MJCET

MECHANICAL ENGG. DEPARTMENT

APPLIED THERMODYNAMICS AND HEAT TRANSFER LABORATORY MANUAL

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MP 331

APPLIED THERMODYNAMICS AND HEAT TRANSFER LAB

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

1. Applied Thermodynamics
2. Determination of Valve/Port timing diagram of an IC engine
3. Determination of Performance characteristics of a multi-cylinder petrol engine
4. To conduct Morse test on multi cylinder petrol engine
5. Determination of Performance characteristics of two-stroke petrol engine
6. To conduct performance test on a variable compression ratio petrol engine
7. To conduct performance test on diesel engine
8. To determine volumetric efficiency, isothermal efficiency of multi-stage reciprocating air compressor
9. Heat Transfer
10. Determination of Thermal conductivity of metal bar
11. Determination of convective heat transfer coefficient under Natural/Forced convection phenomena
12. Determination of Heat transfer coefficient in parallel and counter flow heat exchanger.
13. Determination of Emissivity of a given plate.
14. Determination of the value of Stefan-Boltzman constant.
15. Determination of thermal conductivity of composite wall

APPLIED THERMODYNAMICS & HEAT TRANSFER LABORATORY

Subject: **ATD & HT LAB** Course code: MP 331

Class : B.E.III/IV PRODUCTION

S.No.	Name of the Experiment
	Applied Thermodynamics Experiments
1	Determination of Valve /Port timing diagram of an IC engine.
2	Determination of performance characteristics of a multi-cylinder petrol engine.
3	To conduct Morse test on multi cylinder petrol engine.
4	To conduct performance test on single cylinder Diesel engine under different compression ratios
5	To conduct performance test on diesel engine.
6	To determine volumetric efficiency, isothermal efficiency of a two stage reciprocating Air compressor.
	Heat Transfer Experiments
7	Determination of Thermal Conductivity of metal bar.
8	Determination of convective heat transfer coefficient under Natural/Forced convection phenomena.
9	Determination of Heat transfer coefficient in parallel and counter flow heat exchanger.
10	Determination of Emissivity of a given plate.
11	Determination of Stefan- Boltzman constant.
12	Determination of thermal conductivity of composite wall.

APPLIED THERMODYNAMICS & HEAT TRANSFER LABORATORY

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7. Pin fin apparatus
8. Heat exchanger apparatus
9. Emissivity Apparatus
10. Stefan-Boltzmann apparatus
11. Composite wall apparatus

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. VALVE TIMING DIAGRAM FOR A 4-STROKE SINGLE CYLINDER VERTICAL DIESEL ENGINE

Aim: To draw the valve timing diagram of the given 4-stroke single cylinder vertical diesel engine.

Description: The given engine is a single cylinder vertical 4-stroke Diesel Engine. The inlet and exhaust valves are operated with the help of cams on the camshaft. A fuel injector is present to start the combustion process.

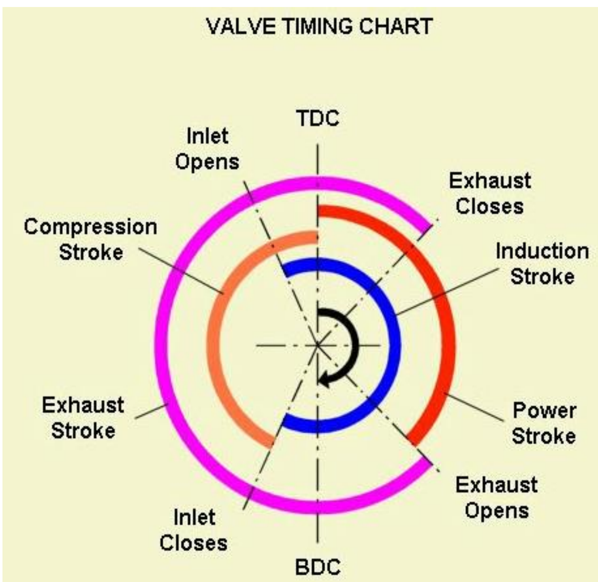
Procedure: The flywheel of the engine is rotated by hand in clock wise direction. The TDC and BDC positions are marked on the flywheel. Then the flywheel is slowly rotated from TDC position. The inlet valve will start opening just before the end of exhaust stroke or before the starting of suction stroke i.e, just before TDC. This can be checked by the slackness of the push rod. During the suction stroke the inlet valve remains open and then it gradually starts closing. The inlet valve is completely closed after the start of the compression stroke. Before the end of the compression stroke, Fuel is injected into the cylinder chamber by means of fuel injector and this indicates the start of ignition process and the fuel injector and this indicates the start of ignition process and fuel injector moves back after sometime and when the piston starts moving down indicates the end of ignition process. After the compression stroke, the expansion stroke starts (piston comes down) during expansion stroke (or it opens before the start of exhaust stroke). The exhaust valve closes after the start of suction stroke. This can be checked by the slackness of the push rod. All the corresponding angles in degrees can be directly read form the protractor which is fixed to the fly wheel. The degrees are then represented in the diagram as the crank angle.

The diagram which shows the position of crank of four stroke cycle engine at the beginning and at the end of suction, compression, expansion, and exhaust of the engine are called as Valve Timing Diagram. The extreme position of the bottom of the cylinder is called “Bottom Dead Centre” [BDC]. The position of the piston at the top of the cylinder is called “Top Dead Centre” [TDC]. In an ideal engine, the inlet valve opens at TDC and closes at BDC. The exhaust valve opens at BDC and closes at TDC. The fuel is injected into the cylinder when the piston is at TDC and at the end of compression stroke. In an actual engine, the inlet valve begins to open 5°C to 20 °C before the piston reaches the TDC during the end of exhaust stroke. This is necessary to ensure that the valve will be fully open when the piston reaches the TDC. If the inlet valve is allowed to close at BDC, the cylinder would receive less amount of air than its capacity and the pressure at the end of suction will be below the atmospheric pressure. To avoid this the inlet valve is kept open for 25° to

40°after BDC. Exhaust valve opening and closing Complete clearing of the burned gases from the cylinder is necessary to take in more air into the cylinder. To achieve this exhaust valve is opens at 35° to 45° before BDC and closes at 10° to 20° after the TCC. Because of this both inlet valve and exhaust valve remains in open for some angle. The crank angles for which the both valves are open are called as overlapping period. This overlapping is more than the petrol engine.

