can be calculated. The heat loss by radiation depends on

a) Characteristics of the material

b) Geometry of the surface and

c) Temperature of the surface

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

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

If a body is losing heat to the surrounding atmosphere, then the area of atmosphere A2 >> area of body A1. Thus if anybody is losing heat by radiation to the surrounding atmosphere, equation takes the form.

$$Q=\sigma A_1 \varepsilon_1 (T_1^4-T_2^4)$$

Where,

σ = Stefan Boltzmann constant = 5.6697×10^{-8} W/m^{2}K^4

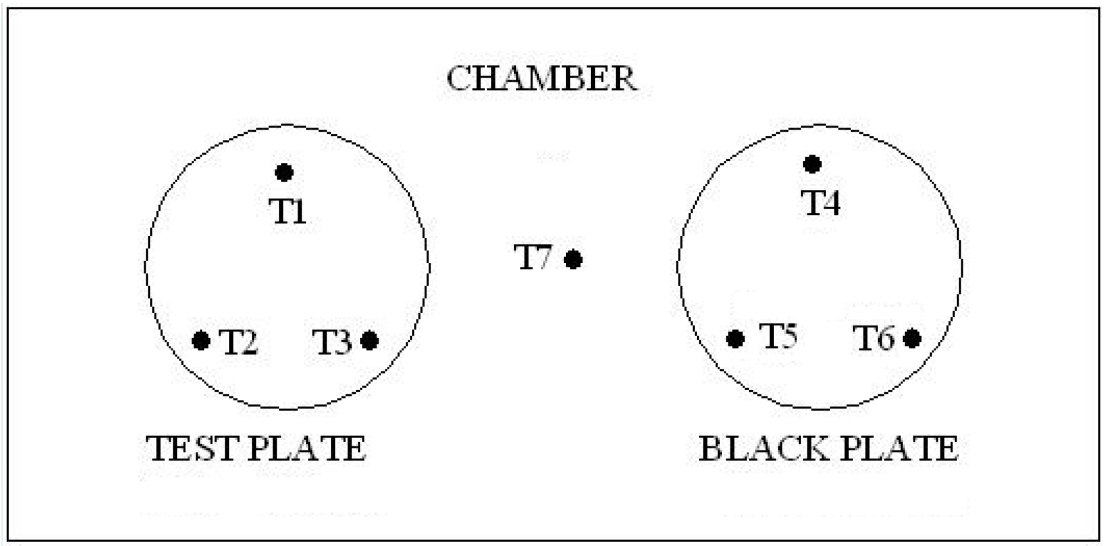

Fig 1: Emissivity measurement apparatus

A_1=Surface area in m^2

ε_1 = Emissivity

T_1 = surface temperature of the body in K and

T_2 = surrounding atmospheric temperature in K

Let us consider a black body & a gray body with identical geometry being heated under identical conditions, assuming conduction & convection heat loss to remain the same.

Let Q_b and Q_g be the heat supplied to black & gray bodies respectively. If heat input to both the bodies are same,
$Q_b = Q_g$

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

Assuming, heat loss by conduction and convection from both bodies to remain same.

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

As geometry of two bodies are identical A = Ag = Ab and ε_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 'c' stands for chamber.

DESCRIPTION THE APPARATUS:

The experimental set up consists of two circular aluminium 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 measured 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 plate to measure the average temperature. One thermocouple is in the chamber to measure the ambient temperature or chamber air temperature.

OBSERVATION TABLE:

Sl. No	Heat input(Gray body)		Heat input(Black body)		Temperature of black surface °C			Temperature of gray surface °C		Chamber Temp °C	
	V(V)	I(A)	V(V)	I(A)	T_1	T_2	T_3	T_4	T_5	T_6	T_7

SAMPLE CALCULATION:

The heat input can be varied with the help of variac for both the plates that can be measured using digital volt and ammeter.

SPECIFICATIONS:

Specimen material:

Specimen Size:

Voltmeter:

Ammeter:

Dimmer stat:

Temperature Indicator:

Thermocouple Used:

Heater:

PROCEDURE:

1. Switch on the electric mains.

2. Operate the dimmer stat very slowly and give same power input to both the heater Say 60 V by using (or) operating cam switches provided panel.

3. When steady state is reached note down the temperatures T_1 to T_7 by rotating the temperature selection switch gently.

4. Also note down the volt & ammeter reading

5. Repeat the experiment for different heat inputs.

SPECIMEN CALCULATIONS:

1. Temperature of the gray body $T_g = [(T_1+T_2+T_3)/3]+273.15K$

2. Temperature of the black body $T_b = [(T_4+T_5+T_6)/3] + 273.15K$

3. Temperature of the Chamber $T_a = T_7+273.15$ K

4. Heat input to the gray body = V x I watt

5. Heat input to the black body = V x I watt

6. Emissivity of gray body

$$\varepsilon_g = \frac{(\mathrm{T_b^4} - \mathrm{T_a^4})}{(\mathrm{T_g^4} - \mathrm{T_a^4})}$$

RESULT:

INFERENCE:

VIVA QUESTIONS:

1) Write a short note on shape factor. Explain its physical significance.
2) Explain emissivity of a body.
3) Define irradiation
4) What do you mean by a gray body?
5) Define monochromatic emissive power.

ASSESSMENT RUBRICS

Category	Score	5	4	3	2	1
Conduct of experiment / Procedure & Timely Completion **(5 Marks)**		Procedure is followed correctly and experiment conducted in an outstanding manner	Procedure is followed and experiment conducted in an excellent manner	Procedure is followed and experiment conducted with difficulty but conducted in good manner.	Procedure is not followed properly and experiment conducted with difficulty.	Procedure is not followed properly and experiment not conducted properly
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Score out of 25						
Viva **5 Marks**		Have good knowledge, communicates clearly and fluently	Answers are correct, have overall idea	Some answers are correct	A few answers are communicated clearly or correctly	Unable to communicate/ unaware of most of the ideas
Attendance **15 Marks**						
Total marks out of 45				**Signature of the faculty**		

Date: **Exp No: 7**

DETERMINATION OF STEFAN BOLTZMANN CONSTANT (STEFAN BOLTZMANN APPARATUS)

AIM:

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

APPARATUS:

Hemisphere, Heater, Temperature indicator, Stopwatch.

THEORY:

Stefan Boltzmann 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 Boltzmann constant=$5.6697\times10^{-8} W/m^2K^4$

E_b is the emissive power which is the energy of thermal radiation emitted in all directions per unit time from each unit area of a surface at any given temperature

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 iron thermocouples are attached at three strategic places on the surface of the hemisphere to obtain the temperatures. The disc is mounted on an bakelite sleeve which is fitted in a hole drilled at the centre of the base plate. Another iron 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.

