MJCET

MECHANICAL ENGG. DEPARTMENT

THERMAL ENGINEERING LABORATORY MANUAL

Prepared by NASEEMA.

ME 431

THERMAL ENGINEERING LAB

Instruction	3 Periods per week
Duration of University Examination	3 Hours
University Examination	50 Marks
Sessional	25 Marks

1. Determination of COP of the Air Conditioning system.
2. Determination of percentage relative humidity and study of humidiiication and dehumidification process in Air Conditioning systems.
3. Determination of COP of Refrigeration systems using capillary tube/thermostatic expansion valve.
4. Determination of overall efficiency of centrifugal blower.
5. Determination of overall efficiency of axial flow fan.
6. Pressure distribution on symmetrical and non-symmetrical specimen in wind tunnel
7. Measurement of lift and drag force of the models in wind tunnel test section.
8. Determination of thermal conductivity of metal bar.
9. Determination of the efficiency of pin-fin subjected to natural and forced convection.
10. Determination of effectiveness of heat parallel flow and counter flow heat exchanger.
11. Determination of emissivity of given test plate.
12. Determination of Stefan-Boltzman constant

THERMAL ENGG. LABORATORY

INDEX

LIST OF EQUIPMENT

1. Low speed wind tunnel
2. Centrifugal blower test rig
3. Axial flow fan test rig
4. Refrigeration and air conditioning test rig
5. Emissivity test rig
6. Pin fin apparatus
7. Stefan-Boltzmann apparatus
8. Thermal conductivity apparatus
9. Heat exchanger apparatus.
10. Refrigeration test rig.

LABORATORY SAFETY RULES AND PRECAUTIONS

1. Clothing should be appropriate for working in the laboratory. Jackets, ties, and other loose garments should be removed. Ideally, dress for lab should include long pants and shoes which cover the entire foot.
2. Carefully follow directions, both written and oral. Do only the steps described in the procedure of the experiment or that are described and approved by the Course Coordinator. If you are in doubt about any procedure, ask your Lab Instructor for help.
3. Students should be familiar with the location of emergency stop button to turn off all electrical power for emergency.
4. Please check wiring connections before switching on the power.
5. Electric extension boards must be kept away from water source
6. Do not overload the AC power.
7. Do not use electric adaptor.
8. Compressed gas cylinders must be kept away from heat source.
9. Keep flammable and combustible materials away from open flames.
10. Extreme caution should be used when using a Bunsen burner. Keep your head and clothing away from the flame and turn off the burner when it is not in use. Long hair should be tied back to avoid it catching on fire. If your clothing catches fire, stop, drop, and roll while your lab partner notifies the lab instructor.
11. Handle toxic or Exhaust gases only under the directions of the Lab Instructor.
12. Students should never interfere the original computer configuration or setup: BIOS setup, Windows Operating System setup, Files and Directory created, etc.
13. Unauthorized copying of software, or using illegally copied software is strictly Forbidden.
14. Please turn off heater or soldering iron after use.
15. Check to see that all gas valves and hot plates are turned off.
16. When an experiment is completed, always clean equipment and return it to the proper place and clean your lab table.
17. Keep insoluble waste material out of the sink. Dispose of waste material as instructed by your Lab Instructor.
18. Students are liable for any damage to equipment due to their own negligence.
19. Never handle broken glass with your bare hands. Use a brush and dustpan to clean up broken glass. Dispose of the glass as directed by your Lab Instructor. Record and report all breakage or loss of apparatus to your Lab Instructor.
20. Report immediately to the laboratory Instructor if any injury occurred.
21. In case of emergency, please evacuate as soon as possible.
22. Wash hands thoroughly with soap and water before leaving the lab.

1.VAPOUR COMPRESSION AIR CONDITIONING SYSTEM

Aim: To determine COP (coefficient of performance) of the vapour compression refrigeration system using air-conditioning test rig.

Description: The vapor compression refrigeration system consists of a compressor, an air cooled condenser, an expansion device (a thermostatic expansion valve and a capillary tube are provided of which one can be used at a time), a rotameter (to measure the flow rate of liquid refrigerant R-22), a filer drier and an evaporator. A fan flower is arranged across the evaporator coil and the coil/fan assembly is incorporated inside a ply wood chamber of a give cross-section and dimensions to provide the refrigerant at various points and also a digital temperature display. Pressure gauges are provided to measure the pressure on the suction side of the compressor and also the discharge side of the compressor. Pressure gauges are also provided to measure the pressures at the condenser outlet and the evaporator inlet.

Refrigeration and air conditioning test rig

Working: The theoretical vapour compression cycle consists of the following processes.

1-2 Reversible adiabatic compression from saturated vapour to a superheated condition.

2-3 Reversible heat rejection at constant pressure (desuperheating and condensation of the refrigerant).

3-4 Irreversible isentropic expansion in the throttle valve/expansion valve.

4-1 Reversible heat addition (evaporation) at constant pressure.

But the actual cycle differs from the theoretical vapour compression cycle due to practical considerations. During evaporation or refrigerating effect in the evaporator, pressure remains constant but here is drop in the pressure, and superheated low-pressure. Vapour enters the compressor. Consideration process in the condenser does not occur at constant pressure but there is drop in pressure. The variation in actual vapour compression cycle from the standard vapour compression cycle is due to frictional resistance to flow through the ducts, and due to the compression process not being isentropic.

Procedure:

1. Start the system by opening the corresponding valves depending on thermostatic expansion valve or the capillary expansion device.

2. Take all the necessary precautions regarding the power supply.

3. Let the system stabilize.

4. Record T_1, T_2, T_3 and T_4 and also P_1, P_2, P_3 and P_4 and the rotameter reading corresponding to the refrigeration system.

Observation:

	P_1 (psi)	P_2 (psi)	P_3 (psi)	P_4 (psi)	T_1 (psi)	T_2 (psi)	T_3 (psi)	T_4 (psi)	Time Taken For 5 rev	Volume Flow Rate(V) Lpm	COP
Capillary Tube											
Thermostatic Expansion Valve											

Calculations:

1. Using (P_1, T_1), (P_2, T_2), (P_3,T_3) and (P_4, T_4) find the values of enthalpy from pressure enthalpy chart for R-22.

H_1= KJ/kg.

H_2= KJ/kg.

H_3= KJ/kg.

H_4= KJ/kg.

2. Energy meter constant = 1800 rev/KW –hr.

Time taken for 5 rev, t = _____________ sec.

Energy consumed by fan = $\frac{(5x3600)}{(1800\,x\,t)} = \frac{10}{t}kW$

3. Volume flow rate of refrigerant (measured from rotameter) $= V\,\frac{10^{-3}}{60} = \_\_\_\_\ m^3/\sec.$

Density of R-22 liquid at condition or stage 3 (from chart), = ______ kg/m^3.

Mass flow rate of refrigerant m = V x p kg/sec.

