5104-ARUNAI ENGINEERING COLLEGE

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DEPARTMENT OF MECHANICAL ENGINEERING

ME 8512 – THERMAL ENGINEERING LAB

LABORATORY MANUAL

ANNA UNIVERSITY: CHENNAI
REGULATION 2017

ME8512 THERMAL ENGINEERING LABORATORY

LIST OF EXPERIMENTS

I.C. ENGINE LAB

1. Valve Timing and Port Timing diagrams.
2. Actual p-v diagrams of IC engines.
3. Performance Test on 4 –stroke Diesel Engine.
4. Heat Balance Test on 4 –stroke Diesel Engine.
5. Morse Test on Multi-cylinder Petrol Engine.
6. Retardation Test on a Diesel Engine.
7. Determination of Flash Point and Fire Point of various fuels / lubricants.

STEAM LAB

8. Study on Steam Generators and Turbines.
9. Performance and Energy Balance Test on a Steam Generator.
10. Performance and Energy Balance Test on Steam Turbine.

HEAT TRANSFER

11. Thermal conductivity measurement using guarded plate apparatus.
12. Thermal conductivity measurement of pipe insulation using lagged pipe apparatus.
13. Determination of heat transfer coefficient under natural convection from a vertical cylinder.
14. Determination of heat transfer coefficient under forced convection from a tube.
15. Determination of Thermal conductivity of composite wall.
16. Determination of Thermal conductivity of insulating powder.
17. Heat transfer from pin-fin apparatus (natural & forced convection modes).
18. Determination of Stefan-Boltzmann constant.
19. Determination of emissivity of a grey surface.
20. Effectiveness of Parallel/counter flow heat exchanger

REFRIGERATION AND AIR CONDITIONING

21. Determination of COP of a refrigeration system
22. Experiments on Psychometric processes.
23. Performance test on a reciprocating air compressor.
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25. Performance test in a fluidized bed cooling tower.

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ENGINE & WORKING PRINCIPLES

A heat engine is a machine, which converts heat energy into mechanical energy. The combustion of fuel such as coal, petrol, and diesel generates heat. This heat is supplied to a working substance at high temperature. By the expansion of this substance in suitable machines, heat energy is converted into useful work.

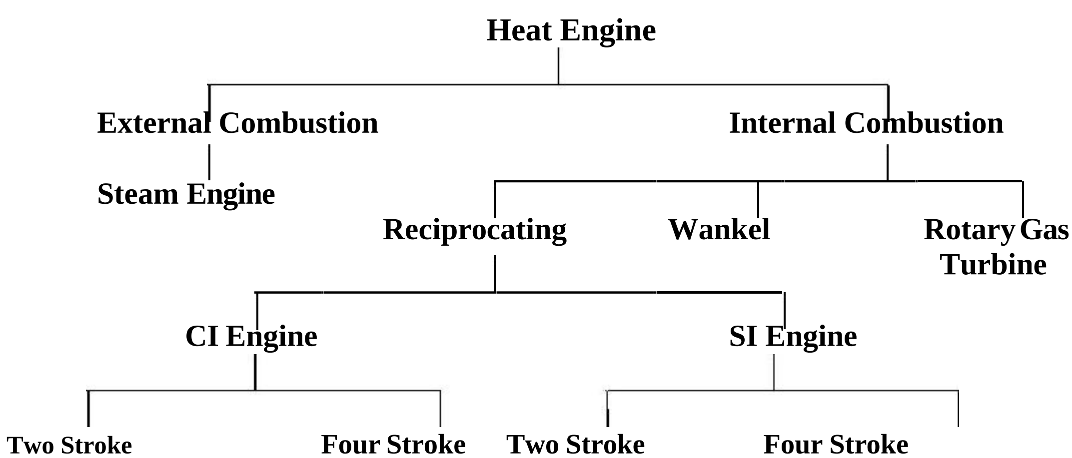
Heat engines can be further divided into two types:

(i) External combustion and
(ii) Internal combustion.

In a steam engine the combustion of fuel takes place outside the engine and the steam thus formed is used to run the engine. Thus, it is known as external combustion engine.

In the case of internal combustion engine, the combustion of fuel takes place inside the engine cylinder itself.

Types of Heat Engines:



Spark Ignition (Carburetor Type) IC Engine

In this engine liquid fuel is atomized, vaporized and mixed with air in correct proportion before being taken to the engine cylinder through the intake manifolds. The ignition of the mixture is caused by an electric spark and is known as spark ignition.

Compression Ignition (Diesel Type) IC Engine

In this only the liquid fuel is injected in the cylinder under high pressure.

Constructional Features of IC Engine:

The cross section of IC engine is shown in Fig. 1. A brief description of these parts is given below.

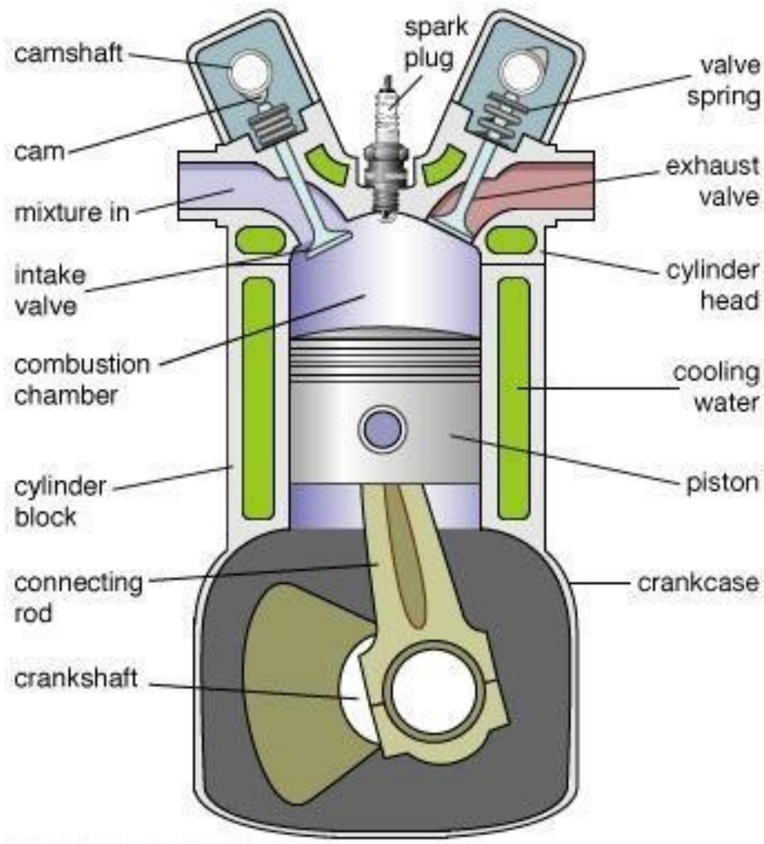


Fig. 1 Cross-section of a diesel engine

Cylinder:

The cylinder of an IC engine constitutes the basic and supporting portion of the engine power unit. Its major function is to provide space in which the piston can operate to draw in the fuel mixture or air (depending upon spark ignition or compression ignition), compress it, allow it to expand and thus generate power. The cylinder is usually made of high-grade cast iron. In some cases, to give greater strength and wear resistance with less weight, chromium, nickel and molybdenum are added to the cast iron.

Piston:

The piston of an engine is the first part to begin movement and to transmit power to the crankshaft as a result of the pressure and energy generated by the combustion of the fuel. The piston is closed at one end and open on the other end to permit direct attachment of the connecting rod and its free action.

The materials used for pistons are grey cast iron, cast steel and aluminum alloy. However, the modern trend is to use only aluminum alloy pistons in the tractor engine.

Piston Rings:

These are made of cast iron on account of their ability to retain bearing qualities and elasticity indefinitely. The primary function of the piston rings is to retain compression and at the same time reduce the cylinder wall and piston wall contact area to a minimum, thus reducing friction losses and excessive wear.