FIG: STEFAN BOLTZMANN APPARATUS

SPECIFICATIONS:

Specimen material:

Size of the disc:

Base Plate:

Inner diameter of hemisphere:

Emissivity of hemisphere:

Emissivity of disc:

Heater:

Copper Bowl:

Digital temperature indicator:

Thermocouples used:

Stop Watch:

Overhead Tank:

Water Jacket:

Mass of specimen, ‘m’:

Specific heat of the disc C_p:

PROCEDURE:

1) Heat the water in the tank by an immersion water heater provided to a temperature of about 80°C.

2) Remove the test disc before pouring the hot water to the container containing hemisphere surface.

3) Pour the hot water to the container

4) Allow sufficient time for thermal equilibrium to attain between the copper hemisphere and the plate. This is indicated by three thermocouples provided for these purpose.

5) Now insert the test disc and position it exactly in groove. A thermocouple is attached to disc to record temperature

6) Start the stop watch immediately and note the temperature at different short interval of time.

7) Repeat the experiment at other temperatures of the hemisphere.

OBSERVATION TABLE:

Thermocouple	Temperature of the hemisphere (° C)	Temperature of the hemisphere (K)
T_1		
T_2		
T_3		
T_4		

Time(s)	Temperature of the disc (° C)	Temperature of the disc (K)

CALCULATIONS:

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

2. Average temperature of the hemisphere

$$T_h=[(T_1+T_2+T_3+T_4)/4]+273.15$$

3. Td = Temperature of the disc before inserting to Test chamber º K (ambient)

4. Rate of change of heat capacity of the disc = $mc_p(dT/dt)$

Net energy radiated on the disc = $\sigma A_d(T_h^4-T_d^4)$

Where
Ad = area of the disc = $(\pi/4)d^2$ in m^2

d = 20 mm
Cp = specific heat of copper = 0.38 kJ/kg–K

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

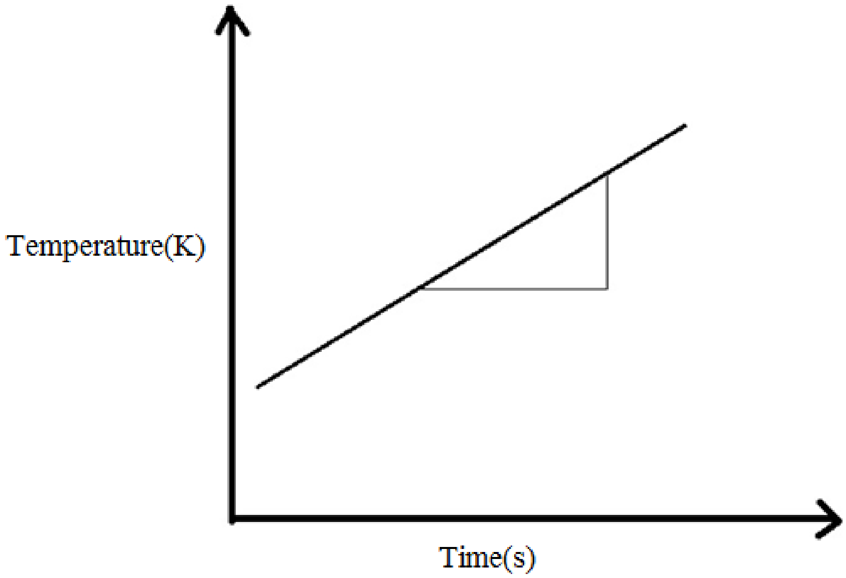
$$mc_p(dT/dt)= \sigma A_d(T_h^4-T_d^4)$$

Thus ‘σ’ can be evaluated as shown

$$\sigma = \frac{mc_p\frac{dT}{dt}}{A_d(T_h^4 - T_d^4)}$$

SAMPLE CALCULATION:

SAMPLE GRAPH:



RESULT:

INFERENCE:

VIVA QUESTIONS:

1) Explain Stefan Boltzmann law for heat transfer by radiation.
2) What is a black body?
3) What are radiation shields?
4) Define radiosity
5) What do you mean by infrared and ultraviolet radiation?

ASSESSMENT RUBRICS

Category	Score	5	4	3	2	1
Conduct of experiment / Procedure & Timely Completion (5 Marks)		Procedure is followed correctly and experiment conducted in an outstanding manner	Procedure is followed and experiment conducted in an excellent manner	Procedure is followed and experiment conducted with difficulty but conducted in good manner.	Procedure is not followed properly and experiment conducted with difficulty.	Procedure is not followed properly and experiment not conducted properly
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Attendance 15 Marks						
Total marks out of 45				**Signature of the faculty**		

Date: **Exp No: 8**

CALIBRATION OF THERMOCOUPLE

AIM: To study the fundamentals of temperature measurement and to calibrate the given copper Constantine thermocouple.

MATERIALS REQUIRED:

- Multimeter
- Digital thermometer
- Electrical device with a thermocouple
- Thermo bath
- Thermocouple table
- Water

THEORY:

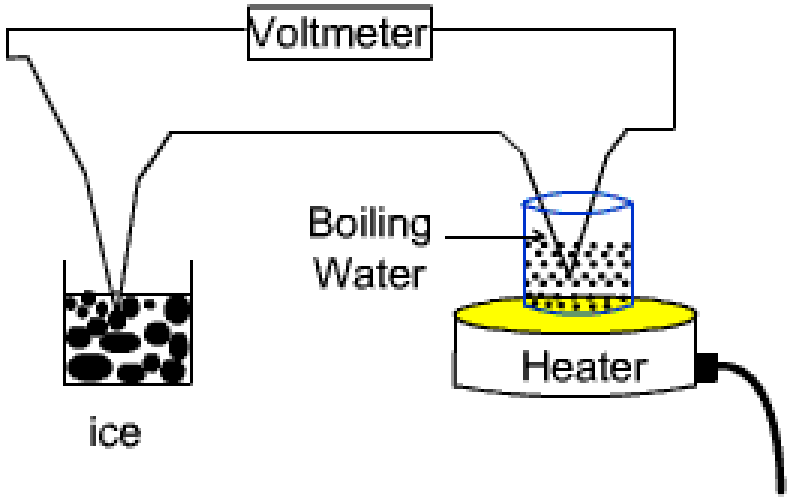
A thermocouple can be any junction between two different metals and may be used to measure temperature. Each metal produces a different electrical potential that varies according to changes in temperature. This rate of change is different for each of the metals in the thermocouple, so a thermocouple produces a voltage that increases with temperature. You can calibrate a thermocouple by plotting the thermocouple's voltage-temperature curve.