4. Net refrigeration effect in k W=m ($h_1 - h_4$) KW.

5. Compressor power consumption = m ($h_2 - h_1$) KW.

$$COP = \frac{Net\ refrigeration\ effect}{Work\ done\ on\ the\ system}$$

$$= \frac{Net\ refrigeration\ effect}{(Compressor\ power\ consumption + condensor\ fan\ power\ consumption)}$$

Result:

1. COP of Vapour compression cycle using capillary tube = _______.

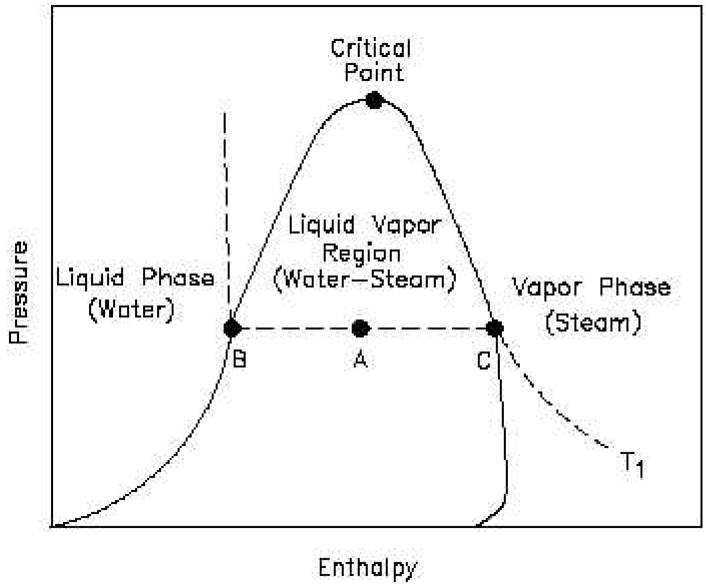
2. COP of Vapour compression cycle using thermostatic expansion valve = ______.

2. VAPOUR COMPRESSION REFRIGERATION SYSTEM

Aim: To determine COP (coefficient of performance) of the vapour compression refrigeration system using Refrigeration test rig.

Refrigeration test rig.

Thermodynamics Cycle on P-h Chart



1-2 Compression of refrigerant from low pressure low temperature to high pressure and high temperature.

2-3 Condensation of high pressure and temperature of saturated /superr heated vapour to liquid at high perssure

3-4 Constant enthalpy process in throttling valve or capillary tube- expansion of high pressure liquid refrigerant to low pressure liquid vapour mixture temperature decreases

4-1Vaporisation of refrigerant in evaporator at constant lower pressure cooling of atmosphere or surroundings take place due to absorpting latent heat in vopourisation

PROCEDURE:

Switch on the mains and console

Keep either thermostatic expansion valve or capillary tube open. When capillary tube is open , thermostatic expansion valve shoulkd be closed and vice versa.

Wait for 5 minutes and note the temperature

T_1 to T_5 and pressure P_1 and P_2

T_1 = Temperature at compressor inlet (°C)

T_2 =Temperature at compressor outlet (°C)

T_3 =Temperature at condensor outlet (°C)

T_4 =Temperature at evaporator outlet (°C)

T_5 =Temperature inside freezer (°C)

P_1=Pressure upstream of the compressor(kg/cm^2)

P_2 = Pressure downstream of the compressor(kg/cm^2)

Note power input to the compressor

	P_1 (Kg/cm^2)	P_2 (Kg/cm^2)	P_3 (Kg/cm^2)	P_4 (Kg/cm^2)	T_1 (C)	T_2 (C)	T_3 (C)	T_4 (C)	COP
Capillary Tube									
Thermostatic Expansion Valve									

COP=Amount of heat extracted in refrigeration

$$COP = \frac{Net\ refrigeration\ effect}{Work\ done\ on\ the\ system}$$

$$= \frac{Net\ refrigeration\ effect}{(Compressor\ power\ consumption + condensor\ fan\ power\ consumption)}$$

Result and conclusions:

1. COP of Vapor compression cycle using capillary tube = _______.

2. COP of Vapors compression cycle using thermostatic expansion valve = ______.

3.AIR CONDITIONING TEST RIG

Aim: To determine the percentage relative humidity and percentage change in humidification and dehumidification in air conditioning system.

Air conditioning test rig

Evaporator duct

Apparatus: Air conditioning test rig, water heater and air heater.

Description: Relative humidity: It is defined as the ratio of actual mass of water vapor in a given volume to the mass of water vapor if air is saturated at same temperature.

Heating and humidification: Addition of water vapor to the air is termed as humidification of air, these can be possible by sending the steam over the air stream by which air temperature and specific humidity increases. Heating and dehumidification: Removal of water vapor from air is termed as dehumidification of air. Dehumidification of air is only possible if air is cooled below dew point temperature of air. It is necessary to maintain coil temperature below dew point temperature of air for effective dehumidification.

Procedure:

1. Start the system by opening the corresponding valves depending on thermostatic expansion valve or capillary expansion devices
2. Take all the necessary precautions regarding the power supply.
3. Let the system stabilize
4. Note inlet temperatures t_{dbt1},t_{wbt1}
5. Using formula and saturation temperature calculate percentage relative humidity Φ
6. For humidification fill water in a pressure cooker up to 1/3 level and allow 10 min for steam to produce.Allow steam in the duct and note outlet cinditions of air using wet bulb and dry bulb thermometers t_{dbt2},t_{wbt2}
7. Find the percentage raise in humidity by using formulas and saturated tables.
8. For dehumidification switch on the heater,allow unit to stabilize and note the temperatures t_{dbt3},t_{wbt3}
9. Find the drop in temperatures and Φ.

Observation:

	Humidification	Dehumidification
Inlet temp.		
Outlet Temp.		

Calculations:

Percentage Relative humidity $\Phi = P_v/P_{vs}$

Where P_v = water vapor pressure at t_{dbt1}, t_{wbt1} is calculated using Carriers equation.

$P_v = (P_{vs})_{wbt1} - [P_t - (P_{vs})_{wbt}][t_{db}-t_{wb}]/[1547-1.44\ t_{wb}]$

