SRI SHANMUGHA COLLEGE OF ENGINEERING AND TECHNOLOGY

(Approved by AICTE, Affiliated to Anna University and Accredited by NAAC & NBA (ECE)

Pullipalayam, Morur (P.O), Sankari (T.k), Salem (D.T) – 637 304

DEPARTMENT OF MECHANICAL ENGINEERING

ME8512 - Thermal Engineering Laboratory

Vision and Mission of the Department

VISION

To prepare competent mechanical engineers capable of working in an interdisciplinary environment contributing to society through innovation, leadership and entrepreneurship

MISSION

M1: To offer quality education which enables them in professional practice and career

M2: To provide learning opportunities in the state-of-the-art research facilities to create, interpret, apply and disseminate knowledge in their profession

M3: To prepare the students as professional engineers in the society with an awareness of environmental and ethical values

PROGRAMOUTCOMES (POs):

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, safety, 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, apply appropriate techniques, resources, 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, 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, environmental contexts, demonstrate the knowledge and need for sustainable development.

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

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

PO10 Communication: Communicate effectively on complex engineering activities with the engineering community with society at large being able to comprehend, write effective reports, design documentation, make effective presentations and receive clear instructions.

PO11 Project management and finance: Demonstrate knowledge, 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, ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSOs):

PSO1 Manufacturing: Modelling, Simulation and Analysis in the field of Manufacturing.

PSO2 Design: Develop and implement new ideas on product design with help of modern CAD tools.

LABORATORY CLASSES – INSTRUCTIONS TO STUDENTS

1. Students must attend the lab classes with ID cards and in the prescribed uniform.
2. Boys-shirts tucked in and wearing closed leather shoes. Girls' students with cut shoes, overcoat, and plait incite the coat. Girls' students should not wear loose garments.
3. Students must check if the components, instruments and machinery are in working condition before setting up the experiment.
4. Power supply to the experimental set up/ equipment/ machine must be switched on only after the faculty checks and gives approval for doing the experiment. Students must start to the experiment. Students must start doing the experiments only after getting permissions from the faculty.
5. Any damage to any of the equipment/instrument/machine caused due to carelessness, the cost will be fully recovered from the individual (or) group of students.
6. Students may contact the lab in charge immediately for any unexpected incidents and emergency.
7. The apparatus used for the experiments must be cleaned and returned to the technicians, safely without any damage.
8. Make sure, while leaving the lab after the stipulated time, that all the power connections are switched off.
9. **EVALUATIONS:**
    - All students should go through the lab manual for the experiment to be carried out for that day and come fully prepared to complete the experiment within the prescribed periods. Student should complete the lab record work within the prescribed periods.
    - Students must be fully aware of the core competencies to be gained by doing experiment/exercise/programs.
    - Students should complete the lab record work within the prescribed periods.
    - The following aspects will be assessed during every exercise, in every lab class and marks will be awarded accordingly:
    - **Preparedness, conducting experiment, observation, calculation, results, record presentation, basic understanding and answering for viva questions.**

LIST OF EXPERIMENTS

<table>
<tr><td>Course Outcomes</td><td colspan="3">Upon the completion of this course the students will be able to
CO1 Sketch the valve timing diagram and port timing diagram for single cylinder four stroke diesel engine and two stroke petrol engine.
CO2 Measure the viscosity, flash and fire point of various fuel/lubricants
CO3 Calculate the mechanical efficiency of four stroke SI engine by Morse test.
CO4 Evaluate the performance of four stroke single cylinder CI engine & Predict actual diagram.
CO5 Evaluate the performance of steam generator and steam turbines.</td></tr>
<tr><th>Sl. No</th><th>K Level</th><th>Name of the Experiment</th><th>Relevance to COs</th></tr>
<tr><td colspan="4">I.C. Engine Lab</td></tr>
<tr><td>1</td><td>K2</td><td>Valve Timing and Port Timing diagrams.</td><td>CO1</td></tr>
<tr><td>2</td><td>K2</td><td>Actual p-v diagrams of IC engines.</td><td>CO1</td></tr>
<tr><td>3</td><td>K4</td><td>Performance Test on 4 – stroke Diesel Engine.</td><td>CO4</td></tr>
<tr><td>4</td><td>K4</td><td>Heat Balance Test on 4 – stroke Diesel Engine.</td><td>CO4</td></tr>
<tr><td>5</td><td>K4</td><td>Morse Test on Multi-cylinder Petrol Engine.</td><td>CO3</td></tr>
<tr><td>6</td><td>K4</td><td>Retardation Test on a Diesel Engine.</td><td>CO4</td></tr>
<tr><td>7</td><td>K3</td><td>Determination of Flash Point and Fire Point of various fuels / lubricants.</td><td>CO2</td></tr>
<tr><td colspan="4">Steam Lab</td></tr>
<tr><td>8</td><td>K2</td><td>Study on Steam Generators and Turbines.</td><td>CO5</td></tr>
<tr><td>9</td><td>K4</td><td>Performance and Energy Balance Test on a Steam Generator.</td><td>CO5</td></tr>
<tr><td>10</td><td>K4</td><td>Performance and Energy Balance Test on Steam Turbine.</td><td>CO5</td></tr>
<tr><td colspan="4">Content Beyond the Syllabus</td></tr>
<tr><td>1</td><td>K3</td><td>Red wood viscometer</td><td>CO2</td></tr>
<tr><td>2</td><td>K2</td><td>Cut section model - 4 stroke 4cy Petrol engine with components</td><td>CO1</td></tr>
</table>

Course Outcomes		Upon the completion of this course the students will be able to **CO1** Conduct tests on heat conduction apparatus and evaluate thermal conductivity of materials. **CO2** Conduct tests on natural and forced convective heat transfer apparatus and evaluate heat transfer coefficient. **CO3** Conduct tests on radiative heat transfer apparatus and evaluate Stefan Boltzmann constant and emissivity. **CO4** Conduct tests to evaluate the performance of parallel/counter flow heat exchanger apparatus and reciprocating air compressor. **CO5** Conduct tests to evaluate the performance of refrigeration and air conditioning test rigs.	
Sl. No	**K Level**	**Name of the Experiment**	**Relevance to COs**
		Heat Transfer Lab	
1	K4	Thermal conductivity measurement using guarded plate apparatus.	CO1
2	K4	Thermal conductivity measurement of pipe insulation using lagged pipe apparatus.	CO1
3	K4	Determination of heat transfer coefficient under natural convection from a vertical cylinder.	CO2
4	K4	Determination of heat transfer coefficient under forced convection from a tube.	CO2
5	K4	Determination of Thermal conductivity of composite wall.	CO1
6	K4	Determination of Thermal conductivity of insulating powder.	CO1
7	K4	Heat transfer from pin-fin apparatus (natural & forced convection modes)	CO1,CO2
8	K4	Determination of Stefan – Boltzmann constant.	CO3
9	K4	Determination of emissivity of a grey surface.	CO3
10	K4	Effectiveness of Parallel / counter flow heat exchanger.	CO4
		Refrigeration and Air Conditioning Lab	
11	K4	Determination of COP of a refrigeration system	CO5
12	K4	Experiments on Psychrometric processes	CO5
13	K4	Performance test on a reciprocating air compressor	CO4
14	K4	Performance test in a HC Refrigeration System	CO5
15	K4	Performance test in a fluidized Bed Cooling Tower	CO5
		Content Beyond the Syllabus	
1	K2	Demonstration of the fins in various application	CO1,CO2