Compression rings are usually plain one-piece rings and are always placed in the grooves nearest the piston head. Oil rings are grooved or slotted and are located either in the lowest groove above the piston pin or in a groove near the piston skirt. Their function is to control the distribution of the lubricating oil to the cylinder and piston surface in order to prevent unnecessary or excessive oil consumption ion.

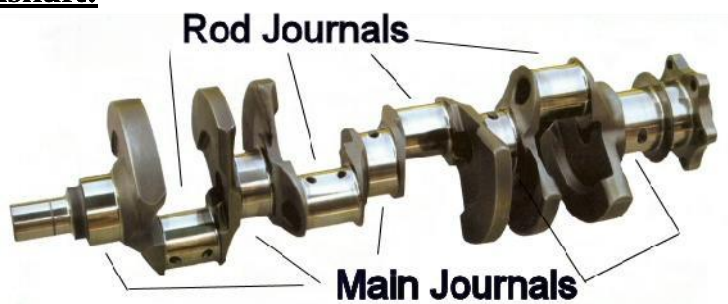
Piston Pin:

The connecting rod is connected to the piston through the piston pin. It is made of case hardened alloy steel with precision finish. There are three different methods to connect the piston to the connecting rod.

Connecting Rod:

This is the connection between the piston and crankshaft. The end connecting the piston is known as small end and the other end is known as big end. The big end has two halves of a bearing bolted together. The connecting rod is made of drop forged steel and the section is of the I-beam type.

Crankshaft:



This is connected to the piston through the connecting rod and converts the linear motion of the piston into the rotational motion of the flywheel. The journals of the crankshaft are supported on main bearings, housed in the crankcase. Counter-weights and the flywheel bolted to the crankshaft help in the smooth running of the engine.

Engine Bearings:

The crankshaft and camshaft are supported on anti-friction bearings. These bearings must be capable of withstanding high speed, heavy load and high temperatures. Normally, cadmium, silver or copper lead is coated on a steel back to give the above characteristics. For single cylinder vertical/horizontal engines, the present trend is to use ball bearings in place of main bearings of the thin shell type.

Valves:

To allow the air to enter into the cylinder or the exhaust, gases to escape from the cylinder, valves are provided, known as inlet and exhaust valves respectively. The valves are mounted either on the cylinder head or on the cylinder block.

Camshaft:

The valves are operated by the action of the camshaft, which has separate cams for the inlet, and exhaust valves. The cam lifts the valve against the pressure of the spring and as soon as it changes position the spring closes the valve. The cam gets drive through either the gear or sprocket and chain system from the crankshaft. It rotates at half the speed of the camshaft.

Flywheel:

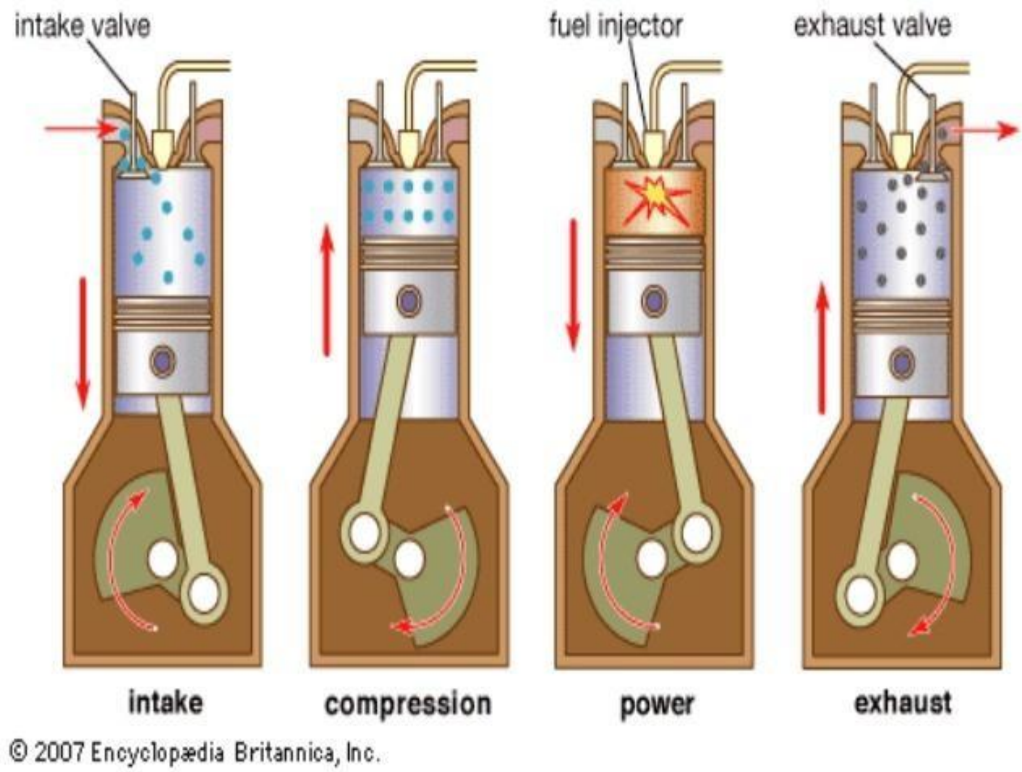
This is usually made of cast iron and its primary function is to maintain uniform engine speed by carrying the crankshaft through the intervals when it is not receiving power from a piston. The size of the flywheel varies with the number of cylinders and the type and size of the engine. It also helps in balancing rotating masses.

PRINCIPLES OF OPERATION OF IC ENGINES:

FOUR-STROKE CYCLE DIESEL ENGINE

In four-stroke cycle engines there are four strokes completing two revolutions of the crankshaft. These are respectively, the suction, compression, power and exhaust strokes. In Fig. 3, the piston is shown descending on its suction stroke. Only pure air is drawn into the cylinder during this stroke through the inlet valve, whereas, the exhaust valve is closed. These valves can be operated by the cam, push rod and rocker arm. The next stroke is the compression stroke in which the piston moves up with both the valves remaining closed.

The air, which has been drawn into the cylinder during the suction stroke, is progressively com-pressed as the piston ascends. The compression ratio usually varies from 14:1 to 22:1.

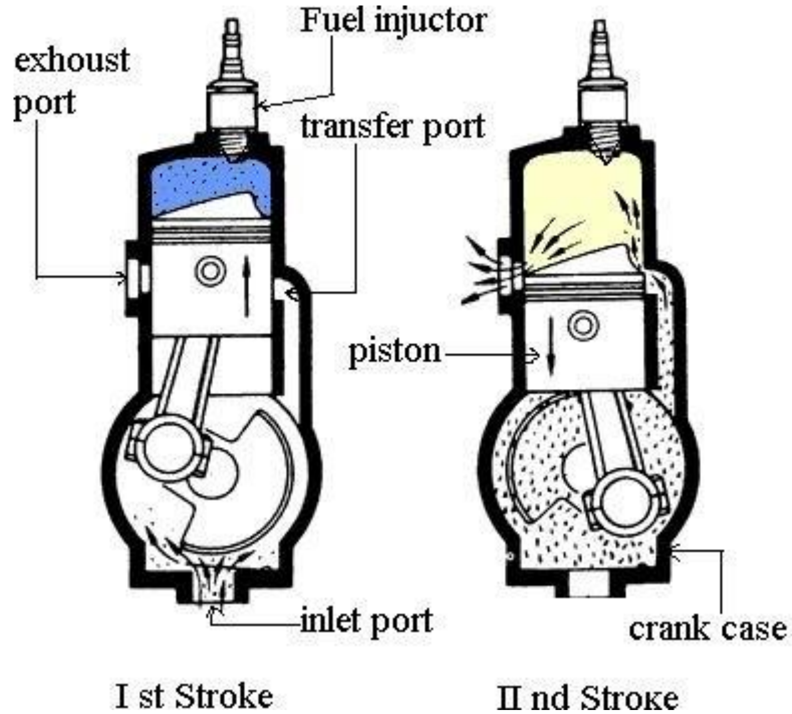


During the fuel injection period, the piston reaches the end of its compression stroke and commences to return on its third consecutive stroke, viz., power stroke. During this stroke the hot products of combustion consisting chiefly of carbon dioxide, together with the nitrogen left from the compressed air expand, thus forcing the piston downward. This is only the working stroke of the cylinder.