Zeroth law of thermodynamics is the fundamental law observed. Here temperature can be measured directly but can be measured by observing the effects that temperature variation causes in the measuring device. Temperature measurement can be classified as non-electrical method, electrical method and variation method

To determine the unknown temperature, the important problem is the calibration of thermo couple. If one junction of the thermo couple is maintained at 0^0C, and the other junction is maintained at some unknown temperature T, then the thermo emf, $\varepsilon = \Delta V$ can be written in the following power series form,

$$\varepsilon = \Delta V = aT + bT^2 + \ldots\ldots\ldots\ldots \quad (1)$$

Where '*a*' and '*b*' are constants, which depend upon particular thermo couple junction. By limiting the power series up to second order, we can write eq. (1) for two known temperatures T_1 and T_2 as,



OBSERVATION:

Sl. No.	Temperature in thermocouple (x)	x^2	emf on heating (V_1)	emf on cooling (V_2)	Mean emf (V) (y)	Temperature from chat (T) ^0C	xy
1							
2							
3							
4							
5							
6							
Σ							

SAMPLE CALCULATION:

$$m = \frac{\Sigma x \Sigma y - n\Sigma xy}{(\Sigma x)^2 - n\Sigma x^2} =$$

PROCEDURE:

(1) Take a thermocouple wire say copper-constantan with two junctions.

(2) For calibrating the thermocouple, take any steady state temperature sources as given below, say boiling point of water = 100 ^{0}C

(3) Take two beakers, one beaker is filled with mixture of ice and water, another beaker is filled with water. Place the second beaker on a hot plate. Switch on the hot plate, and allow the water to boil. Keep sufficient distance between beaker with ice and beaker with boiling water. Note down the thermo - emf voltage from the voltmeter. Note down the thermo-emf readings.

(4) Repeat the above measurement by replacing the boiling water with boiling liquid-Nitrogen. Instead of beaker, a normal flask can be used to hold the liquid nitrogen.

(5) From ε_1 and ε_2 and T_1 and T_2 determine the constants *a* and *b*. Thus the given thermocouple can be calibrated. The constants a and b can be referred as the calibration constants of the given thermocouple. Using the calibration constants and eq. 8, the thermocouple can be used to determine the unknown temperatures.

$$c = \frac{\Sigma xy - m\Sigma x}{n} =$$

$$y = mx + c$$

CALIBRATIONCHART:

x								
y								

RESULT:

INFERENCE:

VIVA:

1. What is a thermocouple?
2. Explain Seebeck and Peltier effects.
3. What are the various types of thermocouple used in industries?
4. Mention any 3 applications of thermocouple.
5. What do you mean by Thomson effect?

ASSESSMENT RUBRICS

Category	Score	5	4	3	2	1
Conduct of experiment / Procedure & Timely Completion **(5 Marks)**		Procedure is followed correctly and experiment conducted in an outstanding manner	Procedure is followed and experiment conducted in an excellent manner	Procedure is followed and experiment conducted with difficulty but conducted in good manner.	Procedure is not followed properly and experiment conducted with difficulty.	Procedure is not followed properly and experiment not conducted properly
Observations & Readings **(5 Marks)**		The readings/observation are taken accurately and tabulated neatly.	The readings/observation are taken and tabulated	The readings/observation are taken with few errors and tabulated	The readings/observation are taken with inaccuracy and not tabulated correctly	The readings/observation taken with errors and not tabulated
Calculations **(5 Marks)**		Formulas used correctly and steps to solutions are very accurate with correct units	Formulas used correctly and steps and solution has no errors	Formulas used, with some error in calculations.	Formulas are used, some error in calculations units incorrect.	Majority of the calculations are incorrect and solutions have errors.
Results (5 Marks)		Determined results from the observations. Units are specified. Inference is completed	Results are in a range. Units are mentioned &Inference is completed	Results are in a range. Units are mentioned & Inference is not completed	Results are not in a range. Units are mentioned & Inference is not completed	Results are not in a range. Units are not mentioned & Inference is not completed
Graphs and Sketches (5 Marks)		Graphs and sketches are neat and clear and all points plotted very accurately	Graphs and sketches made and all points plotted accurately	Graphs and sketches made and all points plotted with few errors	Graphs and sketches are difficult to understand	In correct values/reading not proper

Score out of 25						
Viva 5 Marks		Have good knowledge, communicates clearly and fluently	Answers are correct, have overall idea	Some answers are correct	A few answers are communicated clearly or correctly	Unable to communicate/ unaware of most of the ideas
Attendance 15 Marks						
Total marks out of 45				**Signature of the faculty**		

Date: **Exp No: 9**

CALIBRATION OF PRESSURE GAUGE

AIM:

To calibrate the given Bourdon tube pressure gauge and to obtain the calibration curve by the method of least squares.

APPARATUS:

Pressure gauge tester, spirit level, Bourdon tube pressure gauge.

SPECIFICATION:

Range of dead weight pressure gauge tester = ______________

Range of Bourdon tube pressure gauge = _____________

THEORY:

For getting the best fit line the calibration equation used is:

$y = mx + c$ kgf/cm^2

Where, $m = \dfrac{\Sigma x \Sigma y - n\Sigma xy}{(\Sigma x)^2 - n\Sigma x^2}$ and $c = \dfrac{\Sigma xy - m\Sigma x}{n}$

x = pressure equivalent of weights in kgf/cm^2

y = pressure gauge reading in kgf/cm^2

m = slope of best fit line

c = y intercept of best fit line

PROCEDURE:

1. Ensure that tester is leveled properly by means of spirit level.
2. Pour a clean mineral oil to approximately 2/3 rd of reservoir capacity.
3. (a) Open relief valve
   (b) Turn screw punch handle clockwise fully, this will expel some air from the system and air will bubble out.
   (c) Turn the handle counter clockwise fully to draw in oil into the instrument.
   (d) Repeat clockwise and counter clockwise turning of handle until no bubble appear in the oil cup.
4. (a) Remove blanking plug from the union connector.
   (b) Turn screw pump clockwise slowly until oil shows at the union connector.
   (c) Draw in oil fully and close the release valve.
5. Place necessary weight on carrier so that the pressure wall of the carrier and weight loaded is equal to the first reading to be taken.

OBSERVATIONS:

Sl. No.	Pressure equivalents of weights (x) kgf/cm^2	Pressure gauge reading		Mean y	x^2	xy
		Increasing pressure (y_1)	Decreasing pressure (y_2)			
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

6. Build up the pressure slowly turning screw pump clockwise until the piston with weight rises up and floats freely while building up pressure. The weight with career is rotated by hand to reduce effect of friction in the free piston.
7. Tap the gauge gently to eliminate friction in the gauge mechanism and take reading on it. Write it down against the sum of carrier and weights loaded.
8. Progressively load weights in desired steps on the weight carrier and take readings for measuring pressure at the same point. Ensure that pressure is brought below the specified value before taking off the weights.
9. Plot the calibration graph by least square method.