Engines and Steam lab

COURSE OUTCOME:

COs	Course Outcomes
C217.1	Determination of efficiency of internal combustion engine fueled with Diesel with different types of loading.
C217.2	Determine the efficiency of internal combustion engine fueled with Petrol with mechanical loading.
C217.3	Determine the performance characteristics of steam power plant with its accessories.
C217.4	Demonstrate the performance test on IC Engine with data acquisition system.
C217.5	Determine the friction power of IC engine with Petrol/Diesel fuel.

Course Outcomes	Program Outcomes													
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
C217.1	3	2	2		2		2		2			3		
C217.2	3	2					2		2			3		
C217.3	3	2	2		1		2		2		2	3		
C217.4	3	2	2		2		2		2		1	3		
C217.5	3	2	2		1		2		2		1	3		
C217	**3.00**	**2.00**	**2.00**		**1.50**		**2.00**		**2.00**		**1.33**	**3.00**		

Heat Transfer and R&AC Lab

COURSE OUTCOME:

COs	Course Outcomes
C308.1	Conduct a test to find thermal conductivity of various engineering materials.
C308.2	Measure heat transfer rate in free and forced convection environment.
C308.3	Measure emissivity of grey surface
C308.4	Measure the effectiveness of parallel and counter flow heat exchanger.
C308.5	Measure COP of refrigeration and air conditioning system and performance of air compressor and fluidized bed cooling tower.

Course Outcomes	Program Outcomes													
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
C308.1	3	3	2			2			2			3	1	
C308.2	3	3	2			2			2		1	3	1	2
C308.3	3	3	2			1			2			3		
C308.4	3	3	2				2		2		2	3	1	2
C308.5	3	3					1		2			3		2
C308	**3.00**	**3.00**	**2.00**			**1.67**	**1.50**		**2.00**		**1.50**	**3.00**	**1.00**	**2.00**

HEAT TRANSFER THROUGH NATURAL CONVECTION

AIM:

To find the average heat transfer co-efficient from the vertical cylinder natural convection apparatus.

OBJECTIVE:

To know how heat transfer takes place naturally in a heater coil located in a duct.

APPARATUS REQUIRED:

1. Thermocouple
2. Ammeter
3. Voltmeter
4. Heater rod
5. Temperature indicator

TECHINICAL SPECIFICATION:

1. Length of the heater rod = 500mm
2. Diameter of heater = 38 mm
3. Duct size =20mm*20mm*0.75mm

DESCRIPTION:

A vertical duct is fitted with a cylindrical shaped heater rod mounted vertically inside the duct. Air gets heated and become less dense, causing it rise.

PROCEDURE:

1. Switch "ON" the heater
2. Around the cylindrical rod air is get heated and become less dense casing it to rise.
3. This gives rises to continuous flow of air upwards in the duct.
4. Note down the temperature of the rod say T_1 to T_7.
5. Note down the air inlet and outlet temperatures say T_8
6. Repeat the experiment for different heat input.(Don't exceed 80W)

DIAGRAM:

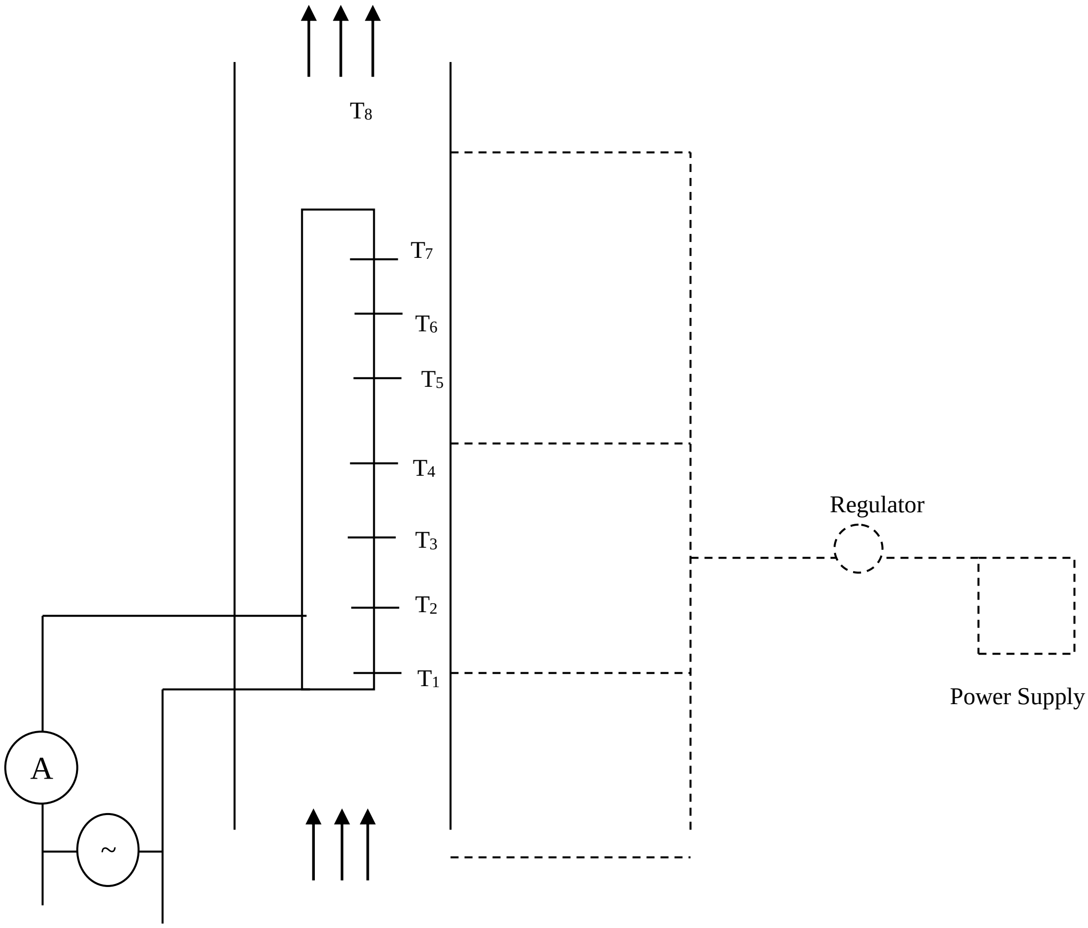


Fig – Heat transfer by Natural convection

OBSERVATION TABLE:

S. No	Current I (A)	Voltage V (V)	Surface Temperature (°C)							Avg. surface Temp	Air Temperature (°C)	h W/m² K
			T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_s(°C)	$Ta=T_8$	

FORMULA USED:

Case (I): Rate of heat transfer (Practical method)

1. Rate of heat supplied $Q = I \times V$ (W)

2. $Q = h A \Delta T$

   $h = Q / A \Delta T$ W/mK

   Where

   $A = \pi DL$

   ΔT – Average temperature of surface – Average air temperature

   Q – Rate of Heat flow

Case (II): Rate of heat transfer (Theoretical method)

3. Coefficient of volumetric expansion, $\beta = 1/(T_{mf})$

   Where:

   T_{mf} = (Average temperature of surface+ Average air temperature)/2

4. $Gr = g \beta L^3 (T_s - T_a) / \gamma^2$

   From data book following parameters for T_{mf}

   Pr - Prantle number

   k – Thermal conductivity

   γ – Kinematic viscosity= 16.288×10^{-6} m^2/sec

5. $Nu = 0.55 \times (Gr \times Pr)^{1/2}$ for $Gr \times Pr < 10^5$

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

   $Nu = 0.133 \times (Gr \times Pr)^{1/3}$ for 10^8 $Gr \times Pr < 10^{12}$

6. $h = Nu K / L$ W/m^2 K (Note: $Nu = hL/K$)

MODEL CALCULATION:

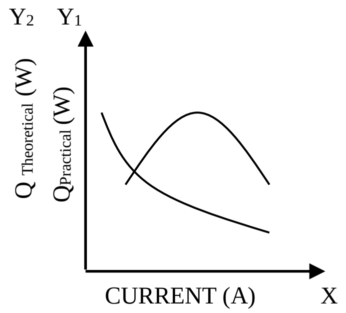
GRAPH:

Graph is drawn between Current Vs heat transfer co-efficient practical and theoretical.

X-axis – Current

Y_1-axis – Heat transfer co-efficient practical

Y_2-axis – Heat transfer co-efficient theoretical.



RESULT:

Thus the Heat transfer coefficient was calculated and results were tabulated

HEAT TRANSFER THROUGH FORCED CONVECTION

AIM:

To find the heat transfer coefficient of horizontal tube losing heat by conduction, to determine the surface temperature distribution along the length of tube.

APPARATUS REQUIRED:

1. Ammeter
2. Voltmeter
3. Temperature indicator
4. Forced convection apparatus

THEORY:

Transfer of heat from one region to another due to macroscopic movement in a fluid or gas in addition to energy transfer by conduction is called heat transfer by convection. If fluid motion is caused by an external agency such as a blower or a pump, situation is to be forced convection. In other words, if convection heat transfer occurs due to the dynamic force of an external agency, then it is known as forced convection heat transfer. Newton's law of cooling governs the heat transfer.

(i.e) Q = h A T

Where h = heat transfer coefficient and is a function of density, diameter of tube (D), absolute viscosity, velocity (V), specific heat and thermal conductivity (K). The dependence of h on all the above parameter is generally expressed in terms of dimensionless number.

1. Nusselt number, NU = h D/k
2. Prandtl number, Pr = $C_p\ \mu/k$
3. Reynolds number, Re = $\rho\ V\ D/\mu$

Reynolds number plays on important role in forced convection heat transfer.

TECHINICAL SPECIFICATION:

1. diameter of the orifice d = 20 mm
2. Inner Diameter, D_i = 25mm
3. Length of the section = 500mm

FORMULA USED:

1. Density of air ρ_a = P/RT
2. Manometer difference of air, h_a = $h_w . \rho_w/\rho_a$ in (m)
3. Discharge, Q = $3600\ C_d\ a\ (2g)^{0.5} h_a$ in m^3/hr
4. Heat supplied through air, q = $m\ c_p\ \Delta T/3600$, kW
5. Heat transfer coefficient, h = $q / A\ (T_S - T_a)$ W/m^2K

Where,

ρ_w - density of water in kg/m^3.
h_w - difference in manometer level.
a - Area of discharge = $\pi d^2/4$,
C_d - coefficient of discharge = 0.64
m - mass flow rate = Q ρ_a kg/hr
ΔT - Temperature difference at two extreme points $\Delta T = T_7 - T_1$°C
A - Surface area in $m^2 = \pi D_i L$.,
T_S - Surface température = (T2+T3+T4+T5) / 4 in °C
T_a - Temperature of air = (T1 + T6) / 2 in °C

PROCEDURE:

1. Switch on the supply and select the range of voltmeter.
2. Adjust the dimmer stat say 50W, 60W and start heating test section.
3. Start the blower and adjust the flow by means of valve to some decide difference in manometer level, say 5 cm.
4. Wait till steady state is reached.
5. Note down the voltmeter, ammeter and thermocouple T1 to T6 readings.
6. Change the heat input to test sections and repeat the experiment.
7. Calculate the heat transfer coefficient by two methods.

MODEL CALCULATION:

Coefficient of discharge of orifice meter, C_d =0.64

Pressure of air at N.T.P, P = 1.01325 bar

Specific heat of air, C_p = 1.005kj/kg k

Density of water ρ_w = 1000 kg/m^3

Density of air ρ_a =

Discharge Q =

Heat supplied $q = m\ C_p\ \Delta t$

$$\text{Heat transfer coefficient } h = \frac{q}{A\,(T_s - T_a)}$$

RESULT:

Thus the Heat transfer coefficient was calculated by varying the flow of air and results were tabulated.

TABULATION:

S.No	Dimmer stat Reading VxI	Voltage V	Ammeter I	Difference in Manometer x10-2	Thermometer Reading						Discharge Q	Heat supplied	Surface Temp	Average Temp	Heat transfer coefficient
					T1	T2	T3	T4	T5	T6					
	W	V	A	m	°c	°c	°c	°c	°c	°c	m^3/hr	kW	°c	°c	W/m^2K

HEAT TRANSFER IN PIN-FIN APPARATUS
(Natural and forced convection)

AIM:

To determine the temperature distributions of a pin-fin apparatus using natural and forced convection mode and also determine the fin efficiency.