TWO-STROKE CYCLE DIESEL ENGINE:

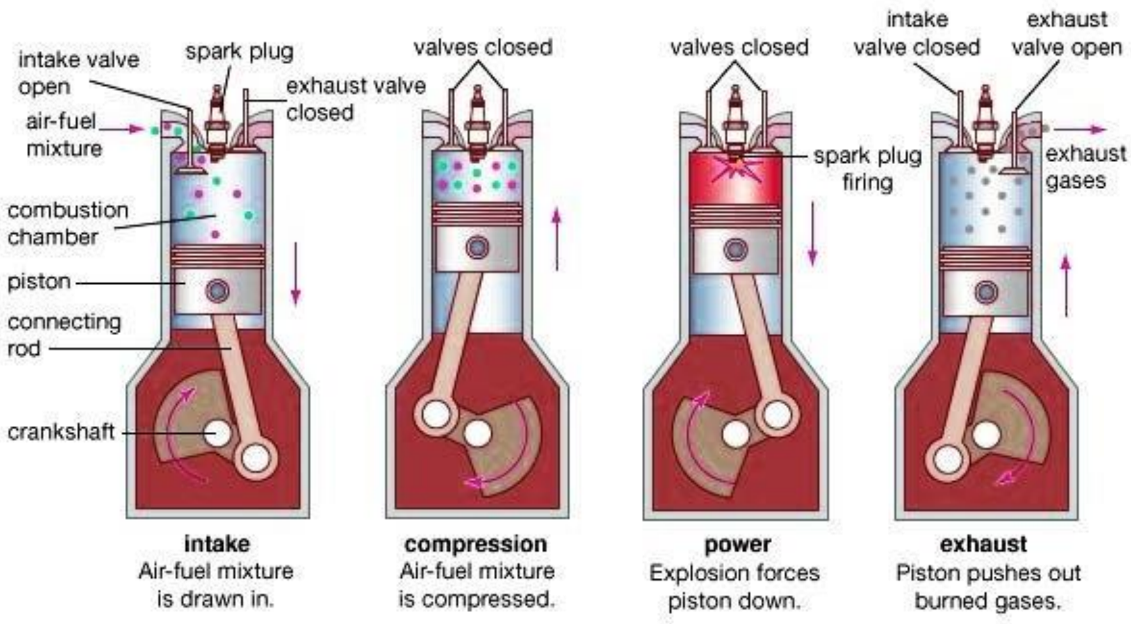
The cycle of the four-stroke of the piston (the suction, compression, power and exhaust strokes) is completed only in two strokes in the case of a two-stroke engine. The air is drawn into the crankcase due to the suction created by the upward stroke of the piston.

On the down stroke of the piston it is compressed in the crankcase, The compression pressure is usually very low, being just sufficient to enable the air to flow into the cylinder through the transfer port when the piston reaches near the bottom of its down stroke.



FOUR-STROKE SPARK IGNITION ENGINE

In this gasoline is mixed with air, broken up into a mist and partially vaporized in a carburetor (Fig. 5). The mixture is then sucked into the cylinder. There it is compressed by the upward movement of the piston and is ignited by an electric spark. When the mixture is burned, the resulting heat causes the gases to expand. The expanding gases exert a pressure on the piston (power stroke). The exhaust gases escape in the next upward movement of the piston. The strokes are similar to those discussed under four-stroke diesel engines. The various temperatures and pressures are shown in Fig. 6. The compression ratio varies from 4:1 to 8:1 and the air-fuel mixture from 10:1 to 20:1.



TWO-STROKE CYCLE PETROL ENGINE

The two-cycle carburetor type engine makes use of an airtight crankcase for partially compressing the air-fuel mixture (Fig. 6). As the piston travels down, the mixture previously drawn into the crankcase is partially compressed. As the piston nears the bottom of the stroke, it uncovers the exhaust and intake ports. The exhaust flows out, reducing the pressure in the cylinder. When the pressure in the combustion chamber is lower than the pressure in the crankcase through the port openings to the combustion chamber, the incoming mixture is deflected upward by a baffle on the piston. As the piston moves up, it compresses the mixture above and draws into the crankcase below a new air-fuel mixture.

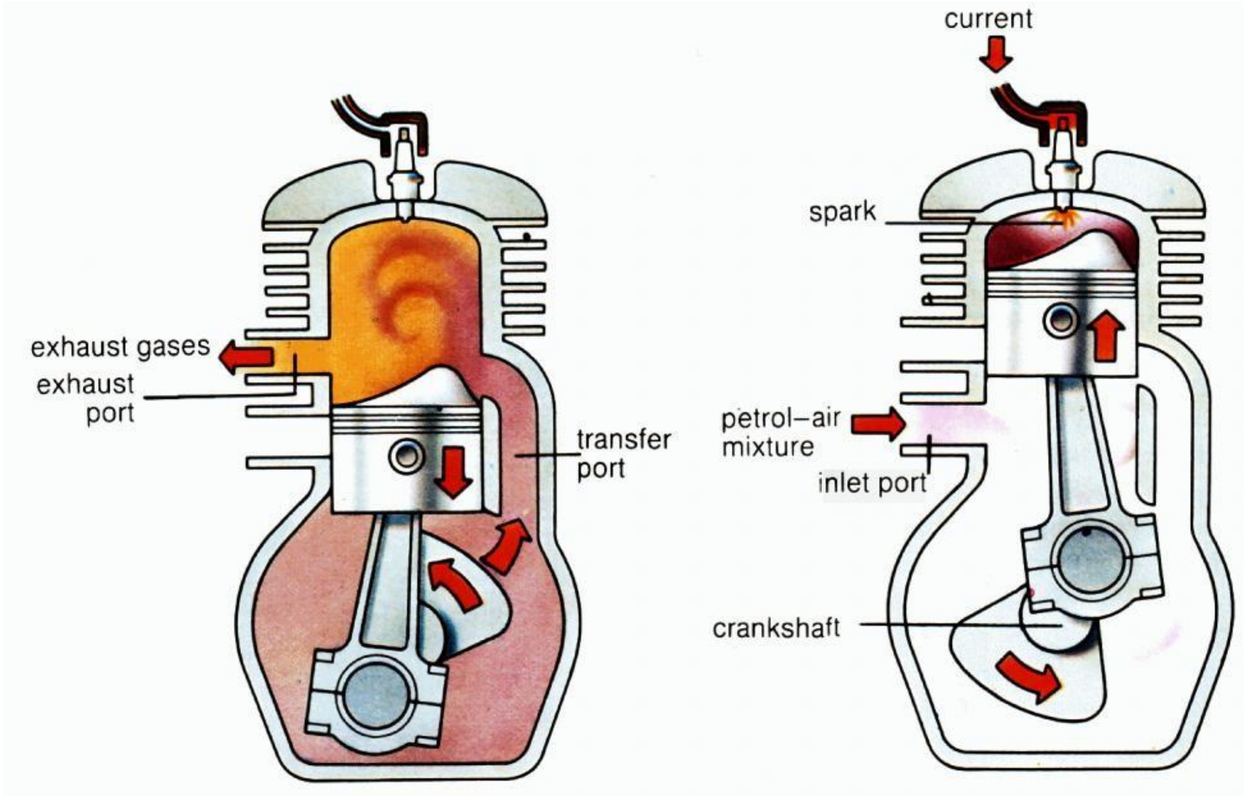


Fig. 6 Principle of operation of two stroke petrol engine

The, two-stroke cycle engine can be easily identified by the air-fuel mixture valve attached to the crankcase and the exhaust Port located at the bottom of the cylinder.