Specific humidity $= \omega = 0.622 \times P_v/[P_t-P_v]$

P_t = total pressure of air

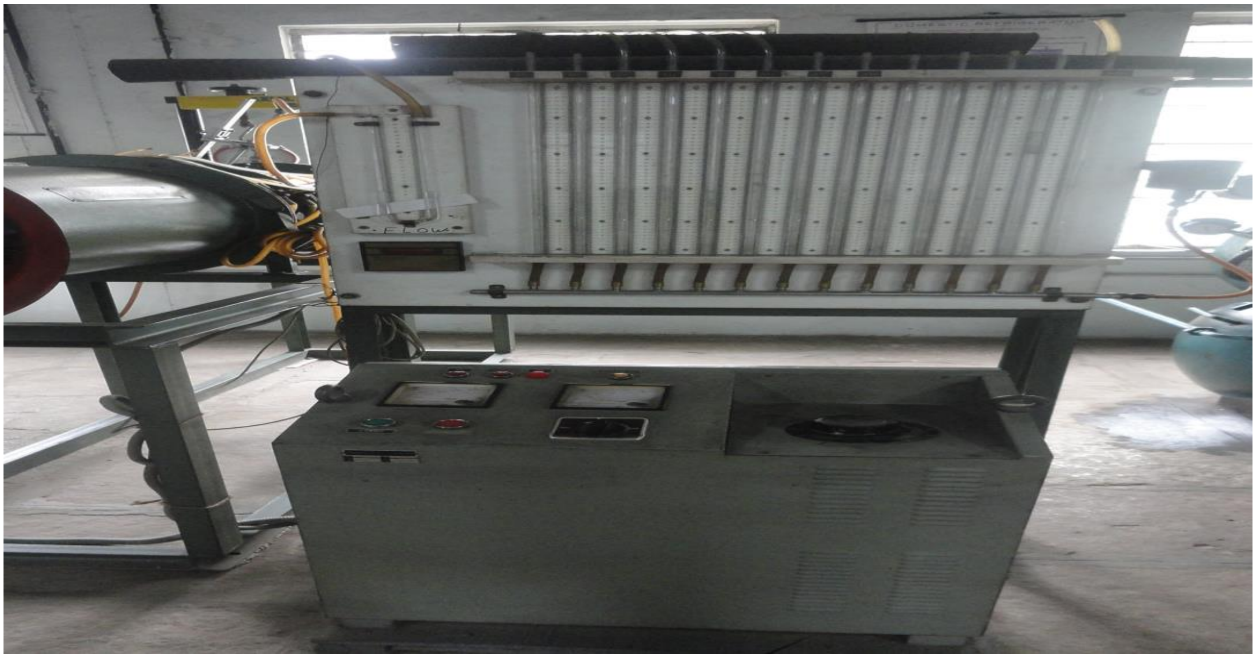
Percentage rise in humidity = $[W_1-W_2]/W_1$

Percentage of dehumidification =

Result and discussions.: Percentage rise relative humidity and Percentage drop in humidity is determined.

4.AXIAL FLOW FAN

Aim: To study the performance characteristics of an axial flow fan at different load vane settings.



Axial flow fan test rig

Specifications:

The various specifications of the fan are

1. Fan blades – 8 (aerofoil section).
2. Speed – 0 to 2800 rpm
3. Inlet and outlet guide vanes – flat plate cross section.
4. Load vanes – 0^o (fully open) to 90^o (fully closed)
5. Pressure taps at tip and hub at different locations.

Description:

The axial flow fan test rig consists of a ducted fan having 8 blades of aerofoil section. The diameter of the duct is constant throughout with a bell-mouthed only section to avoid flow separation. Guide vanes are provided before and after the fan (rotor). Upstream and downstream of the fan, pressure taps are provided at the tip and the hub to study the pressure variation. At the inlet, a pitot-static tube is provided to measure the dynamic pressure and can be arranged across the cross section of the duct. An S-type (Stausheib) probe can be arranged in the radial direction just upstream or downstream of the rotor. The fan is driven by a 5 hp DC motor whose speed can be varied smoothly from 0 to 2800 rpm with the help of thyristor control drive. The motor is provided with extended pressure arms and a spring balance for measurement of motor torque and hence the power output. A non-contact type tachometer gives the speed of the motor on a digital display unit.
An axial flow fan is one in which the flow of air is substantially parallel to the axis of the rotor.Axial flow fans do not develop considerable rise in pressure compared to centrifugal fans.However, they are suitable for applications where a high quantity of air is to be discharged.

An axial flow fan in its simplest from consists of a rotor having a momentum from the blades to the fluid and results in an increase in the stagnation pressure of the fluid.The tip of the rotor blades, which are commonly of aerofoil section, run with as fine a clearance as is practicable in the casing. As compared to a curved sheet, an aerofoil can apply greater force to the fluid, thereby causing more pressure rise and can maintain better efficiency over a wide range of volumetric flows. The primary component of blade force on the fluid is directed axially from inlet to outlet and thus provides the pressure rise by a process that may be called direct blade action. The blade force necessarily has an additional component in the tangential direction providing the reaction to the driving torque; this sets the fluid spinning about the axis independence of its forward motion.Throttling of the flow can be done with the help of load vanes. The head developed by the fan decreases with increasing discharge. However, at certain intermediate values of discharge there is a dip in head developed due to formation of a high vorticity region downstream of the blades.

Procedure:

The inlet and outlet guide blade angles are set at the desired values with the help of bolts provided for each blade. The fan is made to rotate at the desired speed. The speed is noted with the help of a digital rpm indicator. The pressure heads at points 1,2,3 and4 are noted both at tip and at the hub, with the help of muti-tube manometer. The free stream velocity is found using the dynamic pressure measured by the pitot static tube. As the velocity is not uniform after the inlet guide vanes and after the rotor, it is necessary to measure the velocity at many points from the hub to the tip, with the help of which the mean velocity across the duct is found. As the space between the guide vanes and rotor blades is small, it is not possible to insert a pitot-static tube there; hence an S-type tube is used to measure the dynamic pressure at these locations. The mean velocity across the duct, computed from the velocity distribution is multiplied with the cross sectional area of the duct to get the discharge through the duct. The reading of the spring balance provided for measuring the motor load, is noted down. The output of the motor is then calculated. The power output of the motor is the power input to the fan. The rise in pressure head across the fan is found with the help of pressure tappings at the tip and hub before and after the fan rotor. The power output of the fan is calculated from the values; fully open 3/4th open, ½ open, 1/4th open and fully closed and all the parameters are noted. The power input, power output and the efficiency of the fan are calculated at all the load vane settings.

Observation:

S.No	Speed/Load Vane setting/ Guide vane setting	Spring Balance Load (kg)	(cm of water column)									Static Pressure Rise across fan (h_1-h_2)
			H_{1T}	H_{1h}	H_{2T}	H_{2H}	H_{3T}	H_{3H}	H_{4t}	H_{4H}		

01												
02												
03												
04												
05												

S.NO.	Flow rate (Q) (m^3/sec)	Input Power (KW)	Out Power (KW)	Efficiency

Calculations:

Spring balance reading = W kg
Motor Speed = N rpm

1. Input Power (I/P) = $\frac{2\pi NT}{60000}$ kW

T = W x R. (N-m)

Where

W = Load.

R = Radius = 200 mm = 0.2m

2. Output (o/p) = (ρg Q ΔH)/ 60000 KW.

3. Q = Discharge = A x V_{mean} m_3/s.

A = Area of cross section,

Duct Dia = 415 mm.

V_{mean} = Mean Velocity across section

$P_o - P = \frac{1}{2} x \rho_{air} x V^2$ mean

Where $P_o - P = \rho_w \, x \, g \, x \frac{(h_1 - h_2)}{100}$ m.

$(h_1\text{-}h_2)$ = Static pressure rise across the fan.