OBJECTIVE:

To know the temperature distribution that takes place in a pin-fin apparatus.

APPARATUS REQUIRED:

1. Air blower
2. Fin material (Brass)
3. Manometer
4. Air dust
5. Heater coil
6. Temperature indicator

TECHINICAL SPECIFICATION:

1. Duct width (W) = 0.15m
2. Duct breath (H) = 0.1m
3. Orifice co-efficient = 0.62
4. Fin length = 150mm = 0.15m
5. Fin diameter (D_f) = 0.0127m
6. Pipe diameter (d_1) = 0.04m
7. Orifice diameter (d_2) = 0.018m

DESCRIPTION:

The apparatus consists of a pin-fin placed on open dust. One side is open and other end is connected to the suction side of a blower. The delivery side of the blower is taken up through a gate valve and an orifice meter to the atmosphere. The airflow rate can be varied by the gate valve and can be measured on the U tube manometer connected to the orifice meter.

Experimental Procedure:

To study the temperature distribution along the length of a pin fin natural and forced convection, the procedure is as under

(I) Natural Convection:

1. Start heating the fin by switching ON the heater element and adjust the voltage on Dimmerstat to Say 80 volt (Increase slowly from 0 to onwards) Note down the thermocouple reading 1 to 5.
2. When steady state is reached, record the final readings 1 to 5 and also record the ambient Temperature reading 6.
3. Repeat the same experiment with voltage 100 volts and 120 volts.

(II) Forced Convection:

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

OBSERVATION TABLE:

Forced convection:

S. No	Current I (A)	Voltage V (V)	Manometer Readings (cm)		H h_1- h_2 (m)	Surface Temperature (°C)					Avg Surface temp T_s (°C)	Ambient Temp (°C)
			h_1	h_2		T_1	T_2	T_3	T_4	T_5		T_6

Natural convection:

S. No	Current I (A)	Voltage V (V)	Surface Temperature (°C)						Avg Surface temp T_s (°C)	Ambient Temp (°C)
			h_1	T_1	T_2	T_3	T_4	T_5		T_6

FORMULA USED:

1. Volume of air flowing through the Duct(V_o) = $\dfrac{C_d \times A_1 \times A_2 \sqrt{(2gh_a)}}{\sqrt{A_1 - A_2}}$

   Where

   A_1 - Area of pipe = $\pi/4\ (d_1)^2$ = Л/4 $(0.04)^2$ = $1.256\times10^{-3}\ m^2$

   A_2 - Area of orifice = $\pi\ /4\ (d_2)^2$ = Л/4 $(0.02)^2$ = $3.1415\times10^{-4}\ m^2$

   h_a- Head of Air = $(\rho_w\ /\ \rho_a\ ) \times h$

   ρ_w – Density of water corresponding to 30°C = 1000 kg/m^3

   ρ_a - Density of air corresponding to 30°C = 1.16 kg/m^3

   $h = h_1 – h_2$ in meters.

2. Velocity of air in the duct (V) = V_o /(Width × Breath) m/sec

3. Re = $DV/\gamma = LV/\ \gamma$

   Where

   γ – Kinematic viscosity at 30°C from data book

   L = 0.150m

4. $Nu = 0.989 \times (Re)^{0.33} \times (Pr)^{0.33}$ for $1 < Re < 4$

   $Nu = 0.911 \times (Re)^{0.385} \times (Pr)^{0.33}$ for $4 < Re < 40$

   $Nu = 0.683 \times (Re)^{0.486} \times (Pr)^{0.33}$ for $40 < Re < 400$

   $Nu = 0.193 \times (Re)^{0.618} \times (Pr)^{0.33}$ for $400 < Re < 40000$

   $Nu = 0.0266 \times (Re)^{0.805} \times (Pr)^{0.33}$ for $Re > 40000$

   Where Pr – from data book corresponding to 30°C

5. $h = Nu\times K/L$ (Note: $Nu=hD/K=hL/K$)

   Where K from data book corresponding to 30°C

6. Slop (m) = $\sqrt{(hP\ /\ (K_B\ A))}$

   Where

   P – Perimeter = Л D_f = Л×0.012= 0.03768m

   A – Area of the fin = Лd^2 / 4 = Л × $(.012)^2$ / 4 = $1.13\times10^{-4}\ m^2$

   K_B – Thermal conductivity of Fin material (Brass) = 110.7W/mK

7. η Pin-fin = $\dfrac{\text{Actual Heat Transferred by Fin}}{\text{Heat transferred of entire fin}}$

η Pin-fin $= \dfrac{\text{Tan h x (mL)}}{\text{mL}} \times 100$

Where L – Length of the fin = 0.15m

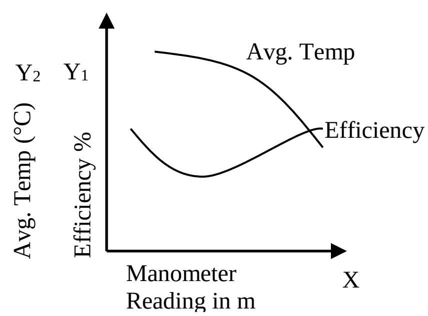
GRAPH:

Graph is drawn between Manometer reading Vs Efficiency and Average temperature.

X-axis – Manometer reading in m

Y_1-axis – Efficiency

Y_2-axis – Average temperature



RESULT:

Thus the efficiency of Pin-Fin apparatus using natural and forced convection mode was determined

STEFAN – BOLTZ'S MAN APPARATUS

AIM:

To find the Stefan's – Boltz's man constant for radiation heat transfer by using the given apparatus.

OBJECTIVE:

To know how radiation absorbed by the copper material in a closed system

APPARATUS REQUIRED:

1. Water heater
2. Radiating hemisphere
3. Water collector tank
4. Selector switch
5. Copper disc

TECHINICAL SPECIFICATION:

1. Mass of disc, m = 0.005 kg
2. Diameter of disc, d= 0.020m
3. Disc material = Copper
4. C_p of Copper = 0.38 kJ/kg K
5. T_1 to T_4 temperature of hemisphere **°C**
6. T_5 – Disc temperature **°C**

DESCRIPTION:

It consists of concentric hemisphere with provisions for the hot water to passes through the annulus. A hot water source is provided for supplying the water to the system. The water flow may be varied using the control valve is provided at the inlet. A small disc is placed at the bottom of the hemisphere which receives the heat radiation and it can remove (or) refitted.