EX. NO :

1 DATE :

DETERMINATION OF FLASH AND FIRE POINTS FOR GIVEN OIL USING OPEN CUP APPARATUS

AIM:

To determine the flash and fire point of the given oil using open cup apparatus

APPRATUS REQUIRED:

- ❖ Open Cup flash point apparatus
- ❖ Thermometer

PROCEDURE:

1. The fuel under examination is filled up to the mark in the oil cup and then heated by heating the water bath by burner.
2. Stirrer is worked between tests at a rate of about 1 to 2 revolution per seconds.
3. Heat is applied so as the raise the oil temperature by about 5°C per minutes.
4. At every 10°C raise of temperature flame is introduced for a moment by working the shuffle.
5. The temperature at which a testing flash a combination of a weak sound and light appears is noted and is the flash points.
6. The heating is continued thereafter and the test flame is applied as before.
7. When the oil ignites and continued to burn for a at least 5 seconds the temperature reading is noted and is five points.

TABULATION: (FLASH AND FIRE POINTS)

GIVEN FUEL = SAE 20-40W

SERIAL NO	**TEMPERATURE (°C)**	**OBSERVED FLASH POINT *(YES/NO)***	**OBSERVED FIRE POINT *(YES/NO)***
01			
02			
03			
04			
05			
06			
07			

RESULT:

Thus the flash and fire point of the given oil is found out experimentally

Flash point =………………………………………………

Fire point =………………………………………………

EX. NO :

2 DATE :

PORT TIMING DIAGRAM FOR TWO STROKE PETROL ENGINE

AIM:

To draw the port timing diagram for the given two stroke diesel engine

APPRATUS REQUIRED:

1. Measuring tape

FORMULA USED:

1 .REQUIRED ANGLE = (Distance X 360°) / (Circumference of the Flywheel)

- **DISTANCE =** Distance of the port opening or closing position marked on flywheel with respect to their dead centre.
- **CIRCUMFERENCE OF THE FLYWHEEL** = 62 cm

PROCEDURE:

1. First the TDC and BDC of the engine are found correctly by rotating the flywheel and the positions are marked on flywheel.
2. Now the circumference of the flywheel is found by using the measuring tape.
3. The flywheel is rotated and the point at which the transfer port starts opening is found out it is position is marked in the flywheel.
4. Similarly position at which it closes is also found out.
5. The distance are measured by using thread with respect to their dead centre and in to angles.
6. The same procedure is respected for the exhaust port also.

<u>TABULATION :</u>(PORT TIMING DIAGRAM FOR TWO STROKE PETROL ENGINE)

EVENTS	DISTANCE FROM THEIR RESPECTIVE DEAD CENTRE IN 'CM'	PORT OPENING PERIOD IN 'DEGREES'
Exhaust Port Open **[EPO]**		
Exhaust Port Close **[EPC]**		
Transfer Port Open **[TPO]**		
Transfer Port Close **[TPC]**		

RESULT:

Thus the port timing diagram for the given two stroke petrol engine found out and it is drawn

Transfer Port Open at_____________ degree

Transfer Port Close at_______________degree

Exhaust Port Open at_______________ degree

Exhaust Port Close at_______________ degree

EX. NO : 3

DATE :

VALVE TIMING DIAGRAM FOR FOUR STROKE DIESEL ENGINE

AIM:

To draw the valve timing diagram for the given four stroke diesel engine.

APPRATUS REQUIRED:

1. Measuring tape

FORMULA USED:

1. REQUIRED ANGLE = (Distance X 360°) / (Circumference of the Flywheel)

- **DISTANCE =** Distance of the valve opening or closing position marked on flywheel with respect to their dead centre
- **CIRCUMFERENCE OF THE FLYWHEEL** = 124cm

PROCEDURE:

1. First the TDC and BDC of the engine are found correctly by rotating the flywheel and the positions are marked on flywheel.
2. Now the circumference of the flywheel is found by using the measuring tape.
3. The flywheel is rotated and the point at which the inlet valve starts opening is found out it is position is marked in the flywheel.
4. Similarly position at which it closes is also found out.
5. The distance are measured by using thread with respect to their dead centre and in to angles.
6. The same procedure is respected for the exhaust valve also.

TABULATION : **(VALVE TIMING DIAGRAM)**

EVENTS	DISTANCE FROM THEIR RESPECTIVE DEAD CENTRE IN 'CM'	VALVE OPENING PERIOD IN 'DEGREES'
Inlet Valve Open **[IVO]**		
Inlet Valve Close **[IVC]**		
Exhaust Valve Open **[EVO]**		
Exhaust Valve Close **[EVC]**		

RESULT:

Thus the valve timing diagram for the given four stroke diesel engine found out and it is drawn

Inlet Valve Open at_____________ degree

Inlet Valve close at_____________ degree

Exhaust Valve Open at_____________ degree

Exhaust Valve Close at_____________ degree

EX. NO :

4 DATE :

ACTUAL P-v DIAGRAM OF TWO STROKE PETROL ENGINE

AIM:

To diagram the Actual PV diagram for the given two stroke petrol engine.

APPRATUS REQUIRED:

1. Measuring tape

FORMULA USED:

1 .REQUIRED ANGLE = (Distance X 360°) / (Circumference of the Flywheel)

- **DISTANCE =** Distance of the port opening or closing position marked on flywheel with respect to their dead centre.
- **CIRCUMFERENCE OF THE FLYWHEEL** = **62** cm

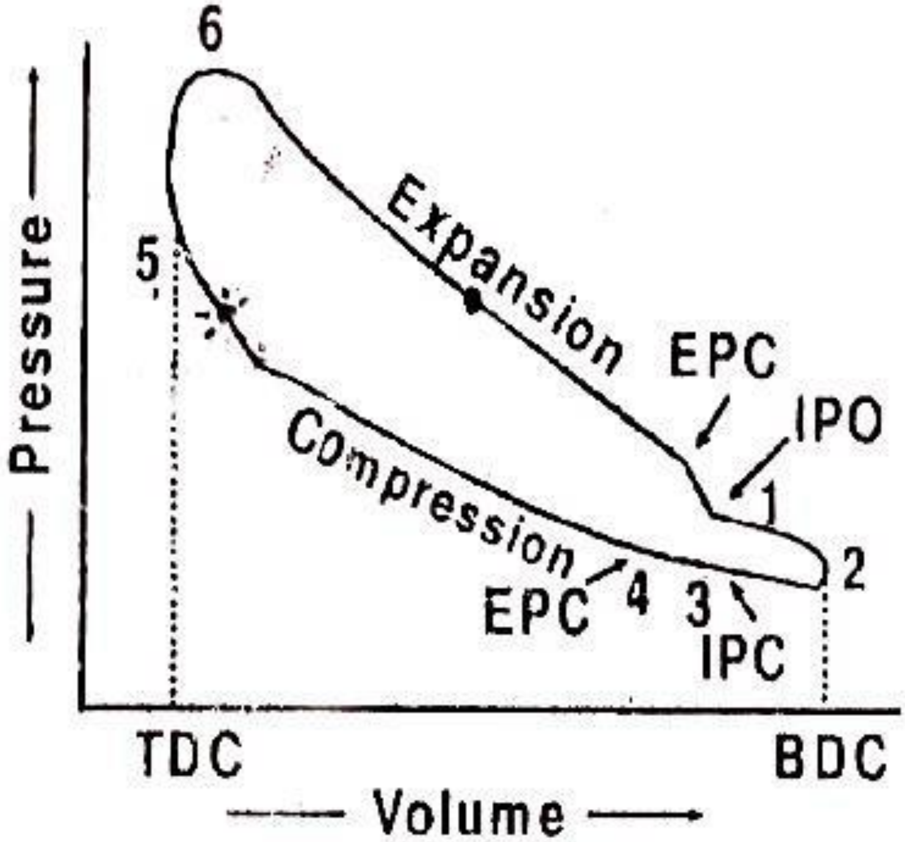
PROCEDURE:

1. First the TDC and BDC of the engine are found correctly by rotating the flywheel and the positions are marked on flywheel.
2. Now the circumference of the flywheel is found by using the measuring tape.
3. The piston moves upward stroke at the time air and fuel mixture gases in compressed and the at the same time fresh air and fuel mixture enters the crank chamber.
4. The piston is moving downwards due to expansion of the gases and the burnt exhaust gases escape through exhaust port.
5. The transfer port then is uncovered immediately and the compressed charge from the crank chamber.
6. The piston the again starts moving from BDC to TDC. Thus the cycle is repeated.