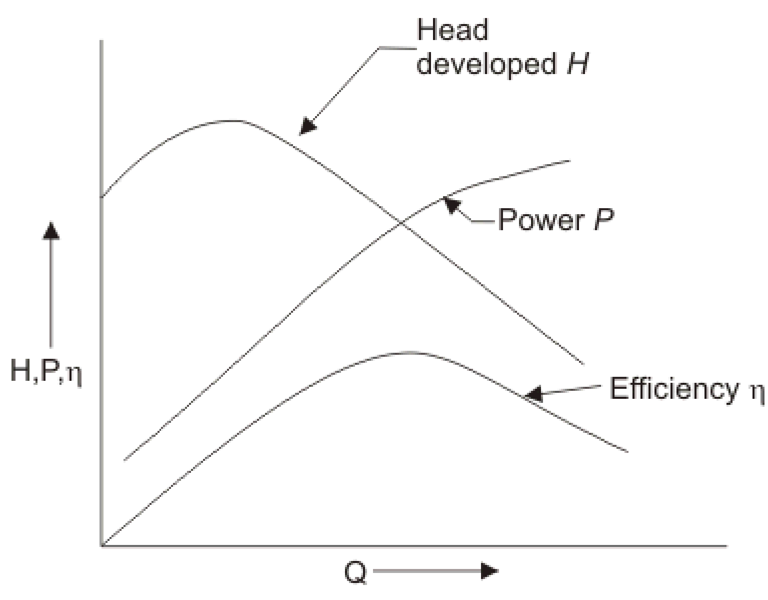
$V_{mean} = \sqrt{\ }(P_o\text{-}P) \times 2 / \rho_{air}$ m/s.

4. Pressure head rise across the fan, ΔH= $[(H_{3T}+H_{3h}) - (H_{2T}+H_{2h})]/200$ m of water

ΔH air $=\rho_w \times \Delta H / \rho_{air}$

5. $\eta_{fan} = \frac{o/p}{i/p}$

Sample graph:



1. Discharge Vs η_{fan}
2. Discharge Vs Static head across the fan.

Result and conclusins:
The Performance characteristics of an axial flow fan at different load setting are_______________.

5. CENTRIFUGAL BLOWER

Aim: To draw the performance characteristics of a centrifugal blower.

Centrifugal blower test rig

Description:

1. Duct (2) Impeller (3) Casing (4) Static Pressure taps

5. Pitot static (6) Shift motor / torque Dynamoter

Figure shows the schematic of the blower test rig, the main components are blower-motor unit and control console.

The blower motor unit essentially consists of centrifugal blower driven by DC motor; the whole unit is mounted on heavy frame work. No foundation is necessary is necessary for installation of the duct test rig. The outlet to the blower is a straight duct of size 150mm x 400mm and 200mm length and is fixed with cove type valve at outlet. The Pitot tube tappings across, duct are connected to digital velocity indicator the tapping for static pressure measurement is also provided at the wall of the duct and connected to double column water manometer and digital head indications.The pressure distribution tapping points on the periphery of blower casing are made at 6-equiangular positions of 60o. these positions are connected to digital head indicator through 6-channel selector switch.The DC motor body frame is mounted on T union bearing which swivels on application of load/torque on the motor.The torque thus developed is transmitted to the spring balance and load cell to the torque indicator.The speed pick up is provided for the measurement of rpm of blower and connected to digital rpm indicator in front of the control console.The control console consists of thyristor speed controller digital speed indicator, digital load and flow velocity indications through transducer for flow and head measurement. Manometer for head (static pressure rise), power meter for electrical input measurement of the motor, the necessary means of indicator and switch is provided for complete instrumentation.

<u>Observation</u>:

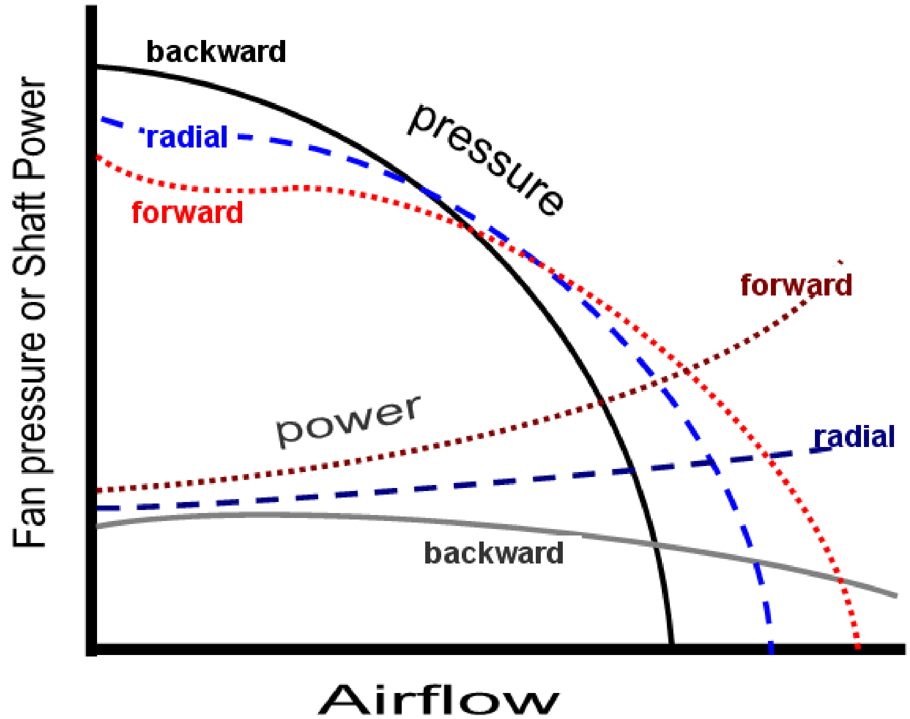
Load Vane Settting	Blower Speed (rpm)	Spring Load (kg)	Static Pressure Head [H] (mm)	Flow Pressure Head (mm) [Po-P]	V air	Q = a x V_{air}	Input Power I/P=	Output Power O/P =	$n = \frac{O/P}{I/P}$

Procedure:

Complete test rig and control console instrumentation are readily connected it is enough to observe the following.

1. Connect the input power for console to 3 Phase AC supply with neutral and earthing.
2. Keep all the switches and control off.
3. Switch on the mains and observe the light indicators are on beneath the console.
4. Switch the console main on.
5. Switch on the instruments.
6. Keep the inlet and valves open fully.
7. Switch on the DC drive so that the motor speed built upto constant rpm.
8. Null balance the torque arm using hand wheel.
9. Take down the readings, namely blower speed, flow head, power meter readings, casing pressure distribution as per the table.
10. Repeat the experiment for different orientation of loading vanes and different type of impeller.
11. Prepare table for calculations using the formulae given in section.

The performance characteristics curves are given by.



(a) Q Vs O/P (b) Q Vs Efficiency. (c) Q Vs H

Experiment is repeated by varying the following parameter independently load vane setting.

Formulae:

1. $p = \frac{1}{V} = \frac{p}{RT}$

2. $P_o - P = \frac{1}{2} pV^2$

3. Q = a x V.

4. Input Power = $= \frac{2\pi NT}{60,000} kW$

5. Output (o/p) = (ρg Q ΔH)/ 60000 KW.

Result and conclusins:

The Performance characteristics ofcentrifugal blower at different load setting are______________.

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6.PRESSURE DISTRIBUTION OVER SYMMETRICAL and ASYMMETRICAL AEROFOIL BLADES

Aim: To study the pressure distribution over a Symmetrical and Asymmetrical aerofoil blades at different angle of attack using a low speed wind tunnel.