PRECAUTIONS:

1. The top face of the weight carrier should be perfectly loaded to ensure free floating action at the piston with carrier and weight.
2. The piston should not be lifted beyond step mark. The piston should be free from any constraint, if it is lifted anywhere within ½ stepped region at the top end.
3. After experiment ensure that the tester is left in following condition so that there is no accidental pressure build up and damaged to free piston which is an expensive component:
   (a) Release valve open
   (b) Screw pump fully in clockwise
   (c) Weight removal from the carrier
   (d) Dust cover placed over the instrument.

SAMPLE CALCULATION:

m = $\frac{\Sigma x\Sigma \mathrm{y}-\mathrm{n}\Sigma \mathrm{xy}}{(\Sigma x)^2-\mathrm{n}\Sigma x^2} =$

c = $\frac{\Sigma \mathrm{xy}-\mathrm{m}\Sigma x}{n}$ =

CALIBRATIONCHART:

x								
y								

RESULT:

INFERENCE:

VIVA QUESTIONS:

1. What are the reasons for measuring pressure?
2. What are the basic parts of Mechanical pressure gauges?
3. What is a pneumatic controller?
4. What is the function of hair spring in a pressure gauge?
5. How would you select a pressure gauge for a process?

ASSESSMENT RUBRICS

Category	Score	5	4	3	2	1
Conduct of experiment / Procedure & Timely Completion **(5 Marks)**		Procedure is followed correctly and experiment conducted in an outstanding manner	Procedure is followed and experiment conducted in an excellent manner	Procedure is followed and experiment conducted with difficulty but conducted in good manner.	Procedure is not followed properly and experiment conducted with difficulty.	Procedure is not followed properly and experiment not conducted properly
Observations & Readings **(5 Marks)**		The readings/observation are taken accurately and tabulated neatly.	The readings/observation are taken and tabulated	The readings/observation are taken with few errors and tabulated	The readings/observation are taken with inaccuracy and not tabulated correctly	The readings/observation taken with errors and not tabulated
Calculations **(5 Marks)**		Formulas used correctly and steps to solutions are very accurate with correct units	Formulas used correctly and steps and solution has no errors	Formulas used, with some error in calculations.	Formulas are used, some error in calculations units incorrect.	Majority of the calculations are incorrect and solutions have errors.
Results **(5 Marks)**		Determined results from the observations. Units are specified. Inference is completed	Results are in a range. Units are mentioned &Inference is completed	Results are in a range. Units are mentioned & Inference is not completed	Results are not in a range. Units are mentioned & Inference is not completed	Results are not in a range. Units are not mentioned & Inference is not completed
Graphs and Sketches **(5 Marks)**		Graphs and sketches are neat and clear and all points plotted very accurately	Graphs and sketches made and all points plotted accurately	Graphs and sketches made and all points plotted with few errors	Graphs and sketches are difficult to understand	In correct values/reading not proper

Score out of 25						
Viva **5 Marks**		Have good knowledge, communicates clearly and fluently	Answers are correct, have overall idea	Some answers are correct	A few answers are communicated clearly or correctly	Unable to communicate/ unaware of most of the ideas
Attendance **15 Marks**						
Total marks out of 45				**Signature of the faculty**		

Date: **Exp No: 10**

STUDY AND PERFORMANCE TEST ON REFRIGERATION (REFRIGERATION TEST RIG)

AIM:

To study refrigeration cycle, determine of coefficient of performance of cycle & determine of tonnage capacity of refrigeration unit.

APPARATUS:

Refrigeration test Rig consists of (Compressor (rotary), Air cooler condenser, Capillary tube, Evaporator coil, voltmeter, current meter, voltmeter, energy meter, Thermocouple pressure gauge, vacuum gauge, and freezer.

DESCRIPTION OF THE TEST RIG:

The experimental refrigeration cycle test rig consist of a compressor unit, condenser, evaporator, cooling chamber, controlling devices and measuring instruments those are fitted on a stand and a control panel. The apparatus is fabricated in such a way; to refrigeration system hermetically sealed compressor is fitted on stand with the help of flexible foundation bolts to minimize vibrations. Electric power input to the compressor is given through thermostatic switch

THEORY:

The coefficient of performance of refrigeration plant is given by the ratio of heat absorbed, by the refrigerant when passing through the evaporator or the system, to the working input to the compressor to compress the refrigeration.

Co-efficient of Performance = Heat removed by refrigerant / Power input

COP $_{plant}$ = m Cp ΔT / K. Wh

Where

m = mass of water kept in cooling chamber Cp = specific heat of water = 4.18 KJ /Kg K ΔT = temperature of cooling water ^{K}

Kwh = 1000 x V.I x 60 x 60 KJ = V.I x KJ = V.I x 3600 KJ

KWH = reading of energy meter.

Co-efficient of refrigeration cycle is given by the ratio of net refrigeration effect to the power required to run the compressor.

COP $_{(cycle)}$ Net refrigerant effect in unit time / Power input in unit time
$= m\ Cp\Delta T$ / KwH

Where (Q), = mass flow rate of the refrigerant m^3 / sec C_p =

Specific heat of refrigerant
ΔT= Temperature difference (T_1-T_3)
KWH = Kilowatt hours energy meter reading.

The co-efficient of performance of a refrigeration system is given by the ratio of heat absorb, to the work input.

Where,
COP = Heat removed by refrigerant / Power input

$= m \times Cp\Delta T$ / K.Wh

m = mass of water kept in cooling chamber C_p = specific heat of water = 4.18 KJ /Kg K ΔT = temperature of cooling water ^{K}
Kwh = power consumed by the compressor in unit time.

PROCEDURE:

- Switch on the compressor and let it run for considerable time.
- Say for automatic cut off by thermostatic switch at normal position.
- Fill a measured quantity of water in ice cane (100 gm) and put it into cooling chamber. Measure initial temperature of water before putting into cooling chamber by noting the value of T4 as T_{4i} note down the energy meter reading.
- Wait till compressor starts.
- Compressor shall be started automatically as and when temperature of cooling chamber falls up to adjusted temperature.
- After starting the compressor note down the temperature T_4 at the interval of every 15 minutes and note it down as $T_4\ ^OC$.
- Note down the power consumed by compressor till ice forms i.e. temperature T4 should reach O°C. At 0°C of ice cane note down all the temperature i.e. T1, T2, T3, T4 and T5. Also note down the suction and discharge pressure by the respective gauges.
- Note down the flow rate of refrigerant by rotometer.