TABULATION: (ACTUAL P-v DIAGRAM OF TWO STROKE PETROL ENGINE)

EVENTS	DISTANCE FROM THEIR RESPECTIVE DEAD CENTRE IN 'CM'	PORT OPENING PERIOD IN 'DEGREES'
Exhaust Port Open **[EPO]**		
Exhaust Port Close **[EPC]**		
Transfer Port Open **[TPO]**		
Transfer Port Close **[TPC]**		

Model P-v diagram:



Indicator Diagram for a Two Stroke Cycle Petrol Engine.

RESULT:

Thus the actual P-v diagram for given two stroke petrol engine is drawn.

EX. NO :

5 DATE :

ACTUAL P-v DIAGRAM OF FOUR STROKE DIESEL ENGINE

AIM:

To diagram the Actual P-v diagram for the given four stroke Diesel engine.

APPRATUS REQUIRED:

1. Measuring tape
2. Chalk piece

FORMULA USED:

1. **REQUIRED ANGLE = (Distance X 360°) / (Circumference of the Flywheel)**
   - **DISTANCE =** Distance of the valve opening or closing position marked on flywheel with respect to their dead centre
   - **CIRCUMFERENCE OF THE FLYWHEEL** = 124cm

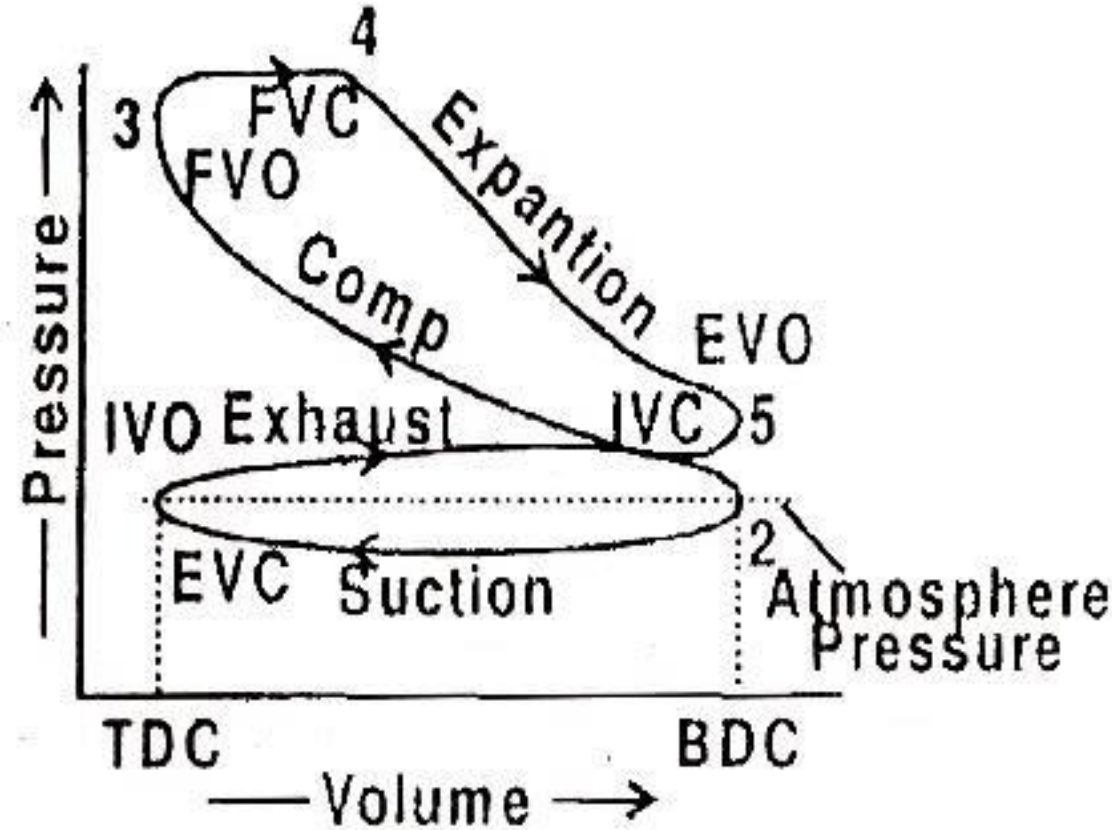
PROCEDURE:

1. Valves are opened and closed by cam mechanism.
2. Valves will balances on its seat are closed abrupt.
3. Opening or closed of valves spread over a certain crank angle
4. Inlet valve open before Top Dead Center (approx).
5. Inlet valve close before Bottom Dead Center (approx) to take advantage of rapidly moving gases.
6. Ignition occurs before Top Dead Center (approx).This to allow the time delay between the spark and commencement of combustion.
7. Exhaust valve open at Bottom Dead Center (approx), else pressure will rise enormously and the work required expecting the gas will increase.
8. Exhaust valve close at Top Dead Center (approx) this is to increases the volumetric efficiency.

<u>TABULATION</u> :(ACTUAL P-v DIAGRAM OF FOUR STROKE DIESEL ENGINE)

EVENTS	DISTANCE FROM THEIR RESPECTIVE DEAD CENTRE IN 'CM'	VALVE OPENING PERIOD IN 'DEGREES'
Inlet Valve Open **[IVO]**		
Inlet Valve Close **[IVC]**		
Exhaust Valve Open **[EVO]**		
Exhaust Valve Close **[EVC]**		

Model P-v diagram:



Indicator diagram for a Four Stroke Cycle Diesel Engines.

RESULT:

Thus the actual P-v diagram for given four stroke diesel engine is drawn.

EX. NO :

6 DATE :

PERFORMANCE TEST OF FOUR STROKE SINGLE CYLINDER DIESEL ENGINE

AIM

To find the load characteristics of four stroke single cylinder diesel engine

APPRATUS REQUIRED:

1. Stop watch.
2. Dead weights

FORMULA USED:

1. **BRAKE POWER:**

$$BP = \frac{2\Pi NT}{60} \quad \text{'KW'}$$

Where,

N=Engine speed in rpm
T=Torque = **W*Re**
Re = Brake drum radius =0.16m
W= Net load in N = ((W1-W2)*9.81)

2. **TOTAL FUEL CONSUMPTION:**

$$T.F.C = \frac{CC}{Tf} \times \text{specific gravity} \times \frac{3600}{1000}$$

Where,

T_f = Time taken to consume 10cc of fuel in seconds
CC = Amount of fuel consumption measured in cc
Specific gravity=0.86 for diesel

3. SPECIFIC FUEL CONSUMPTION:

$$\text{S.F.C} = \frac{\text{TFC}}{\text{Brake power}} \quad \text{'kg/kw-hr'}$$

4. FRICTIONAL POWER:

F.P= 35% to 40% of brake power

5. INDICATED POWER:

I.P= Brake power (BP) + Friction power (FP) 'kw'

6. MECHANICAL EFFICIENCY:

$$\eta_{mech} = \frac{\text{Brake power}}{\text{indicated power}} \times 100 \quad \%$$

7. INDICATED THERMAL EFFICIENCY:

$$\eta_{IT} = \frac{(IP \times 3600)}{(TFC \times CV)} \times 100 \quad \%$$

Where,

CV = Calorific Value of fuel in kJ/kg- 42,000 KJ/Kg for Diesel.

TFC = Total fuel consumption in kg/hr

8. BRAKE THERMAL EFFICIENCY:

$$\eta_{IT} = \frac{(BP \times 3600)}{(TFC \times CV)} \times 100 \quad \%$$

PROCEDURE:

1. The fuel in first filled in the tank.
2. Then the cooling arrangements are made.
3. Before starting the engine the break drum circumference is noted.
4. Before starting check and assure that there is no load on the weight.
5. Now the engine is started and the time taken for 10cc of fuel consumption is noted with help of a stop watch. This reading corresponds to load condition.
6. Now place weight in the weight hanger and the above mentioned readings. The spring balance reading is also noted down.
7. The above procedure is repeated for various loads the readings are tabulated.
8. The calculations are done and various graphs are plotted.