Apparatus: Low speed wind tunne1, Symmetrical and Asymmetrical aerofoil blades and compass.

Low speed wind tunnel test rig

Procedure:

1. Fix the symmetrical aerofoil blade in the test section.
2. Connect pressure tubes coming from the multi tube manometer to steel tube extension of the aerofoil blade.
3. Keep the speed controller knob at ‘0’.on the mains and switch on the console.
4. Now rotate the speed controller know slowly in the clock wise direction and set the required velocity of air flow.
5. Note down the static pressure developed at test section.
6. Repeat the experiment at different angle of attack and with Asymmetric blade.

Observation:

1. Velocity = __________ m/s (Symmetrical Aerofoil)

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P8(mm) P_{13}
$\alpha =$													
C_p													
$\alpha =$													
C_p													
$\frac{X}{C}$	0.05	0.20	0.35	0.50	0.70	.090	0.90	0.70	0.90	0.35	0.20	0.05	

Formulae:

Co-efficient of pressure $C_p(1) = \frac{(P\infty - P_1)/\sqrt{2}}{(P_o - P_1)}$

$P\infty =$ connected to tunnel static pressure.

P_i = Pressure at different point i.e. P_1, P_2 ……………. P_{12}.

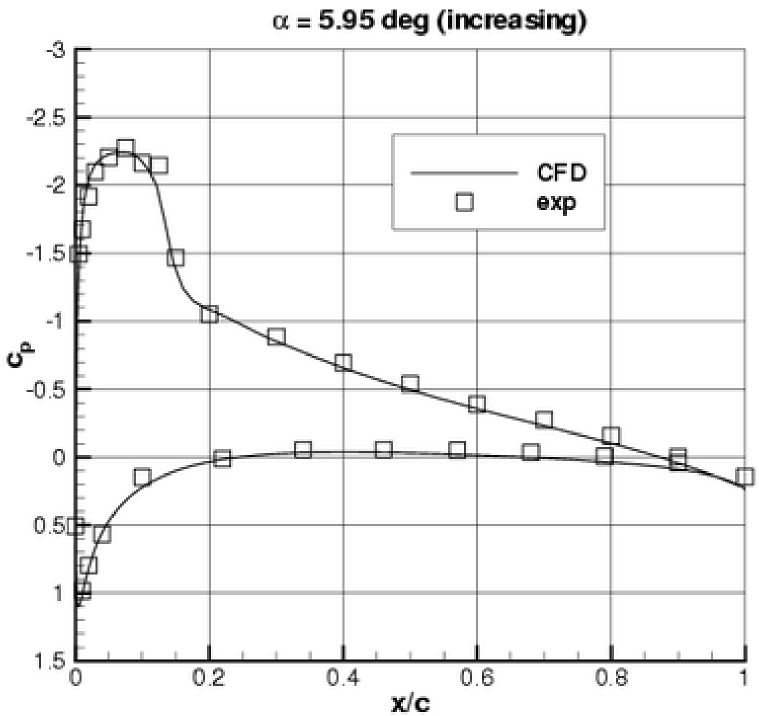
$P_o - P_i = \frac{1}{2} x \rho airx V^2$ air pa

$= \frac{1}{2} x \rho airx V^2$ air x 10.3 x 10^{-2} mm of water.

ρair = Density of air = 1.16 kg/m^2.

V_{air} = Velocity of air m/s.

Graph:



$\frac{X}{C}$ location Vs Co-efficient of pressure (C_p).

Result: Pressure distribution over a symmetrical and Asymmetrical aerofoil blade at different angle of attack using low speed wind tunnel are studied and co-efficient of pressure at different locations are __________________

7.PIN FIN APPARATUS

Aim: To conduct a heat transfer test in the given apparatus and to determine the heat transfer co-efficient and fin efficiency through Natural and Forced convection methods of the Pin Fin section.

Pin fin apparatus

SPECIFICATION:

Size of the main heating block = 50 mm diameter x 50 mm thick.
Diameter of fin = 11.2 to 8.7 mm taper.
Average diameter of the fin =10 mm.
Length of the fin = 165 mm.
Heat capacity = 50 watts approx.
System efficiency = 69%

Thermocouple sensor positions = 1 –Air inlet
2-7 Pin Fin Taper Section
8 Air outlet.

Air Circulation Duct size = 172 x 172 x 645 mm long (outer Dimensions).
= 168 x 168 x 645 mm long (Inner Dimensions).

Thermocouple sensors at 25, 50, 75, 100, 125 and 150 mm distance from the main block inner edge.

PROCEDURE:

1. Start the electric supply and give input to heating system.
2. Keep the dimmerstat at ‘0’ position while starting and is to be increased gradually.
3. Allow few minutes to get the system in steady state.
4. Experiment can be conducted either on Natural Convection method or Force Convection method.
5. In Natural Convection method experiment, do not operate the fan and take readings on Natural air draft method.
6. In Forced Convection method, keep the fan at any desired air velocity by varying the knob and take reading of temperature and velocity of air using Anemometer.
7. Once the experiment is over, the system must be put ‘OFF’ i.e. power supply must be isolated, and the system must be allowed to cool down.

OBSERVATION:

(Free Convection)

S.No	Voltmeter (V)	Ammeter (Amp)	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_m	T_a	h_{exp}	h_{th}	η_{fin}

Formulae:

(Free Convection)

Pin surface mean temperature (T_m) $= \dfrac{T_2 + T_3 + T_4 + T_5 + T_6 + T_7}{6}$

$= \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ {}^{o}C$

Ambient air temperature = $T_a = \dfrac{T_1 + T_8}{2}$ ${}^{o}C$

Area of heat transfer (As) = πdL = _______________ m^2.

Where d = Average diameter of pin fin in meters.

L = Length of the pin fin in meters.

Heat Transfer Rate (Q) = V x I x η_{system} = ________ W

a). Heat Transfer Coefficient (Experimental) = h_{exp} (Free Convection)

$$= \frac{Q}{A_s(T_m - T_a)} = \_\_\_\_\_\_\_\_\_\_ \text{ W/m}^2\text{K}$$

b). Heat Transfer Coefficient (Theoretical) = h_{th} (Free Convection)

Film temperature == $T_f = \frac{T_m + T_a}{2}$ = _________ K

Grashoffs Number (Gr) = gβl^{3}ΔT/ɣ ^{2}

Where,

G= 9.81 m/s2

$\beta = \frac{1}{T_f} K^{-1}$

ΔT = T_m-T_a =___K

L = Length of fin.

From Heat and Mass Transfer Data Book at film temperature get the values of

a). Kinematic Viscosity (v) = ________ m^2/s.

b). Prandtl Number (Pr)=

c). Thermal Conductivity (K) = _________ W/m K.

Using relation for Nusselt Number (Nu)

Nu = 0.15 (Gr x Pr) $^{0.25}$

= __________________

Therefore, Theoretical Convective Heat Transfer Co-efficient is

$H_{th} = \frac{Nu \times K}{d}$ =_______ W/m^2 K.

d is the Average diameter of Pin fin.