Hence Refrigeration effect TR = 336 x 1000 / 24 x 14000 KJ / hour
Where latent heat of fusion of ice = 336 KJ / kg.

OBSERVATION TABLE

Sl no.	Energy meter reading			Mass of water	Temperature of chilling water initial final ΔT	T1	T2	T3	T5
	Initial (a)	Final (b)	C = (a-b)			°C			

RESULT:

INFERENCE:

VIVA QUESTION: -

1. Mention the advantages of vapour compression refrigeration system?
2. Describe the mechanism of a simple vapour compression refrigeration system?
3. What is sub cooling?
4. What is superheating?
5. Why is superheating considered to be good in certain cases?

ASSESSMENT RUBRICS

Category	Score	5	4	3	2	1
Conduct of experiment / Procedure & Timely Completion (5 Marks)		Procedure is followed correctly and experiment conducted in an outstanding manner	Procedure is followed and experiment conducted in an excellent manner	Procedure is followed and experiment conducted with difficulty but conducted in good manner.	Procedure is not followed properly and experiment conducted with difficulty.	Procedure is not followed properly and experiment not conducted properly
Observations & Readings (5 Marks)		The readings/observation are taken accurately and tabulated neatly.	The readings/observation are taken and tabulated	The readings/observation are taken with few errors and tabulated	The readings/observation are taken with inaccuracy and not tabulated correctly	The readings/observation taken with errors and not tabulated
Calculations (5 Marks)		Formulas used correctly and steps to solutions are very accurate with correct units	Formulas used correctly and steps and solution has no errors	Formulas used, with some error in calculations.	Formulas are used, some error in calculations units incorrect.	Majority of the calculations are incorrect and solutions have errors.
Results (5 Marks)		Determined results from the observations. Units are specified. Inference is completed	Results are in a range. Units are mentioned &Inference is completed	Results are in a range. Units are mentioned & Inference is not completed	Results are not in a range. Units are mentioned & Inference is not completed	Results are not in a range. Units are not mentioned & Inference is not completed
Graphs and Sketches (5 Marks)		Graphs and sketches are neat and clear and all points plotted very accurately	Graphs and sketches made and all points plotted accurately	Graphs and sketches made and all points plotted with few errors	Graphs and sketches are difficult to understand	In correct values/reading not proper

Score out of 25						
Viva 5 Marks		Have good knowledge, communicates clearly and fluently	Answers are correct, have overall idea	Some answers are correct	A few answers are communicated clearly or correctly	Unable to communicate/ unaware of most of the ideas
Attendance 15 Marks						
Total marks out of 45				**Signature of the faculty**		

Date: **Exp No: 11**

STUDY AND PERFORMANCE TEST ON AIR CONDITIONING EQUIPMENT (AIR CONDITIONING TEST RIG)

AIM:

To determine the COP of an Air Conditioning system.

APPARATUS:

Compressor, Condenser, Evaporator, Capillary Tube, Ammeter, Voltmeter.

DESCRIPTION OF THE TEST RIG:

Compressor	:Hermetically sealed compressor 1.5 TR with starting and running capacitor.
Refrigerant	:R – 22
Pressure gauge	:0.300 PSI
Suction gauge	:30-0-150 PSI
Rota meter	:0-5 LPM
Condenser & evaporator	:Double row finned.

THEORY:

Air conditioning equipment is used to maintain controlled atmospheric conditions as per required. The controlled atmospheric conditions may be required for human comfort or manufacturing processes of engineering goods. Air conditioning systems are classified in two groups.

1. Packed/Unitary Units
2. Central Unit

A packed unit is self-contained unit, because complete unit including compressor, evaporator, condenser, fan motor etc. are kept in a common enclosure. Capacity of packed or window AC is 1 to 1.5 T.R. This AC is mounted with the room which is required for controlled atmosphere.

A window AC mainly consists of following sub-assemblies:

1. System assembly includes compressor, condenser, evaporator, expansion device, and filter.
2. Motor with blower & fan assembly includes, a double ended shaft motor, a fan and a motor and suitable bracket for it.
3. Cabinet and air distributing assembly – it includes a cabinet as enclosure for whole system, an air distributing system.
4. Control panel assembly – it includes the switched those required to control the entire AC system as per the requirement, IC temperature, humidity etc.

The AC Test Rig is designed and fabricated, to determine the performance and to study its working principle. The AC test Rig consist a 1.5 T sealed compressor unit, a finned condenser (heating coil)

and evaporator (cooling coil), a double ended (shaft) motor to run fan and blower simultaneously and fitted on a wooden stand and properly covered by grill. A duct is assembled along with blower unit as a carrier of comfort air, the velocity of the air passing through the coil is measured by using a pilot tube fitted in duct itself and connected to V-tube manometer which is fitted on control panel. The control panel is fitted over compressor and fan- blower assembly. Control panel consist of 1 phase energy meter to measure power consumed by compressor, a Rota meter to measure flow rate of refrigerant pressure gauge to measure pressure of discharge side compound vacuum gauge to measure suction side pressure, a digital temperature indicator to measure temperature at various places. The desired temperature find out by changing position of selector switch with it. A voltmeter and ammeter is also fitted on control panel

PROCEDURE:

- Switch on the power supply to system i.e. start the compressor simultaneously start fan blower motor also.
- Now compressed refrigerant passing through the condenser and after condensing. It goes to evaporator, where due to cooling effect air, which is sucked by blower cools.
- After few minute the air at the outlet of air duct will become cool at that time. And also measure the static and total pressure by using V-tube manometer and pilot tube.

OBSERVATION TABLE

S. No.	T1	T2	P_{stag}	P_{stat}	P Total	No. of revolution	W = Total power consumed in watts

Sample Calculation

COP = m. $C_p \Delta T$ / KWh = 20 x 4.187 x (12) / 245 x 3.9

And COP = m. $C_p \Delta T$ / W

RESULT:

INFERENCE:

VIVA QUESTIONS:

1. What do you mean by conditioning of air?
2. Explain the working principle of air conditioning system.
3. What are the different types of air conditioning system?
4. What are the various controls system used in air conditioning system?
5. Explain the basic cycle of a household refrigerator.