GRAPHS:

1. BP vs T.F.C
2. BP vs S.F.C
3. BP vs η_{mech}
4. BP vs η_{IT}
5. BP vs η_{BT}

TABULATION: **(PERFORMANCE TEST OF FOUR STROKE SINGLE CYLINDER DIESEL ENGINE)**

S. NO	Dead weight (W_1)	Rope weight (W_2)	Net load (W_1-W_2+1.5)	Time taken for 10cc of fuel consumption (T_f)	Brake power KW	Frictional power KW	Indicated power KW	T.F.C Kg/hr	S.F.C Kg/kw-hr	Brake thermal efficiency η_{BT}	Indicated thermal efficiency η_{IT}	Mechanical efficiency η_{mech}
1												
2												
3												

RESULT:

Thus the load test on four stroke single cylinder diesel engine is performed and its load characteristics are obtained.

EX. NO :

7 DATE :

HEAT BALANCE SHEET TEST ON FOUR STROKE SINGLE CYLINDER DIESEL ENGINE

AIM:

To conduct a test on single cylinder diesel engine and draw the heat balance sheet at various load.

APPRATUS REQUIRED:

1. Stop watch
2. Dead weights

FORMULA USED:

1. **HEAT SUPPLIED TO ENGINE:**

$$Q_s = (TFC * CV)$$

Where,

TFC = Total fuel consumption kg/min
CV = Calorific value of fuel =43000 kJ/kg

2. TOTAL FUEL CONSUMPTION

$$T.F.C = \frac{CC}{T_f} \times \text{specific gravity} \times \frac{3600}{1000} \text{ 'kg/hr'}$$

Where,

T_f = Time taken to consume 10cc of fuel in seconds
CC = Amount of fuel consumption measured in 'cc'
Specific gravity for diesel =0.86

3. HEAT EQUIVALENT TO BREAK POWER

$$Q_{BP} = B.P \times 60 \text{ 'KJ/min'}$$

4. HEAT CARRIED AWAY BY THE COOLING WATER (Q_W)

$$Q_w = Mw*C_{pw}(Two-Twi) \text{ in KJ/min}$$

Where,

M_w = Mass of cooling water circulated in kg/min

C_{pw} = Specific heat of cooling water =4.186 kJ/kg.k

T_{wi} = Temperature of cooling water at inlet in 'K'

T_{wo} = Temperature of cooling water at outlet in 'K'

5. MASS OF AIR ENTERING THE CYLINDER

$$M_a=c_d\times A\times\surd\ (2g\times h_w\times\rho_w\times\rho_a)$$

Where,

C_d = co-efficient of discharge of orifice meter=0.67

A = area of orifice meter in m^2 = Do=25mm,

ρ_w = density of water in kg/m^3=1000

ρ_a = density of air kg/m^3 =1.23

6. MECHANICAL EFFICIENCY:

$$M_g= M_a+M_f$$

Where,

Ma = mass of air consumed per minute

Mf = mass of fuel consumed per minute

M_f = TFC=Total fuel consumption kg/min

7. HEAT CARRIED AWAY BY THE EXHAAUST GAS (Qg):

$$Q_g=M_g\times C_{pg}\ (T_e-T_{wi})$$

Where,

M_g = Mass of the exhaust air in kg/min

C_{pg} = Specific heat of exhaust gas=1.005 kJ/kg.k

T_e = Temperature of exhaust gas in 'K'

- T_{wi} = Room temperature in 'K'

8. UNACCOUNTED HEAT LOSSES:

$$Q_{un}=Q_s-(Q_{BP}+Q_g+Q_w) \text{ ‘kJ/min’}$$

PROCEDURE:

1. From the name plate details, calculate the maximum load chat can be applied on the given engine.
2. Check the engine fuel availability, lubricant and cooling water connection.
3. Release the load on engine completely and start the engine with no load condition .allow the engine to run for few minute to attain the rated speed.
4. Apply the load from no load to required load slowly .at required load note the following.
5. Load on the engine.
6. Speed of the engine in rpm.
7. Time taken for 10cc of fuel consumption.
8. Manometer reading.
9. Temperature of cooling water at engine inlet and outlet in K.
10. Time taken for collection of cooling water.
11. Room temperature and exhaust gases temperature.

<u>TABULATION: 1</u> (HEAT BALANCE SHEET TEST ON FOUR STROKE SINGLE CYLINDER DIESEL ENGINE)

S. NO	Loading			Manometer reading in 'm'			Time taken for 10 cc fuel consumption 'sec'	Time for 5 liter water collection 'sec'	Water inlet temperature °C	Water outlet temperature °C	Exhaust gas temperature °C
	Dead weight W_1	Rope weight W_2	Net load $(w_1-w_2+1.5)$	H_1	H_2	$H=H_1-H_2$					
1											
2											
3											

<u>TABULATION: 2</u> (HEAT BALANCE SHEET TEST ON FOUR STROKE SINGLE CYLINDER DIESEL ENGINE)

Sl. no	Particulars	Credits KJ/min	%	Sl. no	Particulars	Debits KJ/min	%
1	Heat supplied to the engine(Qs)			1	Heat equivalent to brake power(Q_{BP})		
				2.	Heat carried away by cooling water (Q_w)		
				3	Heat carried away by exhaust gas (Q_g)		
				4	Unaccounted heat losses		
TOTAL				TOTAL			

RESULT:

Thus the load test on four stroke single cylinder diesel engine and draw the heat balance sheet at various load.

EX. NO :

8 DATE :

MORSE TEST ON MULTI CYLINDER PETROL ENGINE

AIM:

To find the frictional power and mechanical efficiency of the four stroke multi cylinder petrol engine by Morse test.

APPRATUS REQUIRED:

1. Tachometer.

FORMULA USED:

1. TOTAL BRAKE POWER (BP) = $BP_1 + BP_2 + BP_3 + BP_4$

a) ALL CYLINDERS ARE WORKING CONDITION:

$$\text{BRAKE POWER } (BP_{1234}) = \frac{2\Pi NT}{60} \text{ 'KW'}$$

Where,

N=Engine speed in rpm for all cylinder working
T=Torque = W*Re
Re = Brake drum radius in cm
W= dead weight in kg

b) First cylinder was cut-off and remaining are in working

$$\text{BRAKE POWER } (BP_{234}) = \frac{2\Pi NT}{60} \text{ 'KW'}$$

Where,

N=Engine speed in rpm for first cylinder cut-off and remaining are working

- **First cylinder brake power (BP_1) = $BP_{1234} - BP_{234}$ 'kW'**

ii. Second cylinder was cut-off and remaining are in working

$$\textbf{BRAKE POWER } (\mathbf{BP_{134}}) = \frac{2\Pi NT}{60} \text{ 'KW'}$$

Where,

N=Engine speed in rpm for Second cylinder cut-off and remaining are working

- **Second cylinder brake power (BP_2) = BP_{1234}-BP_{134} 'kW'**

iii. Third cylinder was cut-off and remaining are in working

$$\textbf{BRAKE POWER } (\mathbf{BP_{124}}) = \frac{2\Pi NT}{60} \text{ 'KW'}$$

Where,

N=Engine speed in rpm for Third cylinder cut-off and remaining are working

- **Third cylinder brake power (BP_3) = BP_{1234}-BP_{124} 'kW'**

iv. Fourth cylinder was cut-off and remaining are in working

$$\textbf{BRAKE POWER } (\mathbf{BP_{123}}) = \frac{2\Pi NT}{60} \text{ 'KW'}$$

Where,

N=Engine speed in rpm for Fourth cylinder cut-off and remaining are working

- **Fourth cylinder brake power (BP_4) = BP_{1234}-BP_{123} 'kW'**

2. FRICTIONAL POWER:

- 30 % of Brake power (For petrol engine)

3. INDICATED POWER:

I.P= B.P+ F.P ‘kw’

4. MECHANICAL EFFICIENCY:

$$\eta_{mech} = \frac{BP}{IP} \times \text{‘KW’}$$

PROCEDURE:

1. Calculate maximum speed in rpm.
2. Check the engine for no load coolant supply.
3. Connect the battery terminals.
4. Ensure on position of 4 switches to spark plug.
5. Apply gradually speed is adjust throttle.
6. Now down the speed and load.
7. Connect the first spark plug and disconnect the seconds plug.
8. Repeat the same for remaining cylinder.
9. Remove load and run engine for two minutes switch off the engine and coolant close supply.