For Diesel engines the fuel valve opens at 10° to 15 °before TDC and closes at 15° to 20° after TDC. Evaporation of the fuel will be difficult, if all the fuel is supplied at once. This is because better evaporation and mixing fuel.

In case of petrol engine, Ignition of the fuel occurs 35^0 before TDC, this is to allow the time delay between the spark and the commencement of combustion. For high speed engines, higher values of angles are desirable to take into account the short time interval. Different engines/ vehicles use different valve timings.



Valve timing diagram for four stroke engine

Observation

T.D.C to I.V.O = ________________ Suction Angle = Degrees

T.D.C to EVC = _________________ Compression Angle =

B.D.C to I.V.C = ________________ Power stroke =

B.D.C to E.V.O = ________________ Expansion Stroke =

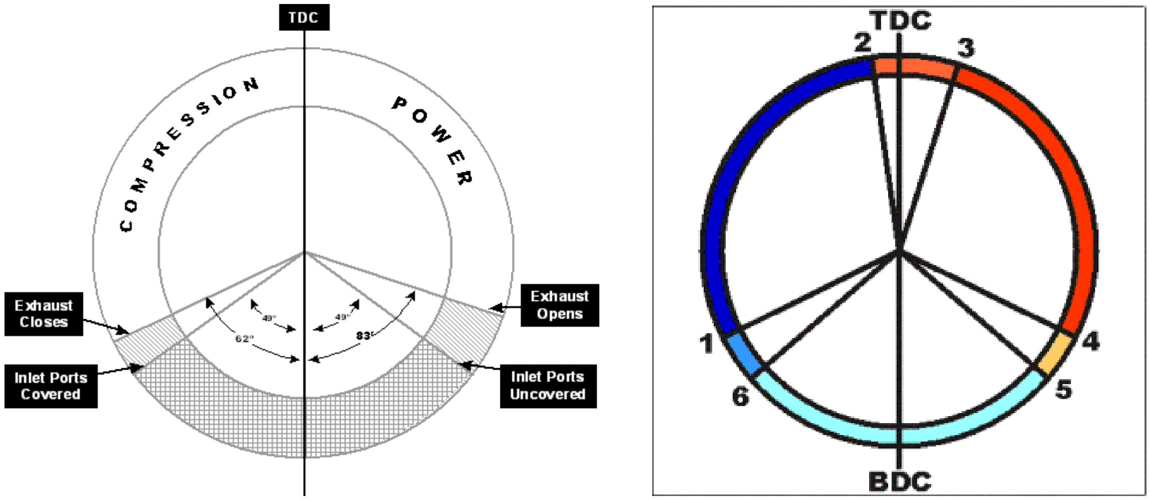
Start of Ignition = _______________ Ignition Angle =

End of Ignition = ________________ Angle of Overlap =

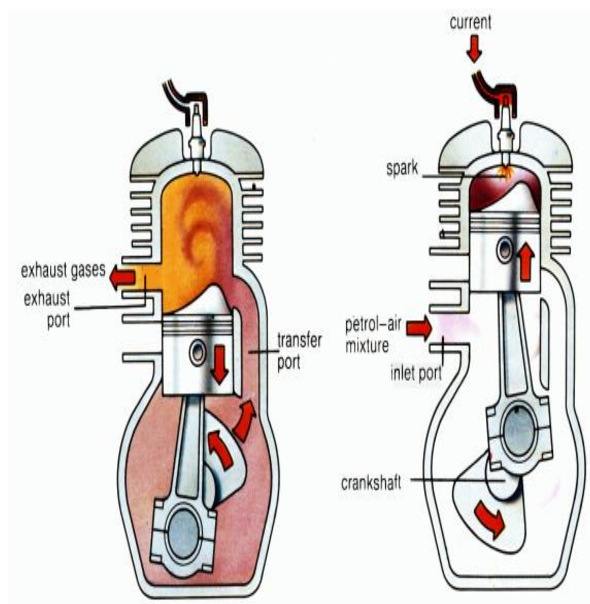
Angle of Overlap=________________

Conclusion: Opening of inlet valve is less than the opening of exhaust valve.

Port timing diagram



Port timing diagram for two stroke engine



2. PERFORMANCE TEST ON 4-S, 4 CYLINDER PETROL ENGINE (MPFI)

Aim: To conduct a performance test on the given 4-S, 4 cylinder water cooled petrol engine.

Specification of the Engine:
Bore & Stroke = 84 mm x 82 mm

Rated Power Output = 75 HP at 5000 RPM

Orifice diameter = 25 mm

Arm length = 0.358 m.

Description of the Test Rig:

The test rig consist of 4-S, 4 cylinder petrol. Engine (water cooled) is coupled to Hydraulic dynamometer. The different Hydraulic loading is achieved by operating the hand wheel on the dynamometer. Exhaust gas calorimeter is provided with Rota meter. Separate cooling water line is provided to the engine with Rota meter. The whole instrumentation is mounted on self-contained unit ready for table operation.