Fin Efficiency $\eta_{fin} = \frac{\tanh(mL)}{mL}$

<u>Observation</u>

Forced Convection

SNO	Voltmeter (V)	Ammeter (Amp)	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_m	T_a	h_{exp}	h_{th}	η_{fin}

CALCULATION:

Forced Convection

Pin surface mean temperature $(T_m) = \dfrac{T_2 + T_3 + T_4 + T_5 + T_6 + T_7}{6}$

Ambient air temperature = $T_a = \dfrac{T_1 + T_8}{2} =$ _____ °C.

Area of heat transfer (As) = $\pi dL =$ ____ m^2.

Where d= Average diameter of pin fin in meters.
L = Length of the pin fin in meters.

Heat Transfer Rate (O) = V x I x n = W

a). Heat Transfer Coefficient (Experimental) = hexp (Forced Convection).

$$h_{exp} = \frac{Q}{A_s(T_m - T_a)} = \_\_\_\_\_ \; W/m^2K .$$

b). Heat Transfer Coefficient (Theoretical) = h_{th} (Forced Convection).

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

Nu = _________

Where,

$$Re = \frac{V\,d}{v}$$

V = Velocity of air in m/s.
D= Diameter of Pin Fin.
v = Kinematic viscosity in m^2/s.

Therefore Convective Heat Transfer Coefficient (h_{th}) = $\dfrac{Nu\,K}{d} =$ _________ W/m^2K

Nu = Nusselt Number
K = Thermal Conductivity
d = Average diameter of pin fin in meters.

RESULT:

Convection Heat Transfer Coefficient and Fin Efficiency are determined for both free and forced convection.

Free Convection	Forced Convection
h_{exp} = ________ $W/m^2\ K$	h_{exp} = ________ $W/m^2\ K$
h_{th} = ________ $W/m^2\ K$	h_{th} = ________ $W/m^2\ K$
$\eta_{\text{fin(exp)}} =$ ______	$\eta_{\text{fin(exp)}} =$ ______
$\eta_{\text{fin(th)}} =$ ______	$\eta_{\text{fin(th)}} =$ ______

8. HEAT EXCHANGER

Aim: To conduct a Heat Transfer test on the given apparatus and to determine the effectiveness of the Heat Exchanger.

Description:

The apparatus consists of a set of concentric tube type pipes in which hot fluid is hot water, which is obtained from an electric geyser and it flows through the inner tube while the cold fluid is cold water flowing through the annulus when the equipment is uses as a parallel flow and counter flow apparatus. The hot water flows from the top of the condenser and air from the air duct fan is made to flow in perpendicular direction to the water flow when the equipment is used as cross flow heat exchanger.

SPECIFICATIONS:

1. Inner Tube Material - (Copper) ID = 12.7 mm.
   OD = 15.9 mm.

2. Outer Tube Material - (GI) ID = 34.3 mm.
   OD = 42.4 mm.

3. Length of the Heat Exchanger, L = 1640 mm.

4. Geyser Heater capacity = 3 x 3000 watts.

5. Thermocouple Sensors: 2 Nos at Hot water line.
   2 Nos at cold water line.

6. Temperature Indicator Digital 12 channels
   0-400 ^oC 'J' Type.

7. Hot water line flow - 175 lph (max)

8. Cold water line flow - 400 lph (max).

9. Water circulation: By self priming pump with less than 0.2 kg/cm^2 operating pressure.

Procedure:

1. Observing all the precautions, switch ON the pump and adjust the water inlet flow to both cold water end as well as hot water end at desired flow levels and ensure free flow from the outlet ends provided. Select the mode of flow i.e. PARALLER or COUNTER through proper selection of valves.
2. Switch ON the Heater by upward push of the MCB switch. Ensure power supply between 210-240 volts. Below 210 volt or above 240 volts may damage the heater element and there by make the apparatus unfit for experiment.
3. Adjust the flow rate on hot water side, between ranges of 0.5 to 2.5 l/min.
4. Adjust the flow rate in cold water side between ranges of 1.0 to 3.0 1/min.
5. Allow the apparatus to run for some time say 5-10 minutes to get the hot water flow become steady, keeping the hot and cold water flow rate at constant levels. Observe the four temperatures and note down the readings once the steady state is reached. if the temperature fluctuations are within 2^{o}C then it shows that steady state is reached.
6. Record the temperature at hot water and cold water side and also the flow rate accurately.
7. Repeat the experiment with second mode as PARALLEL or COUNTER flow arrangement under identical flow rate conditions.
8. After completing the experiment with PARALLEL and COUNTER flow, conduct the experiment on CROSS FLOW and note the reading of temperature of water and air.

Observation:

Parallel Flow:

I. Temperature.

1. Hot water inlet temperature - $T_{hi} = T_1 =$ _______________ ^oC.
2. Hot water outlet temperature – $T_{ho} = T_2 =$ _______________ ^oC.
3. Cold water inlet temperature – $T_{ci} = T_3 =$_______________ ^oC.
4. Cold water outlet temperature – $T_{co} = T_4 =$ _______________ ^oC.

II. Mass flow rate of Water.

1. At Hot water outlet = $m_h =$ _____ 1ph or lps.
2. At cold water outlet = $m_c =$ _____ 1ph or lps.

Counter Flow:

I. Temperature.

1. Hot water inlet temperature – $T_{hi} = T_1 =$ _______________ ^oC.
2. Hot water outlet temperature – $T_{ho} = T_2 =$ _______________ ^oC.
3. Cold water inlet temperature – $T_{ci} = T_3 =$_______________ ^oC.
4. Cold water outlet temperature – $T_{co} = T_4 =$ _______________ ^oC.

II. Mass flow rate of Water.

1. At Hot water outlet = $m_h =$ _____ 1ph or lps.
2. At cold water outlet = $m_c =$ _____ 1ph or lps.

Cross Flow:

1. Hot water inlet temperature - $T_{hi} = T_1 =$ _______________ ^oC.
2. Hot water outlet temperature – $T_{ho} = T_2 =$ _______________ ^oC.
3. Cold water inlet temperature – $T_{ci} = T_3 =$_______________ ^oC.
4. Cold water outlet temperature – $T_{co} = T_4 =$ _______________ ^oC.

Calculation:

A). **For PARALLEL FLOW Operation:**

1. LMTD = Logarithmic Mean Temp Difference.=

$$\frac{[T_{hi}-T_{ci}]-[T_{ho}-T_{co}]}{\ln\frac{T_{hi}-T_{ci}}{T_{ho}-T_{co}}}$$

Area of inner copper tube = $A=\pi DL\ m^2$
D = ID of copper

2. Heat Transfer Rate, 'Q' is calculated as.

Q_h = Heat Transfer Rate through the Hot Water.
= $m_h\ C_{ph}\ (T_{hi} – T_{ho})$ Watts.

Q_c = Heat Transfer Rate through the Cold Water.
= $m_c\ C_{pc}\ (T_{co} – T_{ci})$ Watts.