ASSESSMENT RUBRICS

Category	Score	5	4	3	2	1
Conduct of experiment / Procedure & Timely Completion (5 Marks)		Procedure is followed correctly and experiment conducted in an outstanding manner	Procedure is followed and experiment conducted in an excellent manner	Procedure is followed and experiment conducted with difficulty but conducted in good manner.	Procedure is not followed properly and experiment conducted with difficulty.	Procedure is not followed properly and experiment not conducted properly
Observations & Readings (5 Marks)		The readings/observation are taken accurately and tabulated neatly.	The readings/observation are taken and tabulated	The readings/observation are taken with few errors and tabulated	The readings/observation are taken with inaccuracy and not tabulated correctly	The readings/observation taken with errors and not tabulated
Calculations (5 Marks)		Formulas used correctly and steps to solutions are very accurate with correct units	Formulas used correctly and steps and solution has no errors	Formulas used, with some error in calculations.	Formulas are used, some error in calculations units incorrect.	Majority of the calculations are incorrect and solutions have errors.
Results (5 Marks)		Determined results from the observations. Units are specified. Inference is completed	Results are in a range. Units are mentioned &Inference is completed	Results are in a range. Units are mentioned & Inference is not completed	Results are not in a range. Units are mentioned & Inference is not completed	Results are not in a range. Units are not mentioned & Inference is not completed
Graphs and Sketches (5 Marks)		Graphs and sketches are neat and clear and all points plotted very accurately	Graphs and sketches made and all points plotted accurately	Graphs and sketches made and all points plotted with few errors	Graphs and sketches are difficult to understand	In correct values/reading not proper

Score out of 25						
Viva 5 Marks		Have good knowledge, communicates clearly and fluently	Answers are correct, have overall idea	Some answers are correct	A few answers are communicated clearly or correctly	Unable to communicate/ unaware of most of the ideas
Attendance 15 Marks						
Total marks out of 45				**Signature of the faculty**		

Date: **Exp No: 12**

PERFORMANCE STUDY ON HEAT PIPE

AIM:

To determine the axial heat flux in a heat pipe using water as the working fluid with that of a solid copper with different temperatures.

DESCRIPTION OF THE APPARATUS:

The apparatus consists of a Solid Copper Rod of diameter (d) 25mm and length (L) 500mm with aSource at one end and condenser at other end.

Similarly, Hollow copper pipe without wick and with wick (SS mesh of 180microns) with same outerdia and length is provided.

Thermocouples are fixed on the tube surface with a phase angle of 90□ on each pipe.Control panel instrumentation consists of:

a. Digital Temperature Indicator with channel selector.
b. Digital Voltmeter & Ammeter for power measurement.
c. Heater regulator to regulate the input power.

With this, the setup is mounted on an aesthetically designed MS Powder coated frame with MOVAPAN Board control panel to monitor all the processes considering all safety and aesthetics factors:

PROCEDURE:

- Provide the necessary electrical connection and then CONSOLE ON switch.
- Switch on the heater and set the voltage (say 40V) using heater regulator and the digital voltmeter.
- Wait for sufficient time to allow temperature to reach steady values.
- Note down the Temperatures 1 to 6 using the channel selector and digital temperature indicator.
- Note down the ammeter and voltmeter readings.
- Calculate the axial heat flux for all the pipes.
- Repeat the experiment for different heat inputs and compare the results.

OBSERVATION TABLE

Sl. No.	Temperatures °C						Heater Input	
	T1	T2	T3	T4	T5	T6	V	I
1								
2								
3								
4								
5								

Calculation of heat flux, q

$$q = \frac{Q}{A} = \frac{k \times \delta T}{\delta X} \quad W/m^2$$

where, k = Thermal conductivity of copper = 375 W/m K

dt = Temperature difference.

dx = Length b/w thermocouples

RESULT:

INFERENCE:

VIVA QUESTION: -

1. What do you mean by heat pipe?

2. Explain the working principle of a heat pipe with few applications

ASSESSMENT RUBRICS

Category	Score	5	4	3	2	1
Conduct of experiment / Procedure & Timely Completion (5 Marks)		Procedure is followed correctly and experiment conducted in an outstanding manner	Procedure is followed and experiment conducted in an excellent manner	Procedure is followed and experiment conducted with difficulty but conducted in good manner.	Procedure is not followed properly and experiment conducted with difficulty.	Procedure is not followed properly and experiment not conducted properly
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Calculations (5 Marks)		Formulas used correctly and steps to solutions are very accurate with correct units	Formulas used correctly and steps and solution has no errors	Formulas used, with some error in calculations.	Formulas are used, some error in calculations units incorrect.	Majority of the calculations are incorrect and solutions have errors.
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Score out of 25						
Viva 5 Marks		Have good knowledge, communicates clearly and fluently	Answers are correct, have overall idea	Some answers are correct	A few answers are communicated clearly or correctly	Unable to communicate/ unaware of most of the ideas
Attendance 15 Marks						
Total marks out of 45				**Signature of the faculty**		

Date: **Exp No: 13**

EXPERIMENTAL STUDY OF DROPWISE AND FILMWISE CONDENSATION

AIM:

To determine the experimental and theoretical heat transfer coefficient for drop wise and film wise condensation

SPECIFICATIONS OF THE APPARATUS:

Heater	: Immersion type, capacity 2kW
Voltmeter	: Digital type, Range 0-300V
Ammeter	: Digital type, Range 0-20 amps
Dimmer stat	: 0-240 V, 2 amps Temperature Indicator: Digital type, 0-800°C

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DESCRIPTION OF THE APPARATUS:

The apparatus consists of two condensers, which are fitted inside a glass cylinder, which is clamped between two flanges. Steam from steam generator enters the cylinder through a separator. Water is circulated through the condensers. One of the condensers is with natural surface finish to promote film wise condensation and the other is chrome plated to create drop wise condensation. Water flow is measured by a Rota meter. A digital temperature indicator measures various temperatures. Steam pressure is measured by a pressure gauge. Thus heat transfer coefficients in drop wise and film wise condensation cab be calculated.

PROCEDURE:

- Fill up the water in the steam generator and close the water-filling valve.
- Start water supply through the condensers.
- Close the steam control valve, switch on the supply and start the heater.
- After some time, steam will be generated. Close water flow through one of the condensers.
- Open steam control valve and allow steam to enter the cylinder and pressure gauge will show some reading.
- Open drain valve and ensure that air in the cylinder is expelled out.
- Close the drain valve and observe the condensers.
- Depending up on the condenser in operation, dropwise or filmwise condensation will be observed.
- Wait for some time for steady state, and note down all the readings.
- Repeat the procedure for the other condenser

OBSERVATION TABLE

'V' Volt	'I' Amp	Thermocouple readings(0C)								Volume flow rate of water, V cc/min
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	

Water inlet temperature -T_1
Copper tube surface temperature (Film wise condensation) –T_2
Copper specimen chamber steam temperature - T_3
Gold tube surface temperature (Drop wise condensation) -T_4
Gold specimen chamber steam temperature - T_5
Steam Inlet temperature - T_6
Copper tube Water outlet temperature - T_7
Gold tube Water outlet temperature - T_8