Procedure:

1. Check the petrol in petrol tank and switch on the console.
2. Observe all the indicators in ‘ON’ position and allow cooling water to flow through engine.
3. Allow petrol and start the engine keeping the load in minimum position.
4. The engine is set to the required speed by operating speed regulator knob provided on the control panel.
5. Apply load to the engine by operating the hand wheel on the Hydraulic Dynamometer.
6. Adjust the speed regulator to any desired speed, and note down the corresponding values.
7. Increase the load on the engine by operating hand wheel on the hydraulic Dynamometer.
8. Now the speed of the engine decreases, attain the normal speed by adjusting the load without adjusting the throttle valve, and note down the corresponding readings again.
9. Repeat the experiment for 4 to 5 loads and tabulate the readings and perform calculation for various parameters.
10. Note down all the readings and repeat the experiment for different loads by cutting off the other cylinders one at a time.

Observations:

S.no	Load W (kg)	Engine Speed (rpm)	Fuel consumption for 2 min.(kg/min)	Manometer Reading (h_1-h_2) cm
1				
2				
3				
4				
5				

Calculations:

1. Brake Power (BP) = $\frac{2\pi NT}{60000}$ kW

   T = W x R (Load x Arm Length) N-m

   R = 0.358 m.

   W = (Load in kg x 9.81) N.

2. Total Fuel Consumption per min (TFC, kg / hr).

   TFC = m_f x 60 kg/hr

   m_f = mass of fuel consumed per min.

3. Specific Fuel Consumption (SFC).

   SFC = $\frac{TFC}{BP}$ kg / kW-hr

4. Brake Thermal Efficiency.

   $$\eta_{Bth} = \frac{BP \times 60}{m_f \times CV}$$

   CV for petrol = 44100 kJ/ kg.

5. Volumetric Efficiency (η_{vol})

   $$\eta_{vol} = \frac{V_a}{V_{th}} \times 100\%$$

   V_a = C_d x A x $\sqrt{2gh}$ m^3/s.

   Where Cd = Coefficient of discharge = 0.62

   $A = \frac{\pi d^2}{4}$ Where d = diameter of orifice = 25 mm

$$H = \frac{h_2 - h_1}{100} \text{ x } \frac{\rho_{water}}{\rho_{air}}$$

Where ρ_{water} = 1000 kg/m^3, ρ_{air} = 1.293 kg/m^3.

V_{th}(Theoretical Volume)= $n \text{ x } \frac{\pi D^2}{4} \text{ x } L \text{ x } \frac{1}{2} \text{ x } \frac{N}{60}$ m^3/s

Where n = number of cylinders, D = Inner Diameter of cylinder or Bore (D) = 80 mm, Stroke (L) = 82 mm

Hence, $\eta_{vol} = \frac{V_a}{V_{th}} \text{ x} 100\%$

6. Air Fuel Ratio (A/F).

$$A / F = \frac{m_a}{m_f}$$

Where m_a = V_a x 60 x ρ_{air} kg/min., m_f = mass of fuel consumed per minute.

Table of Calculation:

S.no	Speed (rpm)	Fuel Consumed (kg/hr)	Air Consumed (kg/hr)	A/F	SFC Kg/KW-hr	BP (KW)	η_{Bth} %	η_{vol} %
1								
2								
3								
4								
5								

Graphs:

1. BP Vs SFC.
2. BP Vs η_{vol}
3. BP Vs η_{Bth}

Conclusions: The Performance Characteristics of a 4-Stroke, 4 cylinder MPFI Petrol Engine are determined.

3. MORSE TEST ON 4-S, 4 CYLINDER MPFI PETROL ENGINE

Aim: To measure the indicated power and mechanical efficiency of multi cylinder four stroke petrol engine by Morse test.

Specifications: Type: 4 cylinder, 4-stroke, water cooled petrol engine (Hindustan Motors), Bore: 84 mm, Stroke: 82 mm, arm length(R) = 858 mm, Power and compression ratio: 9:1.

Description:

The engine is a 4 stroke, 4 cylinder, water cooled petrol engine. The output shaft is connected in a hydraulic dynamometer through a flexible coupling and the brake power is determined by running the engine at the required speed. The fuel inlet is connected to engine in raises with water tank.

The purpose of Morse Test is to obtain the Indicated Power and the mechanical efficiency of a multi-cylinder engine. During the test the engine is run at a constant speed and at same throttle opening. First the BP. of the engine with all cylinders operative is measured by means of dynamometer. Next, the BP. of the engine is measured with each cylinder rendered inoperative one by one by shorting the spark plug (Cutting off the power supply to the spark plug) in case of petrol engine (by cutting off the fuel supply in case of diesel engine).

When one cylinder is cut off, power developed is reduced and speed of engine falls. Accordingly, the load on the dynamometer is adjusted so as to restore the engine speed. This is done to maintain FP constant, which is considered independent of the load and proportional to the engine speed. The observed difference in BP between all cylinders firing and with one cylinder cut off is the IP of the cut off cylinder. Summation of IP of all the cylinders would then give the total IP of the engine under test.

Procedure

1. The engine is started by self starter.
2. The engine is allowed to run and the dynamometer water flow is regulated such that the rpm of the engine is constant.
3. The fuel flow rate, dynamometer reading, air flow rate readings are noted.
4. Cut off one cylinder and adjust the load such that the speed becomes to its original value and readings are noted
5. The difference in the output is a measure of the indicated power of the cutoff cylinder.
6. Repeat the experiment by cutting off remaining cylinders one by one.

Precautions:

(i) The BP should be measured as soon as possible after making cylinder inoperative. (ii) The dynamometer load should be adjusted soon to bring the speed to its constant value for the test otherwise the engine may race. In order to plot IP, BP and η_m series of tests should be conducted at predetermined engine speeds because BP varies with load and speed.