Q_a = Average Heat Transfer Rate of water $=\frac{(Q_h+Q_c)}{2}$ Watts

3, The Overall Heat Transfer Coefficient (U).= $Q_a/A\ \Delta T_m$ =__________ W/m² K

4. Effectiveness

$$C=\frac{\text{Actual Heat Transfer Rate}}{\text{Maximum Possible Heat Transfer Rate}} = \frac{m_c\ C_{pc}\ (T_{co}-T_{ci})}{C_{min}\ (T_{hi}-T_{ci})}$$

Where,
m_h = Mass flow rate of Hot Water.
mc = Mass Flow rte of Cold Water
C_{ph} and C_{pc} are specified heat of Hot and Cold Water

C_{min} = Capacity Rate of the fluid (Hot or Cold), which have minimum value of m_h x C_{ph} or m_c x C_{pc}

Note: Cmin = mh x C_{ph} or C_{min} = m_c x C_{pc} (which ever is smaller).

B). For COUNTER FLOW Operation:

1. LMTD = Logarithmic Mean Temp Difference

$$\Delta T_m \frac{[T_{hi}-T_{ci}]-[T_{ho}-T_{co}]}{\ln\frac{T_{hi}-T_{ci}}{T_{ho}-T_{co}}}$$

Area of inner copper tube = $A=\pi DL\ m^2$
D = ID of copper

2. Heat Transfer Rate, 'Q' is calculated as.

Q_h = Heat Transfer Rate through the Hot Water.
= $m_h\ C_{ph}\ (T_{hi} – T_{ho})$ Watts.

Q_c = Heat Transfer Rate through the Cold Water.

$= m_c\, C_{pc}\, (T_{co} - T_{ci})$ Watts.

Q_a = Average Heat Transfer Rate of water

$= \frac{(Q_h + Q_c)}{2}$ Watts

3, The Overall Heat Transfer Coefficient (U).).= $Q_a/A\, \Delta T_m$ =__________W/m^2 K

4. Effectiveness

$$C = \frac{\text{Actual Heat Transfer Rate}}{\text{Maximum Possible Heat Transfer Rate}} = \frac{m_c\, C_{pc}\, (T_{co} - T_{ci})}{C_{min}\, (T_{hi} - T_{ci})}$$

Where,

m_h = Mass flow rate of Hot Water.

mc = Mass Flow rte of Cold Water

C_{ph} and C_{pc} are specified heat of Hot and Cold Water

C_{min} = Capacity Rate of the fluid (Hot or Cold), which have minimum value of m_h x C_{ph} or m_c x C_{pc}

Note: Cmin = mh x C_{ph} or C_{min} = m_c x C_{pc} (which ever is smaller).

.

RESULT:

Effectiveness of PARALL and COUNTER Flow Heat Exchanger are ______________.

9. EMISSIVITY MEASUREMENT OF RADIATING SURFACES

Aim: To determine the emissivity of gray surface

.

Emissivity test rig

Description: The experimental set up consists of two circular brass plates of identical dimensions. One of the plates is made black by applying a thick layer of lamp black while the other plate whose emissivity is to be 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 undistributed 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. 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	: Brass
Specimen Size	: ¢150 mm, 6 mm thickness (gray and black body)
Voltmeter	: Digital type, 0-300 v
Ammeter	: Digital type, 0-3 amps
Dimmerstat	: 0-240 V, 2 amps
Temperature Indicator	: Digital type, 0-300^{o} C, K type
Thermocouple used	: 7 nos
Heater	: Sand witched type Nichrome heater, 400 W

Procedure:

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

Observation:

S.NO	Heater Input			Temperature of black surface ^{o}C			Temperature of gray surface ^{o}C.			Chamber Temperature ^{o}C
	V	I	VxI Watts	T_1	T_2	T_3	T_4	T_5	T_6	T_7

Formulae:

1. Temperature of the black body
   $$T_b = \frac{(T1 + T2 + T3)}{3} + 273.15\,K$$
2. Temperature of the gray body
   $$T_g = \frac{(T4 + T5 + T6)}{3} + 273.15\,K$$
3. Ambient temperature
   Ta = (T_7 + 273.15) K
4. Heat input to the coils = V x I watt
5. Emissivity of gray body,
   $$E_g = (T^4 b - T^4 a) / (T^4 g - T^4 a)$$

Results and conclusions:

Emmisivity of grey body is____________

10. STEFAN BOLTZMAN APPARATUS

Aim: To determine the Stefan Boltzman constant using Stefan-Boltzman Apparatus.

Stefan Boltzman test rig

Description:

The apparatus consist of small sized precision test source hating element and fully black power coated hemispherical shell. Test source heating element is rigidly fitted at the centre.The nucleus of the hemispherical shell and the whole assembly is mounted on a heat resistant Hylam sheet with radiation leak proof gasket. The heating radiation is transferred to the upper surface of the hemispherical shell and the absorbed radiation temperature is measured through the thermo couple sensors fitted at suitable locations while the heat transmission to the bottom surface of the plates are blocked by the highly insulating material.The temperature measured by the thermocouple sensors are brought to the temperature indicators through a silver wafer selector switch. The bottom surface of the heater is highly insulated for maximum heat radiator.

SPECIFICATION:

Effective Test source surface = 41 mm in Diameter.

Effective Hemispherical surface = 310 mm inner diameter.
(326 mm outer diameter)

T_1 = Test source temperature.

T_2, T_3, T_4 and T_5 = Inner Hemispherical Temperature

Max current / load = 0.38 A @ 230 Volts.

Heat capacity = 20 watts (approx)

Maximum safe operating voltage = 60 V.

System efficiency = 59%

PROCEDURE:

1. Switch on the main supply
2. Adjust the voltmeter and Ammeter with the help of dimmerstat.
3. After reaching steady state Note down the Voltmeter, Ammeter and Temperature reading and tabulate it.

OBSERVATION:

S.NO	VOLTS (V)	CURRENT (Amps)	T_1 (ºC)	T_2 (ºC)	T_3 (ºC)	T_4 (ºC)	T_5 (ºC)	$T_m = \frac{T2+T3+T4+T5}{4}$	$\sigma = \frac{Q}{A(T_s^4 - T_M^4)}$

CALCULATION:

Q = Rate of heat transfer in Radiation.

= V * I * n (watts).

$T_1 = T_S$ = Temperature of test source = ___________ K.

$T_m = \frac{T2 + T3 + T4 + T5}{4}$ = Average Hemisphere temperature. = _______________K

$A = \frac{\pi (d)^2}{4}$ =__________ m^2 (Area of the Test Source).

Where d = diameter of the test source in meters.

$$\sigma = \frac{Q}{A(T_s^4 - T_M^4)} \qquad (W/m^2\ K^4)$$

σ = Stefan boltzman constant.

RESULTS:

The value of Stefan Boltzman constant is _________________

11.THERMAL CONDUCTIVITY OF METAL ROD

Aim: To conduct a heat transfer test in the given apparatus and to determine Thermal Conductivity of given materials.