PROCEDURE:

1. Allow water to flow through heater unit and hemisphere
2. Remove the disc from the bottom of hemisphere
3. Switch on the heater and allow the hemisphere to reach a steady temperature.
4. Note down the temperature T_1 to T_3
5. Refit the disc at the bottom of hemisphere and start the stop watch
6. Raise the temperature T_4 and respected time is noted
7. Note down the temperature of disc up to steady state reached for every 15 s.

OBSERVATION TABLE:

S. No	Average temperature of Hemisphere T_h (°C)				Disc temperature (°C)	Time (s)	Steady state temperature (°C)
	T_1	T_2	T_3	T_4	T_5		T_d
						0	
						15	
						30	
						45	
						60	
						75	

FORMULA USED:

1. $Q = \Sigma\ \sigma\ A(T_h^4+T_d^4)$

   $\sigma = Q / (\Sigma A\ (T_h^4+T_d^4))$

   Where

   σ – Stefan – Boltzmann constant, W/m^2K^4

   Q – Rate of heat transfer = $m\ C_P\ \Delta T$

   m – Mass of the disc = 0.005kg

   C_P – Specific heat of water = 0.381kj/kgK

   A – Area of disc = $\pi /4\ d^2 = \pi/4\ (0.020)^2$

   Σ – Emissivity of hemisphere = 1

   ΔT – dT/dt from graph

   T_h – Average temperature of hemisphere

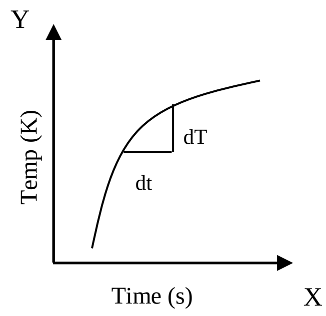
   T_d – Steady state temperature of disc

GRAPH:

Graph is drawn between Time Vs Temperature to find ΔT

X-axis – Time in sec

Y-axis – Temperature in °C



RESULT:

The value of the Stefan Boltzmann constant is__________

EMISSIVITY MEASUREMENT

AIM:

To determine the emissivity of the grey test plate surfaces at different temperature.

OBJECTIVE:

To know how the emissivity differ from polished body to black body in a closed surface with the same heat input

APPARATUS REQUIRED:

1. Heating element
2. Two test specimen
3. Voltmeter
4. Ammeter
5. Temperature indicator

TECHINICAL SPECIFICATION:

1. Diameter of the grey body (or) test body = 150mm
2. Diameter of black body = 150mm
3. $\sigma = 5.67\times10^{-8}$ W/m^{2}K^4

FORMULA:

$$\text{Emissivity} \quad \Sigma_P = (Tb^4 - Ta^4)/(Tg^4 - Ta^4)$$

Where,

Tb – Temperature of black plate
Ta – Ambient temperature
Tg- Temperature of grey plate

THEROY:

All substances at all temperature emit thermal radiation. The rate of emission increase with temperature level, Thermal radiation is an electromagnetic wave and do not required any material medium for.

Propagation in addition to emitting radiation the body also has the capacity for absorbing all or a part of the radiation coming from the surrounding towards it when a ray of thermal radiation strike a surface of a body it may be affected in one of the three ways.

(1). A portion of the incident energy may be reflected…
(2). A portion of the incident energy may be absorbed by the body and
(3). A portion of the incident energy may be transmitted through the body.

PROCEDURE:

1. Give the power supply and adjust the reading in it equal to room temperature by rotating compensation knob.

2. Selected the proper range of volt meter

3. Gradually increase the input to the on black plate and adjust it into some value 30,40 or 50

4. Adjust the heater input to the slightly value than black plate say 27,37 or 47 watts

5. Check the temperature of two plates with small time intervals and adjust input of the test plate will maintain the same temperature (ie) Black Temperature Ts.

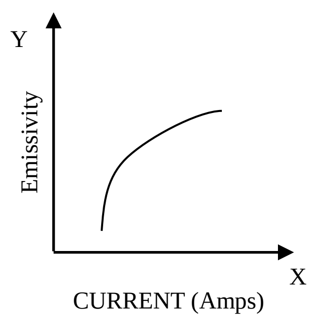
Record the reading VI, I1, V2, I2 with the temperatures and Ta, Repeat the above procedure for various surface temperatures with increasing order.

GRAPH:

Graph is drawn between current and Emissivity.

X-axis - Current

Y-axis - Emmisivity



MODEL CALCULATION:

Heat input to black plate (W_1) $= V_1 I_1$

Heat input to test plate (W_2) $= V_2 I_2$ ($W_1 = W_2$)

Area of plate $= \pi d^2 / 4$

Temperature of black plate Tb $= T_1$

Temperature of test plate Tg $= T_2$

Ambiant température Ta $= T_3$

TABULATION:

Sl.No	Voltmeter	Ammeter	Black plate readings (° C)	Grey plate readings (° C)	Ambient Temp (° C) T_3	Emissivity Σ_P
	V	I	T_1	T_2		
1.						
2.						
3.						

RESULT:

The emissivity of the grey body is________________

DOUBLE PIPE HEAT EXCHANGER
PARALLEL FLOW AND COUNTER FLOW

AIM:

To find the rate of flow of heat transfer, Logarithmic mean temperature difference (LMTD) of the parallel and counter flow heat exchanger.

OBJECTIVE:

To know heat exchanger working and how to increase the cold water temperature and how to reduce the hot water temperature

APPARATUS REQUIRED:

1. Thermocouple with thermal indicator
2. Stop watch

OBSERVATION:

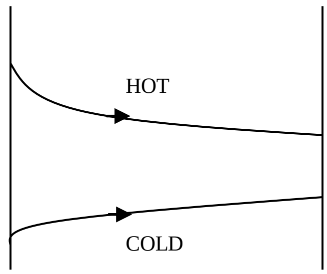
1. Length of heat exchanger = 2 m
2. Inner Tube material :GI
   Outer diameter, d_o = 12 mm
   Inner diameter, d_i = 10 mm
3. Outer Tube material : GI pipe
   Outer diameter, D_o = 33.5 mm
   Inner diameter, Di = 27.5 mm

4. Specific Heat of Water = 4.186 kW/kg K

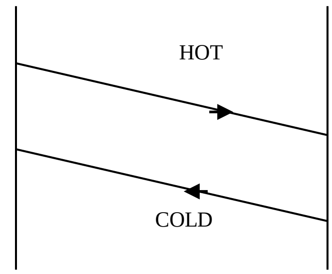
PROCEDURE:

1. Note the initial temperature of water
2. Start the flow of heat in hot water side
3. Arrange the parallel flow arrangement
4. Switch “ON” the electric heater.
5. adjust the flow rate of hot water side with help of valve
6. Keep the flow rate same way, wait for the steady state condition is reached
7. Record the temperature of the hot water side and cold water side and also know flow rate accurately
8. Repeat the experiment in counter flow condition

DIAGRAM:



PARALLEL FLOW



COUNTER FLOW

OBSERVATION TABLE:

Parallel Flow

S.no	Flow rate of hot water (m_h),kg/s	Flow rate of cold water (m_c),kg/s	Hot Water Side Temperature °C		Cold Water Side Temperature °C	
			Inlet(T_{hi})	Outlet(T_{ho})	Inlet(T_{ci})	Outlet(T_{co})

Counter Flow

S.no	Flow rate of hot water (m_h),kg/s	Flow rate of cold water (m_c),kg/s	Hot Water Side Temperature °C		Cold Water Side Temperature °C	
			Inlet(T_{hi})	Outlet(T_{ho})	Inlet(T_{ci})	Outlet(T_{co})

FORMULA USED

1. Heat exchanger rate of hot fluid

   $Q_h = m_h\ C_{ph}\,(T_{hi} – T_{ho})$

   Where

   m_h – Mass flow rate of hot water in kg/hr

   C_{ph} = 4.187 kJ/kg K

2. Heat transfer rate of cold fluid

   $Q_c = m_c\, C_{pc}\,(T_{co} – T_{ci})$

   Where

   m_c – Mass flow rate of cold water in kg/hr

   C_{pc} = 4.187 kJ/kgK

3. LMTD

   for counter flow

$$\Delta T_m = \frac{(T_{hi} – T_{ci}) – (T_{ho} – T_{ci})}{\ln ((T_{hi} – T_{co}) / (T_{ho} – T_{ci}))}$$

   for parallel flow

$$\Delta T_m = \frac{(T_{ho} – T_{co}) – (T_{hi} – T_{ci})}{\ln ((T_{ho} – T_{co}) / (T_{hi} – T_{ci}))}$$

4. Overall Heat transfer coefficient

   $Q = U×A× \Delta T_m$

   Where,

   U_i =based on $A_i = \pi\, d_i\, L$

   U_o =based on $A_o = \pi\, d_o\, L$

5. Effectiveness of the heat exchanger

   €= Q_c / Q_h

RESULT:

Thus the heat transfers rates, Logarithmic mean temperature difference (LMTD) of the parallel and counter flow heat exchanger were determined

DETERMINATION OF COP USING REFRIGERATION TEST RIG

AIM:

To conduct the coefficient of performance test on the refrigeration test rig and to observe the characteristics of refrigeration test rig by using different expansion valves.

APPARATUS REQUIRED:

Stop watch, refrigeration test rig, and thermometer.

FORMULA USED:

Actual cop : Actual refrigerating effect / Power input to the compressor.

: $m_w C_{Pw} \Delta T / t$

m_w : volume of tank x density of water

C_{Pw} : 4.1896 kJ/kg K

Volume of tank: 0.38 x 0.25 x 0.23

Power input : $\dfrac{3600 \times n \times \eta_{compressor}}{1200 * T}$

n : no of revolution in energy meter

$\eta_{compressor}$: 80%

T : time taken for 10 revolutions for compressor in energy meter.

PROCEDURE:

1. First the refrigeration test rig is checked whether every regulator and switch are in off position .
2. The regulator is kept in minimum position and the main is switched on. The regulator for heater is kept in one position and we have to wait for 10 to 20 minutes.
3. The regulator is turned to next position in the similar way. The values are noted. The time taken for compressor is taken separately.

RESULT:

The coefficient and refrigerating capacity of the test rig where calculated.

The actual coefficient of performance (capillary tube expansion valve) = -----------

TABULATION:

For capillary tube expansion valve

Time taken for 10 revs in Energy meter (sec)	Temperature(^{0}C)				Pressure(Kg/cm^2)			
t	$T_{1\ comp\ in}$	$T_{2\ comp\ out}$	$T_{3\ con\ out}$	$T_{4\ expan\ out}$	$P_{1\ comp\ in}$	$P_{2\ comp\ out}$	$P_{3\ con\ out}$	$P_{4\ expan\ out}$

AIR CONDITIONING TEST RIG

AIM:

To find out the co-efficient of performance of the given air conditioning system

APPARATUS REQUIRED:

1. Air conditioning unit
2. Ammeter
3. Voltmeter
4. Stop watch

PROCEDURE:

1. Initially the air condition unit is cleaned and the wet bulb temperature knobs are filled with water(to measure WBT)
2. The air conditioning unit is switched ‘ON’ after measuring WBT
3. The inlet pressure and the outlet pressure of the evaporator and condenser are noted.
4. The initial temperature of the conditional space is noted before starting test rig.
5. After starting the test rig the WBT and DBT of the surrounding and the conditioned space are noted.
6. The ammeter, voltmeter readings and time taken for 10 revolutions of the energy meter are noted.
7. The readings are tabulated.

FORMULA:

1. COP = Refrigeration effect / Work done

2. Refrigeration Effect (RE) = m_{ref} $(h_1\text{-}h_4)$

   Where:-

   m_{ref} – Mass flow rate of refrigerant in kg/sec (1.1212kg/min)

   h_1, h_4 – Enthalpy of refrigerant corresponding to the compressor inlet temperature and evaporator inlet temperature

3. Input power by energy meter method

   Work done = K*3600 / t * c

   Where:-

   K = Number of revolutions of energy meter disc. (5rev)

   t = Time in seconds for 5 revolutions.

   C = Energy meter constant.

4. Mass flow rate of air $m_a = V_a \times \rho$ =0.03724 kg/sec

   Where:-

   V_a – Volume of air delivered (m^3/sec) = 2.9222×10^{-2} m^3/sec

   ρ - Density of air at inlet (kg/m^3) = $P_a / (R_a \times T_a)$ = 1.2743 kg/m^3

5. Capacity of cooling coil = $m_a (h_i - h_o) \times 60/210$

   h_i, h_o – Enthalpy of air corresponding to the air inlet temperature and outlet temperature

OBSERVATION TABLE:

S. No	Ambient condition temperature (˚C)		Conditioned space temperature (˚C)		Condenser pressure		Evaporator pressure		Cooling surface temperature (˚C)	Time taken for 50 rev of Heater (sec)	Time taken for 50 rev of energy meter (sec)
	DBT	WBT	DBT	WBT	INLET	OUTLET	INLET	OUTLET			

RESULT:

Thus the co-efficient of performance of the given air conditioning system was determined. The COP value is-------------

HEAT TRANSFER THROUGH LAGGED PIPE APPARATUS

AIM:

To find the thermal conductivity of the given saw dust in different heat inputs by using lagged pipe apparatus.