Observation and Tabulations

S.no.	Cylinder Condition	Engine Speed-N rpm	Load -kg	BP- kW	IP- kW
1	All cylinders are firing			BP=	IP=
2	First cylinder cut off			BP_1=	IP_1=
3	Second cylinder cut off			BP_2=	IP_2=
4	Third cylinder cut off			BP_3=	IP_3=
5	Fourth cylinder cut off			BP_4=	IP_4=

Calculations:

1. When all cylinders are firing, total brake power

$$BP = \frac{2\pi NT}{60x10^3} kW$$

T = (load in kg x 9.81) x arm length(R)
Where R = 0.358 m

2. B.P. when first cylinder is cut off

   $BP_1 = \frac{2\pi NT}{60x10^3} kW$, Indicated power $IP_1 = BP - BP1$

3. B.P. when 2nd cylinder is cut off

   $BP_2 = \frac{2\pi NT}{60x10^3} kW$, Indicated power $IP_2 = BP - BP2$

4. B.P. When 3rd cylinder is cut off

   $BP_3 = \frac{2\pi NT}{60x10^3} kW$, Indicated power $IP_3 = BP - BP3$

5. B.P. When 4th cylinder is cut off

   $BP_4 = \frac{2\pi NT}{60x10^3} kW$, Indicated power $IP_4 = BP - BP4$

6. Total indicated power $IP = IP_1+IP_2+IP_3+IP_4$

   Mechanical Efficiency = $\frac{\mathbf{BP}}{\mathbf{IP}}$

Conclusions:

IP for each cylinder and total IP are determined. Mechanical efficiency is ___ %.

4. PERFORMANCE TEST ON 4-S SINGLE CYLINDER VARIABLE COMPRESSION RATIO DIESEL ENGINE COUPLED TO AC GENERATOR

Aim: To conduct the performance test on four stroke cylinder diesel engine connected or coupled to an alternator.

Description: Diesel engine is a single cylinder, four stroke developing about SHP, 3600 rpm. The engine is coupled to an alternator through a coupling. Heaters are provided for loading. The alternator is supplied from a tank through a fuel measuring glass by which fuel consumption is found. Air supplied to the engine in the air box with an orifice plate allowing a controlled supply. Manometer is provided to measure the drop in pressure across he orifice.

Procedure: Start the engine by automatic switch. Now load the engine by switching on the loads provided for the heater. Increase the speed to maximum and note down the readings in voltmeter, Ammeter, Manometer and time for10cc of fuel vary the load.

Specifications:

Brake diameter D = 85 mm

Stroke length, L = 110 mm

Orifice diameter, d = 20 mm

C_d = 0.64.

Compression ratio, r= 21.99, 24.5, 20.03, 18.35

Calorific value of Diesel fuel (CV) = 39150 kJ/kg.

Formulae:

1. $BP = \frac{V \text{ x } I}{1000 \text{ x } n_{alt}}$ kW.

   n_{alt} = 90%=0.9

2. $m_f = \frac{\text{VOLUME OF FLUID x SPECIFIC gravity of fuel x 60}}{\text{Time taken for 10cc of fuel consumed}}$

3. $n_{Bth} = \frac{BP \text{ x } 60}{CV \text{ x } m_f}$

4. $SFC = = \frac{m_f \text{ x } 60}{BP} \text{ kg / KW hr}$

5. $n_{vol} = \frac{V_a}{V_s}$

V_a = Actual Volume of air taken inside the cylinder during suction stroke.

$= C_d\, A\, \sqrt{2gH}\, m^3/s$

$H = \frac{h_2 - h_1}{100} \times \frac{1000}{1.16}$

V_s = Swept Volume

$= \frac{\pi}{4}\frac{D^2 LN}{60}\ m^3/s$

Observation,Readings & Calculations:

Table 1:

S,no.	Speed (rpm)	V Volts	I Amps	Manometer Reading		Time for 10cc consumption of fuel (sec)
				h1 (cm)	h2(cm)	
1						
2						
3						
4						
5						

Table 2:

S.no.	BP (KW)	SFC (kg/kW-hr)	n_{Bth}(%)	n_{vol}(%)
1				
2				
3				
4				
5				

Table 3:

Speed (rpm)	Volts	Amps	Manometer Reading		Time for 10cc consumption of fuel (sec)
			h1 (cm)	h2(cm)	
1					
2					
3					
4					
5					

Table 4:

S.NO	BP (kW)	SFC (kg/kW-hr)	n_{Bth}(%)	n_{vol}(%)
1				
2				
3				
4				
5				

Result:

The break thermal efficiency = ___________

The Volumetric efficiency is = ___________

Table of Calculation:

S.no	Speed (rpm)	Fuel Consumed (kg/hr)	Air Consumed (kg/hr)	A/F	SFC	BHP	η_{Bth}	η_{vol}
1								
2								
3								
4								
5								

Graphs: Draw the following graphs

1. BP Vs SFC
2. BP Vs η_{vol}
3. BP Vs η_{Bth}
4. A/F Vs BP
5. A/F Vs SFC

Result and conclusions:

5. PERFORMANCE TEST ON 4-S SINGLE CYLINDER VERTICAL DIESEL ENGINE WITH EDDY CURRENT DYNAMOMETER

Aim: To conduct a performance test on the given (Field Marshal) vertical 4-Stroke Single Cylinder water cooled Diesel Engine.

Specifications:

Cylinder Bore (D) = 80 mm

Stroke length = 110 mm

Orifice Diameter (d) = 17.1 mm

Arm Length = 184 mm

Description of The Test Rig:

Field Marshal 4-Stroke single cylinder vertical diesel engine is used for this test. It is a water cooled engine coupled to the eddy current dynamometer. The exhaust gas from the engine is fed to the exhaust gas calorimeter.

Procedure:

1. Start the engine and run at no load at rated speed for a few minutes, keeping the cooling water flow and fuel supply, keep the Eddy current dynamometer electronic torque controller on zero position.
2. Observe the fuel flow from fuel gauge and note down the time for consumption of 10 cc of fuel at no load.
3. Note down the time taken for water flow from the flow meter, for measuring cooling water flow rate and also find the difference in manometric heads.
4. Inlet and Outlet cooling water temperatures and also the exhaust gas temperature are to be measured.
5. After ‘no load’ readings, Load the engine through the eddy current dynamometer’s torque controller in steps of 2 or 3 kg.
6. Repeat the same procedure at different loads.