<u>TABULATION</u>: (ORSE TEST ON MULTI CYLINDER PETROL ENGINE)

SL .NO	SPEED ON THE ENGINE RPM					LOAD ON THE ENGINE	BRAKE POWER	INDICATED POWER	FRICTIONAL POWER	MECHANICAL EFFICIENCY
	All cylinder	Cut off 1	Cut off 2	Cut off 3	Cut off 4					

RESULT:

The frictional power and mechanical efficiency of the four stroke petrol engine are found out by conducting Morse test.

HEAT TRANSFER LAB

THERMAL CONDUCTIVITY – GUARDED HOT PLATE METHOD

AIM:

To find the thermal conductivity of the specimen by two slabs guarded hot plate method.

SPECIFICATIONS:

- Specimen material = Asbestos
- Thickness of the specimen L = 24 mm= 12+12=24 mm
- Diameter of cylinder D = 150 mm

FORMULAE:

1. **HEAT INPUT:**

The power input to heater

$$Q = V \times I \text{ in } \textit{Watts}$$

Where,

Q = heat input
V = volts
I = current in amps

2. **THERMAL CONDUCTIVITY(K):**

$$K = \frac{(q \times L)}{A \times AT} \text{ in } W/m\,K$$

- * Two specimen pieces, so one at the top and another one at the bottom.
- * Thermal conductivity of specimen $K = \frac{(K_1 + K_2)}{2}$

Where,

$$K_1 = \frac{(q \times L_1)}{A \times \Delta T_1} \qquad K_2 = \frac{(q \times L_2)}{A \times \Delta T_2}$$

- q= heat input in *watts*
- L= thickness of the specimen = 76.20 *mm*
- L_1 = lower specimen =12 *mm*
- L_2 = upper specimen =12 *mm*
- A = area of the specimen

$$\Delta T_1 = \frac{(T_2+T_3)}{2} - T_7$$ in *K* **(LOWER SIDE**)

$$\Delta T = \frac{(T_5+T_6)}{\quad} - T$$ in *K* **(UPPER SIDE**)

PROCEDURE:

1. Switch on the unit, allows the unit to stabilize for about 15 to 25 minutes.
2. Now vary the voltmeter reading and note down the temperature T_1 to T_2 ammeter reading.
3. The average temperature of each cylinder is taken for calculation. The temperature

TABULATION:

THERMAL CONDUCTIVITY – GUARDED HOT PLATE METHOD

S.No	**Heat Input** *'W'*			**Main Heater** ^0C	**Ring Heater** ^0C	**Bottom Specimen Temperature** ^0C		**Top specimen Temperature** ^0C		**Water Outlet Temperature** ^0C		**Water Inlet Temperature** ^0C	**Thermal Conductivity K** *(W/mK)*
	V	**I**	**Q =V X I**	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_8**	**T_9**	

RESULT:

The thermal conductivity of the specimen is found to be **(K) =**__________________ *W/mK***.**

THERMAL CONDUCTIVITY - LAGGED PIPE METHOD

AIM:

To find the thermal conductivity of the specimen by lagged pipe method.

DESCRIPTION OF APPARATUS:

The apparatus consists of a guarded hot pipe and cold pipe. A specimen whose thermal conductivity is to be measured is saw dust between the hot and cold pipe thermocouple are attached to measure temperature in between the hot pipe and specimen pipe.

A multi point digital temperature with indicator selector switch is provided to not the temperature at different locators. An electric regulators is provided to not and vary the input energy to the heater.

The whole assembly in kept in an enclose with insulating material field all around to minimum to the heat loss

FORMULAE:

1. **HEAT INPUT:**

The power input to heater

$$Q = V \times I \text{ in } Watts$$

Where,

Q = heat input
V = volts
I = current in *amps*

2. **THERMAL CONDUCTIVITY(K):**

$$K = \frac{\left(q \times \ln\left(\frac{r_2}{r_1}\right)\right)}{2G \times L \times AT} \text{ in } W/m^2 k$$

Where,

- q = Heat input supply in watts
- K = Thermal conductivity *W/m k*
- r_1= Radius of inner pipe = 25.40 *mm*
- r_2= Radius of outer pipe = 76.20 *mm*
- L = Length of the pipe =500 *mm*
- ΔT=Average outside temperature inner pipe- Average in side temperature outer pipe

$$\Delta T = \frac{(T_1+T_2+T_3)}{3} - \frac{(T_4+T_5+T_6)}{3} \quad \text{in } K$$

Where,

- T1,T2,T3=Outside temperature inner pipe
- T4,T5,T6=Inside temperature outer pipe

PROCEDURE:

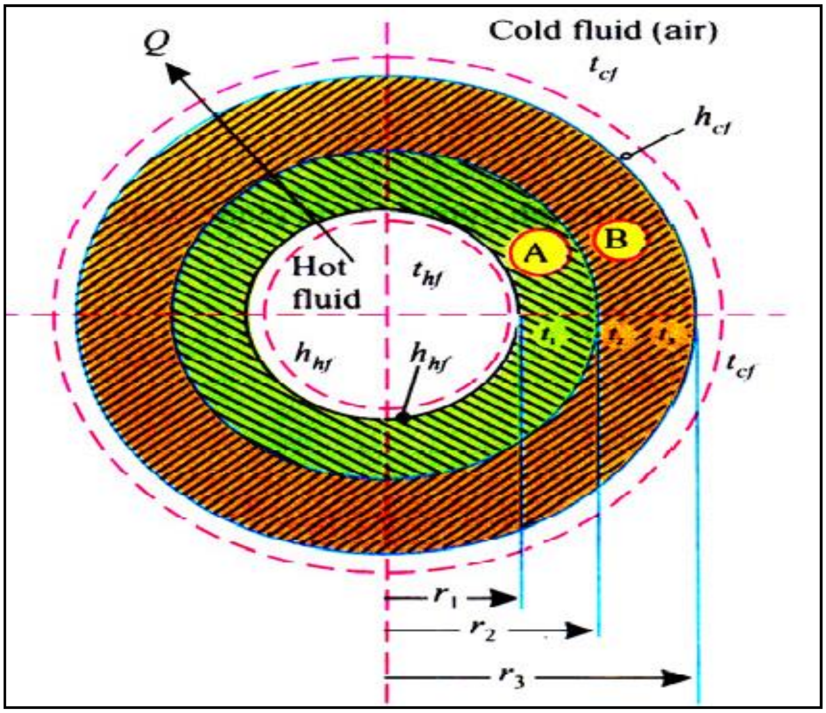
1. Switch on the unit, allows the unit to stabilize for about 15 to 25 minutes.
2. Now vary the voltmeter reading and note down the temperature T_1 to T_2 ammeter reading.
3. The average temperature of each cylinder is taken for calculation. The temperature is measured by thermocouples with input multipoint digital temperature indicator.

TABULATION:

THERMAL CONDUCTIVITY - LAGGED PIPE METHOD

Sl.No	Heat Input 'W'			Outside Temperature Of Inner Pipe ^0C				Inside Temperature Of Inner Pipe ^0C				Thermal Conductivity(K) 'W/mK'
	V	I	Q=V X I	T_1	T_2	T_3	AVG	T_4	T_5	T_6	AVG	

DIAGRAM:



RESULT:

The thermal conductivity of the specimen is found to be **(K) =**________________ *W/mK.*

DETERMINATION OF HEAT TRANSFER COEFFICIENT UNDER NATURAL CONVECTION FROM A VERTICAL CYLINDER

AIM:

To determine the convective heat transfer co-efficient for heated vertical cylinder losing heat to the ambient by free or natural convection

DESCRIPTION OF APPARATUS:

Convection is a made of heat transfer where by a moving fluid transfer heat from a surface when the fluid movement is caused by density differences in the fluid due to temperature variation. It is called **FREE or NATURAL CONVECTION**.