OBJECTIVE:

To know how the heat transfer takes place from heater to saw dust through glass wool in a lagged pipe apparatus.

APPARATUS REQUIRED:

1. Heater
2. Glass wool
3. Voltmeter
4. Ammeter
5. Temperature indicator

TECHINICAL SPECIFICATION:

1. Heater rod outer diameter = 200mm = 0.2m
2. Diameter of heater and insulation = 300mm = 0.3m
3. Length of the pipe = 600mm = 0.6m

PROCEDURE:

1. Switch "ON" the unit and check if all channels of temperature indicator showing proper temperature
2. Switch "ON" the heater using regulator keep the power input at some particular value.
3. Allow the unit to stabilize about 20 to 30 minutes note down ammeter, voltmeter reading which gives heat input.

   T_1, T_2, T_3 = Temperature of the inner surface

   T_4, T_5, T_6 = Temperature of at 100mm radius

   T_7, T_8, T_9 = Temperature of the outer surface

4. Repeat the experiment for different input current values.

DIAGRAM:

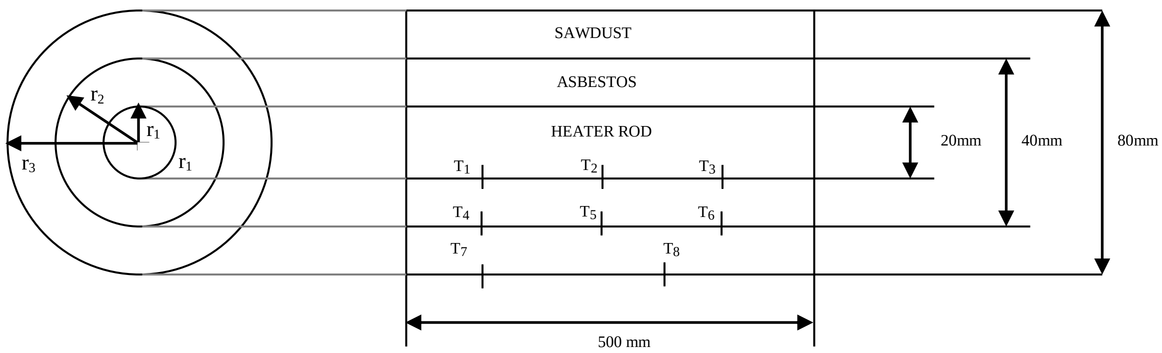


Fig – Lagged pipe apparatus

OBSERVATION TABLE:

S. No	Current I (A)	Voltage V (V)	Heater Temperature (°C)				Asbestos Temperature (°C)				Sawdust Temperature (°C)		
			T_1	T_2	T_3	ΔT_1	T_4	T_5	T_6	ΔT_2	T_7	T_8	ΔT_3
1													
2													
3													

FORMULA USED:

1. $Q = \dfrac{2\pi K_I L(\Delta T_1 - \Delta T_2)}{\ln(R_2/R_1)}$ W/m^2

2. $Q = \dfrac{2\pi K_2 L(\Delta T_2 - \Delta T_3)}{\ln(R_3/R_2)}$ W/m^2

where

k_1 – Thermal conductivity of pipe, W/mK

k_2 - Thermal conductivity of insulation (To Find) W/mK

T_{is} – Average temperature of inner surface = $(T_1 + T_2 + T_3)/3$ °C

T_A - Average temperature at 100mm radius = $(T_4 + T_5 + T_6)/3$ °C

T_{os}- Average temperature of outer surface = $(T_7 + T_8)/2$ °C

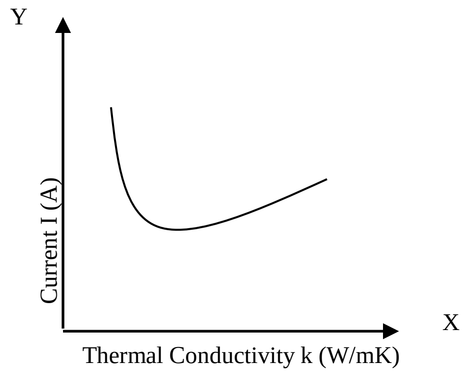
D_1 – Diameter of the heater rod = 20mm

D_2 – Diameter of the asbestos = 40mm

D_3 – Diameter of the saw dust = 80mm

GRAPH:

Graph is drawn between current and thermal conductivity of saw dust. Current (I) is taken in Y-axis and thermal conductivity (k_2) in X-axis.



RESULT:

Thus the thermal conductivity was calculated for the given saw dust in different heat inputs by using lagged pipe apparatus.

THERMAL CONDUCTIVITY OF GAURDED HOT PLATE

AIM:

To find the thermal conductivity of the specimen by slab guarded hot plate.

DESCRIPTION OF APPARTUS:

The apparatus consists of a guarded hot plate and cold plate. A specimen whose thermal conductivity is to be measured is sand witched between the hot and cold plate. Both hot plate and guard heaters are heated by electrical heaters. A small trough is attached to the cold plate to hold coolant water circulation. A similar arrangement is made on the other side of the heater as shown in the figure. Thermocouples are attached to measure temperature in between the hot plate and specimen plate, also cold plate and the specimen plate.

A multi point digital temperature indicator with selector switch is provided to note the temperatures at different locations. An electronic regulator is provided to control the input energy to the main heater and guard heater. An ammeter and voltmeter are provided to note and vary the input energy to the heater.