Observations:

S.no.	Load W (kg)	Speed N (rpm)	Time for 10 cc of fuel T_f in (sec)	Manometer readings in water column			BP (kW)	SFC Kg/kW-hr	η_{vol} %	η_{Bth} %
				h_1	h_2	(h1-h2)cm				
1										
2										
3										
4										
5										
6										

1. **Brake Power (BP)** = $\dfrac{2\pi NT}{60x10^3}$ kW

   Torque T = W x R (W x 9.81) x R   N-m.

   Where W = load in (kg)

   R = Arm length = 0.184 m

2. **Mass of fuel Consumed per min (m_f).**

   $$m_f = \frac{\alpha \text{ x Sp Gravity of fuel x } 60}{\text{t x} 1000}$$

   where α = 10 cc of fuel consumed

   T = time in sec

   Sp Gravity of Diesel = 0.82

   Total Fuel Consumption (TFC) = m_f x 60 kg / hr.

3. **Specific Fuel Consumption (SFC)**

   $$\text{SFC} = \frac{(\text{mf x } 60)}{\text{BP}} \text{ kg / kW} - \text{hr}$$

4. **Brake Thermal Efficiency (η_{Bth})**

$$\eta_{Bth} = \frac{BP \times 60}{m_f \times CV}$$

CV for diesel = 45,455 kJ / kg.

Volumetric Efficiency (η_{vol})

$$\eta_{vol} = \frac{V_a}{V_{th}} \times 100\%$$

$V_a = C_d \times A \sqrt{2gh}$ m^3/s

Where

Cd = Coefficient of discharge = 0.62

$A = \frac{\pi d^2}{4}$ where d = diameter of orifice = 17.1 mm

$$H = \frac{h_2 - h_1}{100} \times \frac{\rho_{water}}{\rho_{air}}$$

Where $\rho_{water} = 1000\ kg / m^3$

$\rho_{air} =$ kg/m^3 at the atm. temperature

V_{th} = Theoretical Volume = $n \times \frac{\pi D^2}{4} \times L \times \frac{1}{2} \times \frac{N}{60}\ m^3/s$

Where n = number of cylinder

D =Diameter of cylinder = Bore (D) = 80 mm

Hence,

$$\eta_{vol} = \frac{V_a}{V_{th}} \times 100\%$$

5. **Air Fuel Ratio (A/F).**

A/F = $\mathbf{m_a / m_f}$

where $m_a = V_a \times 60 \times \rho_{air}$ kg/min

Graphs:

1. BP Vs SFC
2. BP Vs η_{vol}
3. BP Vs η_{Bth}

Conclusions: Performance characteristics are determined for the given Field Marshal Engine.

6. TWO STAGE RECIPROCATING AIR COMPRESSOR

Aim: To conduct a test on air compressor and to determine volumetric efficiency and isothermal efficiency at various delivery pressures.

Description:

The air compressor is two stage, reciprocating type. The air is sucked from atmosphere and compressed in the first cylinder. The compressed air then passes through the air intercooler to the second cylinder where it is further compressed. The air further goes to the air reservoir through a safety valve, which operates the electrical switch, when the pressure exceeds the limit.

The test units consist of an air chamber, containing an orifice pate, the manometer, compressor, and an electrical dynamometer type induction motor.

Specifications:

Diameter of low pressure cylinder	= 110 mm
Diameter of high pressure cylinder	= 80 mm
Length of stoke	= 89 mm
Diameter of orifice	= 0.014 m

Procedure:

1. The outlet valve is closed.
2. The manometer connections are checked (the manometer may be fitted with water upto the half level).
3. The compressor is started, the pressure develops slowly.

4. At the required pressure, the outlet is opened slowly and adjusted so that the pressure is maintained constant.

Observations:

Atmospheric temperature: _____ °C

SNO	Required Delivery Pressure (kgf/cm^2)	Speed of motor (N_m) (rpm)	Speed of Compressor (N_c) (rpm)	Time taken for 10 rev of wattmeter (t) in (second)	Manometer Reading in (cm)	
					h_1	h_2
1						
2						
3						
4						
5						
6						

Calculation:

1. Volumetric Efficiency
2. Isothermal Efficiency

1. Calculation of Volumetric Efficiency.

$$\text{Volumetric Efficiency} = \frac{\text{Actual volume of air entering the compressor per second at NTP}}{\text{Theoretical volumes of air entering the compressor per second}}$$

Where,

Actual volume of air entering the compressor is determined using the reading of manometer fixed to the air chamber

Actual volume of air entering the compressor at RTP = $V_{a(RTP)} = Cd * a * \sqrt{2gH}\ m^3/sec.$

Where C_d = Coefficient of discharge = 0.64,

a = Area of orifice in $m^2 = \dfrac{\pi d^2}{4}$

d= diameter of orifice meter = 0.014 m.

H = difference of pressure in manometer in meters of air = $\dfrac{(h_1 - h_2)}{100} \times \dfrac{\rho_{water}}{\rho_{air}}$ meters of air.

NOTE: (h_1- h_2) is in cm which can be taken from tabular column.

ρ_{water} (Density of water) = 1000 kg/m^3.