CALCULATIONS:

(FILM WISE & DROP WISE CONDENSATION)

Water flow m_w= kg/sec

Water inlet temperature = °C

Water outlet temperature = °C

(T_8 for drop-wise condensation and T_7 for film-wise condensation)

Heat carried away by the water,

$Q = m_w.c_p.(T_{7\ or\ 8} - T_1)$ Watts

Q=………… Watts

Where c_p = Specific heat of water = 4.2×10^3 J / Kg-K

Surface area of the condenser, $A = \pi dL$ m^2

Experimental heat transfer coefficient, $h = \frac{Q}{A(T_s - T_w)} \; W/m^{2\,o}C$

(for both film wise and drop wise condensation)

Where T_s = Temperature of steam (T_3 or T_5)

T_W = Condenser wall temperature (T_2 or T_4)

Theoretically, for film wise condensation

$$h = 0.943 \left[\frac{h_{fg} \cdot \rho^2 \cdot g \cdot k^3}{(T_s - T_w) \cdot \mu L} \right]^{0.25}$$

Where

h_{fg} = Latent heat of steam at T_S J/kg

(Take from temperature tables in steam tables)

ρ = Density of water, Kg / m^3

g = Gravitational acceleration, m / sec^2

k = Thermal conductivity of water W / m° C

μ = Viscosity of water, N.s/m^2

L = Length of condenser = 0.15 m

(For drop wise condensation, determine experimental heat transfer coefficient only) In film wise condensation, film of water acts as barrier to heat transfer whereas, in case of drop formation, there is no barrier to heat transfer, Hence heat transfer coefficient in drop wise condensation is much greater than film wise condensation, and is preferred for condensation. But practically, it is difficult to prolong the drop wise condensation and after a period of condensation the surface becomes wetted by the liquid. Hence slowly film wise condensation starts.

RESULT:

INFERENCE:

VIVA QUESTIONS:

1. What is condensation heat transfer?

2. What is drop wise and film wise condensation method?

3. Drop wise condensation method is more preferable. Justify your view?

ASSESSMENT RUBRICS

Category	Score	5	4	3	2	1
Conduct of experiment / Procedure & Timely Completion **(5 Marks)**		Procedure is followed correctly and experiment conducted in an outstanding manner	Procedure is followed and experiment conducted in an excellent manner	Procedure is followed and experiment conducted with difficulty but conducted in good manner.	Procedure is not followed properly and experiment conducted with difficulty.	Procedure is not followed properly and experiment not conducted properly
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Score out of 25						
Viva **5 Marks**		Have good knowledge, communicates clearly and fluently	Answers are correct, have overall idea	Some answers are correct	A few answers are communicated clearly or correctly	Unable to communicate/ unaware of most of the ideas
Attendance **15 Marks**						
Total marks out of 45				**Signature of the faculty**		

Date: **Exp No: 14**

PERFORMANCE STUDIES ON A SHELL AND TUBE HEAT EXCHANGER

AIM:

To perform an experiment on a shell and tube heat exchanger for finding out the overall hear transfer coefficient and to determine the effectiveness of the STHC

APPARATUS REQUIRED:

Shell and Tube heat exchanger test rig

SPECIFICATIONS

Outside diameter of the tube= 12mm

Effective length of the tube-= 1020 mm

Total number of tubes=12

Number of passes=2

THEORY

A heat exchanger is a device which is used to transfer heat from one fluid to another. Exchange of heat is required at many industrial operations as well as chemical process. Common examples of heat exchanger are radiator of car, condenser of a refrigeration unit or cooling coil of an air-conditioner. Industrial applications include mainly the steam power plant.

Heat exchangers are of three types-

(i) Transfer type- in which both fluids pass through the exchanger and heat gets transferred through the separating walls between the fluids.

(ii) Storage type - in this, firstly the hot fluid passes through a medium having high heat capacity and then cold fluid is passed through the medium to collect the heat. Thus hot and cold fluids are alternately passed through the medium.

(iii) Direct contact type - in this type, two fluid streams comes into direct contact, exchange heat and are then separated.

Transfer type heat exchangers are the type most widely used. In transfer type heat exchangers, three types of flow arrangements are used, viz. parallel, counter or cross

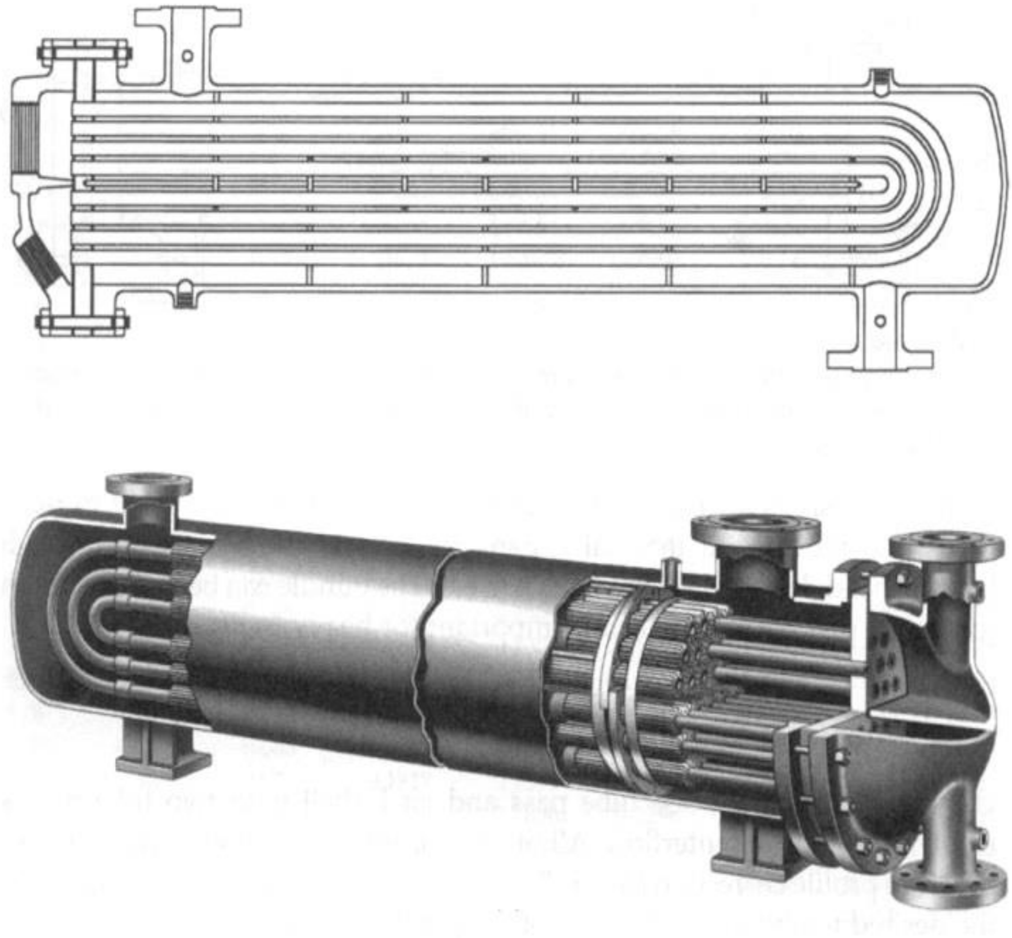

Fig 1: Schematic view of a single shell pass and two tube pass U-tube Shell and Tube heat exchanger

flow depending upon the direction of flow of fluid. Shell and tube heat exchangers are special case of parallel or counter flow heat exchangers.