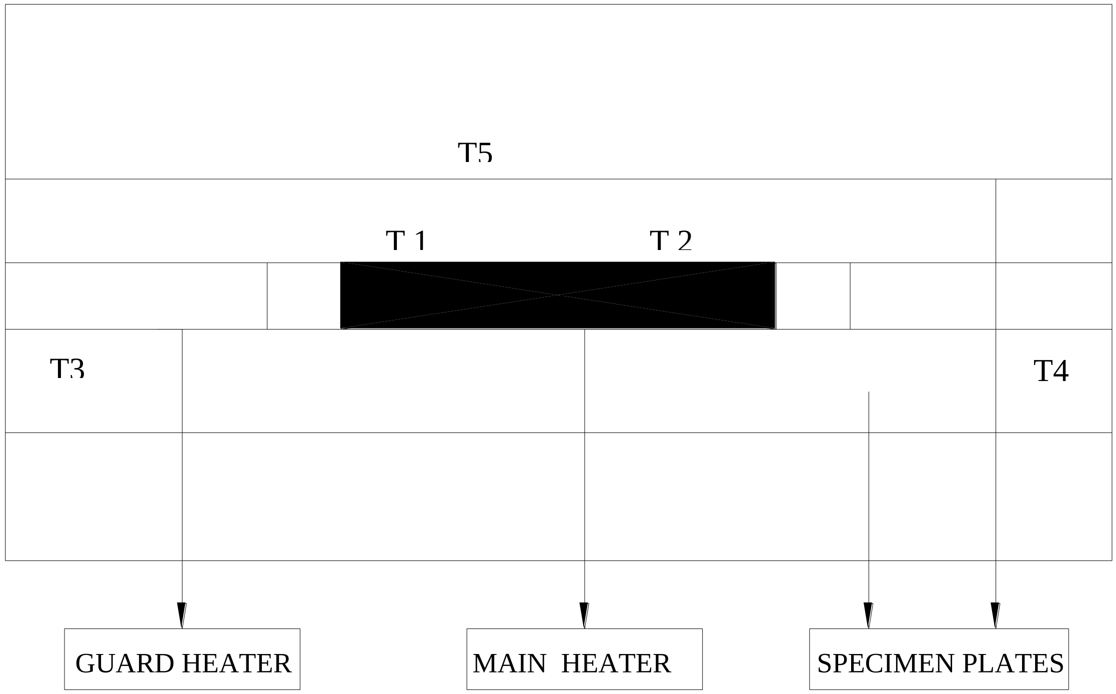
The whole assembly is kept in an enclosure with heat insulating material filled all around to minimize the heat loss.

SPECIFICATION:

Thickness of specimen = 12mm

Diameter of specimen (d) = 15cm

THERMAL CONDUCTIVITY APPARATUS



TABULATION:

Sl. No.	Central heater				Guarded Heater				Cooling plate	
	Voltmeter reading (V)	Ammeter reading (A)	T_1 ^0C	T_2 ^0C	Voltmeter reading (V)	Ammeter reading (A)	T_3 ^0C	T_4 ^0C	T_5 ^0C	T_6 ^0C

FORMULA USED:

Since the guard heater enables the heat flow in unidirectional

$q = KA\ dT/dx$

Where A = surface area of the test plate considered for heat flow

dx = thickness of the specimen plate

dt = average temperature gradient across the specimen

q = Q/2 since the heat flow is from both sides of the heater , watts

$T_h = T_{1+} T_2 / 2$; $Tc = T_5 + T_6 / 2$;

Q = V.I. Watts

Where dx = 12.5mm = 0.0125m

Diameter of specimen

d = 18cm = 0.18m

PROCEDURE:

1. Connect the power supply to the unit. Turn the regulator knob clockwise to power the main heater to any desired value.
2. Adjust the guard heater's regulator so that the main heater temperature is less than or equal to the guard heater temperature.
3. Allow water through the cold plate at steady rate. Note the temperatures at different locations when the unit reaches steady state. The steady state is defined, as the temperature gradient across the plate remains same at different time intervals.
4. For different power inputs is in ascending order only the experiment may by repeated and readings are tabulated as below.

RESULT:

The thermal conductivity of the specimen is found to be ------------- W/mK.

PERFORMANCE TEST ON TWO STAGE RECIPROCATING AIR COMPRESSOR

AIM:

To conduct the performance test on a two stage reciprocating air compressor and to draw the following graphs:

- Delivery pressure VsVolumetric efficiency
- Delivery pressure Vs Isothermal efficiency
-

APPARATUS REQUIRED:

- Stop Watch
- Tachometer

SPECIFICATION:

Diameter of Cylinder D	: 63 mm
Stroke Length of Cylinder L	: 88.9 mm
Coefficient of discharge of orifice	: 0.62
Diameter of orifice D_0	: 10 mm

DESCRIPTION:

The two stage air compressor is a reciprocating type (driven by a AC Motor prime mover) through a belt. The test rig consists of a base on which the tank (air reservoir) is mounted. The outlet of the air compressor is connected to the reservoir. The temperature and pressure of the compressed is indicated by a temperature and pressure gauge. A pressure switch is provided for additional safety. A manometer is provided for measuring pressure difference across the orifice. The input to the motor is recorded by energy meter.

PROCEDURE:

1) Check the manometer connections (fill the manometer with water upto half level)
2) Start the compressor.
3) Close the outlet valve and observe the slowly developing pressure.
4) Slightly ahead of the desired pressure, open and adjust the outlet valves so that the pressure is maintained constant.
5) Note down the readings for different delivery pressures.

FORMULA USED:

Theoretical Volume (V_t):

$$V_s = V_t = (\pi D^2 L N) / 4 \times 60$$

Head (H):

$$H = h (\rho_w / \rho_a)$$

Where, h = manometer difference ($h_1 - h_2$) in m

ρ_w = Density of water = 1000 Kg/m^3

ρ_a = Density of air = 1.293 Kg/m^3

Actual Volume (V_a):

$$V_a = C_d A_o \sqrt{2 g H}$$

Where, C_d = Coefficient of discharge of orifice = 0.62

A_o = Area of orifice in m^2 = $\pi D_0^2/4$

g = Acceleration due to gravity (9.81 m/s^2)

Volumetric Efficiency (η_{Vol}):

$$\eta_{Vol} = \frac{Va}{Vt} \times 100$$

Actual Work:

Actual work = (No. of Impulse x 3600 x 0.8) / (Time x E.M.C)

Where,

No of Impulse = 10

E.M.C = 1600 imp / kW hr.

Isothermal Work:

Isothermal work = $P_a V_a \ln (P_2 / P_1)$

Isothermal Efficiency ($\eta_{Isothermal}$):

$$\eta_{Isothermal} = (\text{Isothermal Work} / \text{Actual Work})$$

TABULATION:

S.No	Reservoir Pressure gauge reading P kgf/cm^2	U – tube manometer reading			Time for 20 pulses of energy meter (sec)
		h1	h2	$h = (h_1 - h_2)$ cm	

MODEL CALCULATION:

RESULT:

Thus the performance test on a two stage reciprocating air compressor was done and the following graphs were drawn.

- Delivery pressure VsVolumetric efficiency
- Delivery pressure Vs Isothermal efficiency
- Delivery pressure Vs Adiabatic efficiency