ρ_{air} (Density of air) = ____ kg/m^3. To be calculated at the atmospheric pressure and temperature

Actual volume of air entering the compressor at NTP = $V_{a(NTP)} = \frac{V_{a(RTP)} * 273}{\text{Room temp in } ^oK}$ m^3/sec

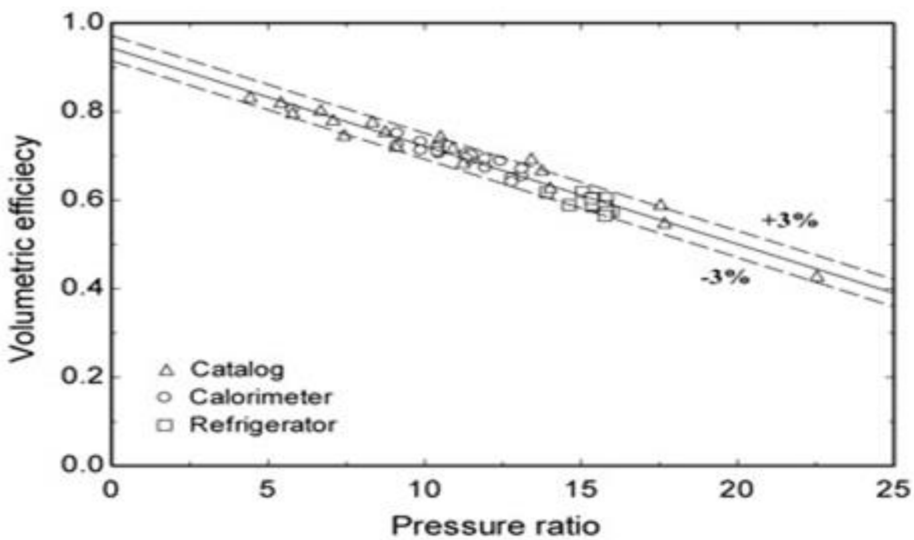
Theoretical volume of air entering the compressor per second = Piston displacement of the Low pressure cylinder during the suction stroke per second = $\frac{\pi * d_2 * L * N_c}{4*60}$ m^3/sec.

Where D = Diameter of Low pressure cylinder = 110 mm = 0.11m

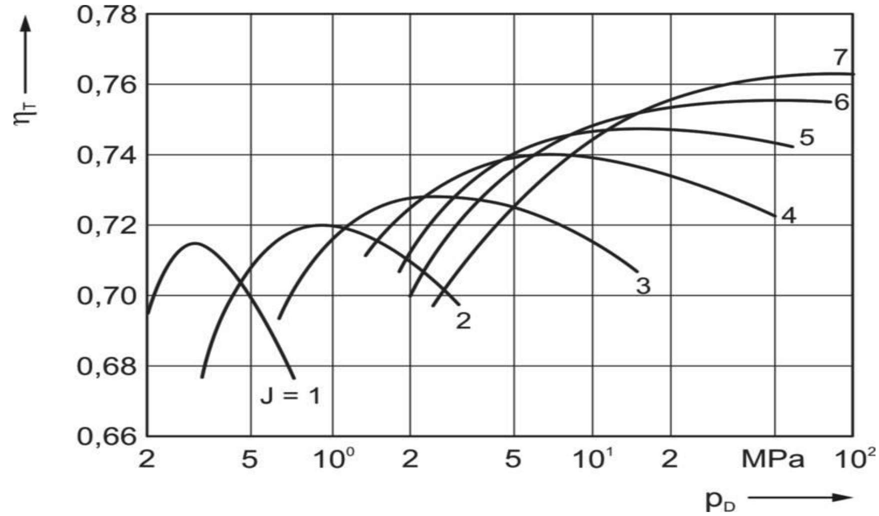
L = Length of stroke which is common for both the cylinders =89mm = 0.089 m.

N_c = Speed of compressor (rpm)

Substituting (a) and (b) in equation (l), we get the volumetric efficiency of the compressor.



Correlation between the volumetric efficiency and pressure ratio.



2. Calculation of Isothermal Efficiency.

Isothermal efficiency = $\dfrac{\text{Work done during isothermal cycle}}{\text{Actual work done on air}}$

Isothermal efficiency = $\dfrac{\text{isothermal power in kilowatts}}{\text{Shaft input in kilowatts}}$

Shaft Input = Wattmeter reading in kW x transmission Efficiency x Motor Efficiency.

= __________ kW x 0.85 x 0.95

150 revolution of wattmeter - 1 k W hr

10 revolutions of wattmeter - 1/15 kW hr

Let t is the time taken for ten revolutions in seconds.

Wattmeter Reading = $\dfrac{3600}{15 \times t}$ kW

Isothermal power = Theoretical power supplied assuming single stage isothermal compression from atmospheric pressure to deliver pressure.

Considering Isothermal compression

W.D/cycle = $P_1 V_1 \ln r$, Note: V_1 is in (m3)

And power supplied assuming single stage isothermal compression = $P_1 V_1 \ln r$.

Where V_1 is volumetric flow rate in m^3/sec

Isothermal power = $P_{atm} * V_{a\,(RTP)} * \ln r$.

Where r = compression ratio = $\dfrac{V_1}{V_2}$

During isothermal process $P_1 V_1 = P_2 V_2$

i.e. $\frac{V_1}{V_2} = \frac{P_2}{P_1}$ (1 kgf/cm^2 = 0.981 x 10^3 N/m^2)

Isothermal Power = $P_{atm} * V_{a\,(RTP)} * \ln (P_2/P_1) = P_{atm} * V_{a\,(RTP)} * \ln (P_{out}/P_{in})$.

NOTE: P_{in} = 101.3 kN/m^2 & P_{out} = High Pressure Gauge reading = $P_H + P_{atm}$

Precautions:

1. The orifice should never be closed; otherwise the manometer liquid (water) will be sucked into the tank.
2. At the end of the experiment the outlet valve at the air reservoir should be opened, as the compressor is to be started again at low pressure, prevent undue strain on the piston.

RESULTS:

S.No	Delivery Pressure (kgf/cm^2)	η_{iso} %	η_{vol} %
1			
2			
3			
4			
5			

Conclusions:

Hence Volumetric Efficiency and Isothermal Efficiency at various Deliver Pressures are determined.