Shell and Tube heat exchangers:

Shell and tube heat exchangers consist of an outer shell and a number of small tubes inside. The direction of flow of fluid in the shell and tubes will either be in the same direction as that of parallel flow or in the opposite direction as in the case of counter flow or can be in both directions depending upon the number of passes of tube side fluid inside the shell. Baffles are provided in between which serves for two purposes. Baffles are provided to support the tubes and to allow the shell side fluid flow to have a cross flow. In order to increase the heat transfer rate the number of passes of tube side fluid is increased to more number of passes. Pass partitions are provided in the header and footer side of the heat exchanger to increase the number of passes and to prevent the tube side fluids to get inter nixed:

LMTD calculations

$$LMTD = \frac{\theta_1 - \theta_2}{ln\left(\frac{\theta_1}{\theta_2}\right)}$$

Effectiveness = Q/Q_{max} , is the ratio of actual heat transfer to the maximum possible heat transfer.

EXPERIMENTAL PROCEDURE

1.) Switch on the pump to supply hot water into the tubes. Switch on the heaters.
2.) Open the cold water supply valve and let the water to flow inside the shell.
3.) Keep the mass flow rate of shell side fluid and tube side fluid constant.
4.) Keep the hot fluid inlet temperature constant.
5.) Measure the hot fluid outlet and cold fluid inlet and outlet temperatures.
6.) Vary the tube side fluid discharge by keeping the discharges of sell side and temperature of hot water inlet constant.
7.) Repeat the same procedure.
8.) Take at least 4 to 5 sets of readings.
9.) Tabulate the observations.

OBSERVATION COLUMN

Sl No.	Fluid temperature rate- hot water T_1 ºC	Fluid temperature rate hot water T_2 ºC	Fluid temperature rate cold water T_3 ºC	Fluid temperature rate cold water T_4 ºC	Pressure drop in mm of Hg	Flow in cc/sec

RESULT

INFERENCE

VIVA QUESTIONS:

1. Why a heat exchanger is used for?

2. What do you mean by overall heat transfer coefficient?

3. What is LMTD and effectiveness?

4. What is the common problem in shell & tube heat exchanger?

5. What is the purpose of using baffle plates in shell and tube heat exchanger?

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Attendance **15 Marks**						
Total marks out of 45				**Signature of the faculty**		

Date: **Exp No: 15**

DETERMINATION OF THERMAL CONDUCTIVITY OF LIQUIDS

AIM:

To determine the thermal conductivity of given liquid

APPARATUS REQUIRED:

The setup consists of the following items.

Aluminum Cylinder, Heaters: Cooling arrangement Thermocouples: Channel selectors and digital temperature indicators, Heat control or Regulator, Digital Voltmeter and Digital Ammeter

SPECIFICATIONS:

Diameter of cylinder containing liquid: 100 mm
Height of the cylinder: 100 mm
Distance between the thermocouples: 25 mm

THEORY

Heat is transferred or propagated by three different processes, viz., Conduction, Convection and Radiation. The fact that heat can be conducted through a body is very well known. For example when a metal rod is heated at one end, the heat gradually spreads along the rod and the other end becomes hot after some time. The power of transmitting heat in this manner is proposed by all substances solids, liquids, gases, to vary degree and the process is called Conduction.

Conduction is a process of heat transfer through solids or liquids. For a given temperature difference between surfaces , rate of heat transfer (Q watts) depends upon the coefficient of thermal conductivity of a substance (K , W/m^oC) , area of the heat transfer (A,m^2) and temperature difference ($\Delta t,^0C$) between the surfaces and thickness of the material (ΔX , m) according to the equation,

$$Q = kA(\Delta T/\Delta X)$$

Substances such as metals conduct more heat and have a high value of thermal conductivity, as high as 200 W/m^0C. Insulating materials conduct less heat and have lower values of thermal conductivity say about 0.1 to 1 W/m^0C. In circumstances where the heat loss from the system has to be minimized, such as power transmission lines, furnaces etc,. it is essential to cover them with proper materials. This setup has been designed to study heat transfer through liquids.

TABULAR COLUMN

SL. NO	V	I	Q	Mass FlowRate		Thermocouple Reading ,Oil temperature				Water inlet temperature	Water outlet temperature	Q_w	Q_L	K
				LPM	Kg/s	T1	T2	T3	T4	(T5)	(T6)			W/m°C

1. Heat gained by water:

Q_W= m x CP x (T6 – T5)

where ,m= Mass flow rate in Kg/s.

C_P= Specific heat of water= 4187 J/KgK

T6= Water outlet temperature

T5= Water inlet temperature

2. Heat Conducted through liquid

Q_L= K A (dT/dX)

Where, K= Thermal conductivity of Liquid in W/m2C

A= Area of the cylinder in m2

dT/dX =Temperature slope

On Equating

K = (Q/A)(dT/dX) W/m C

In determination of conductivity of liquids, the problem is to eliminate Convection which will transmit more heat than conduction. By insulating on all sides and circulating cooling water on one side this effect can be minimized.

PROCEDURE

1. Switch - ON the Mains and the Console.
2. Switch - ON the Heater.
3. Set the heat control or regulator.
4. Allow water to flow through the cooling jacket. Wait for some time till the temperature stabilizes with time, i.e, steady state is reached.
5. Read the temperatures T1 to T6 using channel selector and digital temperature indicator.
6. Note down the Voltmeter and Ammeter Readings.
7. Using the temperatures, measure rate of heat transfer and the coefficient of the thermal conductivity using given procedure.

RESULT

INFERENCE

VIVA QUESTIONS

1. State Fourier's law of conduction

2. What are Newtonian and non-Newtonian fluids?

3. Define Reynolds number.

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