Thermal conductivity apparatus

Specification:

Solid Rod (Aluminium)	Solid Rod (Brass)	Hollow Rod (Stainless steel)
Dia of the metal rod = 75 mm		Inside diameter = 35 mm Outside diameter = 45 mm
Length of metal rod = 81mm		Length of Rod = 262 mm
T_1, T_2 and T_3 = Inlet heat thermocouple sensors	T_8= Inlet water temp T_9 = outlet water temp	Water jacket = OD 75 mm x 71 mm x 225 mm long
T_4, T_5, T_6, T_7 = Outlet heat thermocouple sensors		T_8 and T_9 = Inlet and outlet temp of the water.
Maximum current / Load = 0.86 amps @ 230 volts, n_{sys} = 76%	n_{sys} = 72%	Water Rotameter = 60-180 LPH.
Heater capacity = 100 watts		

Apparatus:

The experimental set up consists of a solid metal rods and hollow rod. For solid rods the one end is heated by an electric heater while the end is free to atmosphere. For hollow rod one end of which is heated by an electric heater while the other end of the bar projected inside the cooling water jacket.

Procedure:

1. Start the electric supply and give input to the heater by slowly rotating the dimmer stat and adjust it to voltage equal to 0V, 50V, 70V etc (for solid aluminum rod) and 220 V to (Hollow stainless steel).
2. Experiments can be conducted in either on Natural convection method for solid rods and by forced convection method for hollow rod.
3. For metal rod 1, tabulate the reading of temperatures at constant intervals of time san 10 or 15 min, by putting ‘ON’ the system. Immediately switch OFF on entering the reading.
4. For metal rod 2, tabulate the reading of temperature of water inlet and outlet after 15 min by putting ON the system. Immediately switch OFF on entering the reading.
5. Fore Hollow rod, tabulate the readings of temperature of water inlet and outlet after 15

CALCULATIONS:

Solid Rod 1:

Thermal conductivity (K) = $\dfrac{Q}{A x \dfrac{dt}{dx}}$ W/m°C

Where

Q = V x I x n_{sys} = ______________ watss

Area (A) = $\dfrac{\pi}{4} x d^2$ = _________________ Sq mts

Temperature Difference (dT) = $\dfrac{(T_1 + T_2 + T_3)}{3} - \dfrac{(T_4 + T_5 + T_6 + T_7)}{4}$ = _________________ °C

d x = length of the rod = ______ mm.

Solid Rod 2:

Thermal conductivity (K) = 110.7 x n = ____ W/m°C

Where

Efficiency (n) = output / input = ______________ %.
Output = m_w x C_{pw} x ΔT= ____________ kW.
m_w = mass of water in seconds = _____ (kg/s).
C_{pw} = Specific heat of water = _________ (kJ/kgK)
$\Delta T = T_9 - T_8$ = ___________ °C.
Input = Q = V x I X n_{sys} = ________ kW

Results and Conclusions:
Thermal conductivity of metal rod 1 and metal rod 2 are _____________

12. MEASURE LIFT AND DRAG FORCE OF MODELS IN WIND TUNNEL TEST SECTION.

Aim: The determine lift and drag forces acting on an aerofoil blade.

Low speed wind tunnel test rig

Introduction:

In this experiment, we will use a wind tunnel to explore the effect of lift and drag on an airfoil. A fluid flowing past a body, in this case an airfoil has a force exerted on it. Lift is defined to be the component of this force that is perpendicular to the oncoming flow direction. The drag force is the opposite of lift, which is defined to be the component of the fluid-dynamic force parallel to the flow direction. We will explore how the angle of attack changes the amount of lift the airfoil experiences. The angle of attack (α) is the angle between flow and the chord line. The chord line is a straight line between the most forward point and most aft point of the body. We will also study the effects of velocity on lift, if the angle of attack is kept constant and velocity increased we would expect an increase in lift. We will measure the airfoil lift as a function of velocity. The drag coefficient (C D) and lift coefficient (CL) are functions of dimensionless parameters such as Reynolds number (Re), Mach number (Ma), Froude number (Fr) and relative roughness of the surface (ε/l). The lift and drag coefficients are mostly dependent on the shape of the airfoil,we use a symmetrical airfoil and a non-symmetrical airfoil. The shapes play a huge role on the amount of lift and drag generated and will be seen in this experiment. In order to be able to use equations (1),(2) and (3) the velocity needs to be known. This is done by using a pitot-static tube which will be able to make a pressure gradient measurement and then by using the Bernoulli's equation calculate velocity

Notation

V: Velocity

C_L: Coefficient of Lift

CD: Coefficient of Drag

ρ: Density

A_S: Surface Area

l: Span (Airfoil Width)

c: Chord (Airfoil Length)

z: Height

γ: Specific Weight

The lift is a function of dynamic pressure, surface area and lift coefficient as shown in Equation (1).

$L = 1/2\ \rho V^2 A_s\ C_L$ (1)

The drag is a function of dynamic pressure, surface area and drag coefficient as shown in Equation (2).

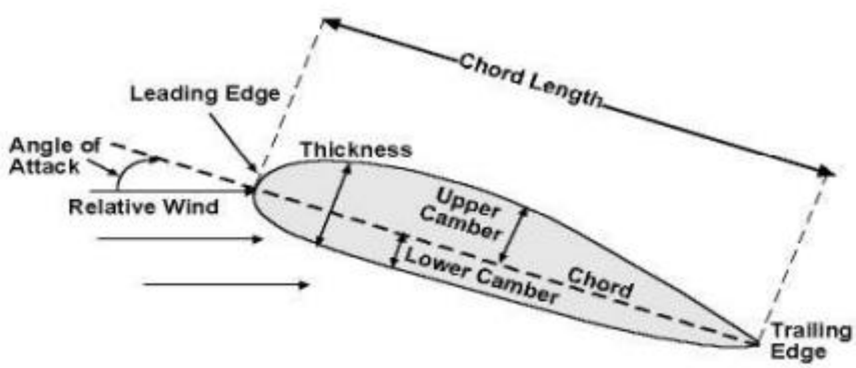
$D = 1/2\ \rho V^2 As C_D$ (2)

Dynamic Pressure is shown in Equation (3)

. $Pd = 1/2\ \rho V^2$

Surface Area (As) is a function of the chord and span and is shown in Equation (4).

$A_S = c$l



Airfoil Nomenclature

Bernoulli's Equation is a function of pressure, density, velocity and specific weight and is shown in Equation (5).

$$P_1 + \frac{1}{2}\rho V_1^2 + \gamma z_1 = P_2 + \frac{1}{2}\rho V_2^2 + \gamma z_2 \tag{5}$$

Assuming if $z_1 = z_2$, meaning the heights are at the same level then the equation can be written as Equation (6) which then can be rearranged into Equation (7) which is the velocity along the streamline.

$$\Delta P = \frac{1}{2}\rho V^2 \tag{6}$$

$$V = \sqrt{2\frac{\Delta P}{\rho}} \tag{7}$$

Table 1: Lift Calibration Table

Applied Mass (g)	Meter Output (mV)

Table 2: Drag Calibration Table

Applied Mass (g)	Meter Output (mV)

<u>Results and conclusions:</u>

Lift and drag forces are calculated and are as follows: ________