7. THERMAL CONDUCTIVITY OF METAL ROD

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

SPECIFICATIONS:

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 & 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 & 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		

<u>APPARATUS:</u>

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.

<u>PROCEDURE:</u>

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 (Brass rod).
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

OBSERVATIONS: Solid Rod 1:

S.No	Voltmeter V (Volts)	Ammeter I (Amps)	T_1 °C	T_2 °C	T_3 °C	T_4 °C	T_5 °C	T_6 °C	T_7 °C

Solid Rod 2:

S.No	Voltmeter V (Volts)	Ammeter I (Amps)	T_8 °C	T_9 °C

CALCULATIONS:

Solid Rod 1:

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

Where

$Q = V \text{ x } I \text{ x } \eta_{sys}$ = ______________ watts

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

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

dx = length of the rod = ______m.

Solid Rod 2:

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

Where

Efficiency (η) = 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 = 4.18 (kJ/kgK)
$\Delta T = (T_9 - T_8)$ = __________ ^oC.
Input = Q = V x I X η_{sys} X1000= ________ kW

RESULTS:

Thermal conductivity of solid rods 1 and 2 is determined.

8. PIN FIN APPARATUS

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

SPECIFICATIONS:

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 & 150 mm distance from the main block inner edge.

OBSERVATIONS:

(Free Convection)

S.No	Voltmeter (V)	Ammeter (Amp)	T_1 °C	T_2 °C	T_3 °C	T_4 °C	T_5 °C	T_6 °C	T_7 °C	T_8 °C	T_m °C	T_a °C	h_{exp} W/m^2°C

(Forced Convection)

SNO	Voltmeter (V)	Ammeter (Amp)	T_1 °C	T_2 °C	T_3 °C	T_4 °C	T_5 °C	T_6 °C	T_7 °C	T_8 °C	T_m °C	T_a °C	h_{exp} W/m^2°C

CALCULATIONS:

(Free Convection)

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

= ____________________°C

Ambient air temperature = $T_a = \dfrac{T_1 + T_8}{2}$ °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)

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

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 = $T_a = \dfrac{T_1 + T_8}{2} = \_\_\_\_\_$ ^oC.

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 (Q) = V x I x n = W

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

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

<u>PROCEDURE:</u>

1. Start the electric supply and give input to heating system.
2. Keep the dimmer stat 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.

RESULT:

Convective Heat Transfer Coefficient is determined for both free and forced convection.

Free Convection	Forced Convection
h_{exp} = _________ W/m^2 K	h_{exp} = _________ W/m^2 K

9. HEAT EXCHANGER

AIM: To conduct a Heat Transfer test on the given apparatus and to determine Overall heat transfer coefficient of Parallel flow and Counter flow Heat Exchanger.

APPARATUS:

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 & 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 ^{o}C ‘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.

DESCRIPTION:

Heat Exchanger is devices in which heat is transferred from one fluid to another. The necessity for doing so arises in a number of industrial and domestic applications. Some common examples are the Radiators of a car, lorry etc. The condenser at the back of domestic Refrigerator, Air conditioning etc. Heat Exchanger is classified in three categories.

1. Transfer Type
2. Storage Type
3. Direct Contact Type

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

The Transfer type Exchanger are further classified according to flow arrangement as,

1. PARALLEL FLOW in which fluids flow in the same direction.
2. COUNTER FLOW in which fluids flow in the opposite direction.
3. CROSS FLOW in which fluids flow at right angles to each other.

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 & 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 & 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.

OBSERVATIONS:

Parallel Flow:

I. Temperature.

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

II. Mass flow rate of Water.

1. At Hot water outlet = m_h = _____ 1pm.
2. At cold water outlet = m_c = _____ 1pm.

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 – $T_{ci} = T_4 =$_______________ ^oC.
4. Cold water outlet temperature – $T_{co} = T_3 =$ _______________ ^oC.

II. Mass flow rate of Water.

1. At Hot water outlet = $m_h =$ _____ 1pm.
2. At cold water outlet = $m_c =$ _____ 1pm.

CALCULATION:

A). **For PARALLEL 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.
= $m_h\ C_{ph}\ (T_{hi} – T_{ho})$ KW.
C_{ph} = Specific heat of water =4.18 (kJ/kgK)
Q_c = Heat Transfer Rate through the Cold Water.
= $m_c\ C_{pc}\ (T_{co} – T_{ci})$ KW.
C_{pc} = Specific heat of water =4.18 (kJ/kgK)
Q_a = Average Heat Transfer Rate of water

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

3, The Overall Heat Transfer Coefficient (U).

1. $U = \frac{Q_a}{A \Delta T_m} =$ __________ $KW/m^{2o}C$

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.

= $m_h C_{ph} (T_{hi} - T_{ho})$ KW.

C_{ph} = Specific heat of water =4.18 (kJ/kgK)

Q_c = Heat Transfer Rate through the Cold Water.

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

C_{pc} = Specific heat of water =4.18 (kJ/kgK)

Q_a = Average Heat Transfer Rate of water

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

3, The Overall Heat Transfer Coefficient (U).

1. $U = \frac{Q_a}{A \Delta T_m} =$ __________ KW/m^{2o}C

CONCLUSION:

Hence the Experiment is performed on PARALLEL, COUNTER Flow Heat Exchanger.

10.EMISSIVITY MEASUREMENT OF RADIATING SURFACES

AIM: To determine the emissivity of gray surface.

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 & ammeter reading.
5. Repeat the experiment for different heat inputs.

OBSERVATION TABLE:

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

SPECIMEN CALCULATIONS:

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,
   $$E_g = (T^4 b - T^4 a)/(T^4 g - T^4 a)$$

CONCLUSION:

11.STEFAN BOLTZMAN APPARATUS

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

APPARATUS:

The apparatus consist of small sized precision test source hating element & 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.

SPECIFICATIONS:

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 & 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%

LAW OF THERMAL RADIATION:

Stefan Boltzmann law states that rate of Radiation heat transfer is directly proportional to surface area and fourth power of absolute temperature difference.

i.e. $Q \alpha A (T_1^4 - T_2^4)$

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

Where,

σ = Stefan Boltzman constant

PROCEDURE:

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

OBSERVATIONS:

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

CALCULATIONS:

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.

PRECAUTIONS:

1. Keep the dimmer set at 0 Volts while switching the system 'ON' or 'OFF'.
2. Multi channel Temperature indicator selector switch knob must be handled softly, gently and should not be tampered.
3. Do not exceed voltmeter reading beyond 80V & Temperature of 150 °C.
4. It is better to conduct experiment at 100 voltage which yield better results.

CONCLUSION:

The value of Stefan Boltzman constant is determined.

12. HEAT TRANSFER THROUGH COMPOSITE WALL

AIM: To determine the Thermal conductivity and Thermal Resistance of a composite wall.

SPECIFICATIONS:

Slab Size:

a) Mild steel : 300 mm diameter x 23 mm thick
b) Hylam (Bakelite) : 300 mm diameter x 14 mm thick
c) Wood : 300 mm diameter x 19 mm thick.

CALCULATIONS:

Rate of heat supplied $= \frac{V \, x \, I}{1000}$ kW

Heat supplied n each direction $= \frac{V \, x \, I}{1000} * \frac{1}{2}$ kW

1. Thermal conductivity of Mild Steel slab K mild steel.

$Q = - K_{\text{mild steel}} * A * (dT/dx)$ (kW)

$= K_{\text{mild steel}} * A * \frac{T_A - T_B}{b_{\text{mild steel}}}$ (kW)

Where

A = area of mild steel slab = $\frac{\pi D^2}{4}$ (m^2)

D = diameter of mild steel slab (m)

$b_{\text{mild steel}}$ = thickness of mild steel slab (m)

Q = Heat transfer rate. (kW)

$T_A = \frac{(T_1 + T_2)}{2}$ (K)

$T_B = \frac{(T_3 + T_4)}{2}$ (K)

$K_{\text{mild steel}}$ = ____________ (kW/ m K)

2. Thermal conductivity of Wooden slab K wood.

$Q = - K_{wood} * A * (dT/dx)$ (kW)

$= K_{wood} * A * \frac{T_B - T_C}{b_{wood}}$ (kW)

Where

A = area of wooden slab $\frac{\pi D^2}{4}$ (m^2)

D = diameter of wooden slab (m)

b_{wood} = thickness of wooden slab (m)

Q = Heat transfer rate. (kW)

$T_B = \frac{(T_3 + T_4)}{2}$ (K)

$T_C = \frac{(T_5 + T_6)}{2}$ (K)

$K_{mild\ steel}$ = ____________ (kW/ m K)

3. Thermal conductivity of Bakelite slab K bakelite

$Q = - K_{wood} * A * (dT/dx)$ (kW)

$= K_{wood} * A * \frac{T_B - T_C}{b_{wood}}$ (kW)

Where

A = area of bakelite slab $\frac{\pi D^2}{4}$ (m^2)

D = diameter of bakelite slab (m)

$b_{bakelite}$ = thickness of bakelite slab (m)

Q = Heat transfer rate. (kW)

$T_C = \frac{(T_5 + T_6)}{2}$ (K)

$T_D = \frac{(T_7 + T_8)}{2}$ (K)

$K_{bakelite}$ = ____________ (kW/ m K)

4. Thermal conductivity of Composite slab K composite.

$Q = - K_{composite\ slab} * A * (dT/dx)$ (kW)

$$= K_{\text{composite slab}} * A * \frac{T_A - T_D}{b_{\text{composite slab}}} \qquad \text{(kW)}$$

Where

A = area of composite slab $\frac{\pi D^2}{4}$ (m^2)

D = diameter of composite slab (m)

$b_{composite}$ = thickness of composite slab (m)

Q = Heat transfer rate. (kW)

$$T_A = \frac{(T_1 + T_2)}{2} \qquad \text{(K)}$$

$$T_D = \frac{(T_7 + T_8)}{2}$$

$K_{composite}$ = ____________ (kW/ m K)

5. Thermal resistance of Mild Steel ($R_{\text{mild steel}}$)

$$Q = K_{\text{mild steel}} * A * \frac{(TA + TB)}{b_{\text{mild steel}}}$$

$$Q = \frac{(TA + TB)}{b_{\text{mild steel}} / K_{\text{mild steel}} * A} \qquad \text{(K/kW)}$$

6. Thermal resistance of Wood (R_{wood}).

$$Q = K_{wood} * A * \frac{(T_B - T_C)}{b_{wood}}$$

$$Q = \frac{(T_B - T_C)}{b_{wood} / K_{wood} * A}$$

$$\text{i.e. Rwood} = \frac{b_{wood}}{K_{wood} * A} \qquad \text{(K/kW)}$$

7. Thermal resistance of Bakelite ($R_{bakelite}$).

$$Q = K_{bakelite} * A * \frac{(T_C - T_D)}{b_{bakelite}}$$

$$Q = \frac{(T_C - T_D)}{b_{bakelite} / K_{bakelite} * A}$$

i.e. $R_{bakelite} = \dfrac{b_{bakelite}}{K_{bakelite} * A}$ (K/kW)

8. Thermal resistance of composite wall ($R_{composite\ wall}$).

$$Q = K_{composite\ wall} * A * \frac{(T_C - T_D)}{b_{composite\ wall}}$$

$$Q = \frac{(T_C - T_D)}{b_{composite\ wall} / K_{composite\ wall} * A}$$

i.e. $R_{composite\ wall} = \dfrac{b_{composite\ wall}}{K_{composite\ wall} * A}$ (K/kW)

PROCEDURE:

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

CONCLUSION:

The value of thermal conductivity and thermal resistance of composite wall is determined.