The apparatus provides students with a sound introduction to the features of free convection heat transfer from a heated vertical rod. A vertical duct is fitted with a heated vertical placed cylinder. Around this cylinder air gets heated and becomes less dense causing in to rise. This turn gives to a continuous flow of air upwards in the duct. The instrumentation provides give the heat input and the temperature at different points on the heated cylinder.

SPECIFICATIONS:

- Length of cylinder L = 450 mm
- Diameter of cylinder D = 48 mm

FORMULA USED:

1. THEORETICAL HEAT TRANSFER CO-EFFICIENT (h_{the}):

$$h_{the} = \frac{(Nu.K)\,L}{} \quad \text{in } W/m^2\,K$$

Where,

- Nu = Nusselt number
- K = Thermal conductivity of air in $W/m\,K$
- L = Characteristics Length is height of the cylinder in mm

A. Nusselt number (Nu):

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

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

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

Where,

- ➢ h = heat transfer co-efficient
- ➢ L = Characteristics Length is height of the cylinder in mm
- ➢ Gr = Grashoft number
- ➢ Pr = prandtl number of air

B. Grashoft number (Gr):

$$Gr = \frac{(L^3 \times \beta \times g \times \Delta T)}{V^2}$$

Where,

- ➢ h= heat transfer co-efficient
- ➢ L = Characteristics Length is height of the cylinder in mm
- ➢ g = Acceleration due to earth's gravity
- ➢ $\Delta T = T_s - T_a$ in K
- ➢ T_s=Average surface temperature in K
- ➢ T_a=Average ambient temperature in K
- ➢ $\beta = 1/T_f$ in K
- ➢ V^2=Kinematic viscosity of air at film temperature

C. Film temperature (T_f):

$$T_f = \frac{(Ts - Ta)}{2} \text{ in K}$$

Where,

- ➢ T_f = Film temperature in K
- ➢ T_s=Average surface temperature in K
- ➢ T_a=Average ambient temperature in K

*****NOTE*****

The following air properties data should be taken from the HMT Data book for film temperature (T_f)

Air properties

- Pr =Prandtl number
- K = Thermal conductivity of air in *W/m K*
- υ = Kinematic viscosity of air in
- ρ_a = Density of air

2. EXPERIMENTAL HEAT TRANSFER CO-EFFICIENT (h_{exp}):

The power input to heater

$$q = V \times I \text{ in Watts}$$

Where,

Q =heat input

V =volts

I = current in amps

$$h_{exp} = \frac{q}{A \times \Delta T}$$

Where,

A = Area of pipe

ΔT = Ts-Ta in K

ΔT = Tube temperature -Air temperature in K

TABULATION:

DETERMINATION OF HEAT TRANSFER COEFFICIENT UNDER NATURAL CONVECTION FROM A VERTICAL CYLINDER

Sl.No	Heat Input ‘W’			Surface Temperature °C								Ambient Temperature °C	Heat Transfer Co-Efficient Of Theoretical (h_{the})	Heat Transfer Co-Efficient Of Experimental (h_{exp})
	V	I	Q=V*I	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_S	T_8		

RESULT:

1. The theoretical heat transfer co-efficient is found to be $\mathbf{h_{the}}$= ___________ W/m^2K.

2. The experimental heat transfer co-efficient is found to be $\mathbf{h_{exp}}$= ___________ W/m^2K.

DETERMINATION OF HEAT TRANSFER COEFFICIENT UNDER FORCED CONVECTION FROM A TUBE.

AIM:

1. To determine the convective heat transfer co-efficient for a horizontal pipe through which air flow under forced convection
2. To find the theoretical heat transfer co-efficient for the above condition and to compare with the experimental value.

SPCIFICATION:

- Inside diameter of the pipe (D)=25 mm
- Orifice diameter (d_o) =20 mm
- Length of the pipe (L) =400 mm

PROCEDURE:

1. Switch on the main and on the blower.
2. Adjust the regulator to any desired power into input to heater.
3. Adjust the position of the valve to any desired flow rate of air.
4. Wait till steady state temperature is reached.
5. Note down the manometer reading h_1, h_2 and temperatures T_1, T_2, T_3, T_4, T_5, T_6 and T_7.
6. Take the voltmeter and ammeter reading.
7. Adjust the position of the valve and vary the flow rate of air and repeat the experiment.
8. For various valve openings and for various power inputs the readings may be taken to repeat the experiments.

FORMULA USED:

1. THEORETICAL HEAT TRANSFER CO-EFFICIENT (h_{the}):

$$h_{the} = \frac{(N_u.K)}{D} \quad \text{in } W/m^2 K$$

Where,

Nu = Nusselt number

K = Thermal conductivity of air in *W/m K*

D = Diameter of the tube in *mm*

A. REYNOLDS NUMBER (Re):

$$Re = \frac{(UD)}{y}$$

Where,

U = velocity of flow in *m/s*

D =Diameter of the specimen =25 *mm*

B. NUSSELT NUMBER (Nu):

$$Nu = C.Re^{n}.Pr^{1/3}$$

Where,

Re =Reynolds number

Pr =Prandtl number

For,

Re = 0.4 to 4.0		C = 0.989 & n = 0.33
Re = 4 to 40		C = 0.911 & n = 0.385
Re = 40 to 4000	E	C = 0.683 & n = 0.466
Re = 4000 to 40000		C = 0.293 & n = 0.618
Re = 40000 to 400000		C = 0.27 & n = 0.805

C. VELOCITY OF FLOW (U):

$$U = (Q/A) \quad \text{in } m^3/sec$$

Where,

Q = Discharge of air m^3/sec

A = Area of pipe = ΠDL

D. DISCHARGE OF AIR (Q):

$$\mathbf{Q = C_d \times a_o \times \sqrt{(2g.H_{air})}} \quad \text{in } m^3/sec$$

Where,

C_d = Co-efficient of discharge = 0.62

a_o = Area of orifice = $\pi/4 \times \mathbf{d}_0^2$

H_{air} = Heat of air = $\left(\frac{q_w - q_{air}}{q_{air}}\right) \times \mathbf{H_m}$

****NOTE****

The following air properties data should be taken from the HMT Data book for mean temperature (T_m).

Air properties

Pr =Prandtl number

K = Thermal conductivity of air in W/m K

υ = Kinematic viscosity of air

ρ_a = Density of air

E. MEAN TEMPERATURE:

$$\mathbf{T_m} = \frac{(T_s+T_a)}{2} \quad \text{in } °C$$

Where,

T_s – Surface temperature of tube *°C*

T_a – Temperature of air *°C*

F. TEMPERATURE OF SURFACE OF THE PIPE (Ts):

$$\mathbf{T_s} = \frac{(T_2+T_3+T_4+T_5+T_6)}{5} \quad \text{in } K$$

G. AIR TEMPERATURE (Ta):

$$\mathbf{T_a} = \frac{(T_1+T_7)}{2} \quad \text{in } K$$

2. EXPERIMENTAL HEAT TRANSFER CO-EFFICIENT (h_{exp}):

The power input to heater

$$q = V \times I \text{ in Watts}$$

Where,

q=heat input

V=volts

I= current in amps

$$h_{exp} = \frac{q}{A \times \Delta T}$$

Where,

A = Area of pipe, $\Delta T = T_a - T_s$ in *K*

ΔT = Air Temperature-Tube temperature in *K*

TABULATION:

Determination of heat transfer coefficient under forced convection from a tube.

Sl.No	Heat Input 'W'			Manometer Reading 'm'			Air Temperature °C		Tube Temperature °C						Heat Transfer Co-Efficient Of Theoretical (h_{the})	Heat Transfer Co-Efficient Of Experimental (h_{exp})
	V	I	Q	h_1	h_2	h	T_1	T_7	T_2	T_3	T_4	T_5	T_6	T_S		

RESULT:

Thus the convective heat transfer co-efficient for convection

1. Theoretical heat transfer co-efficient is $\mathbf{h_{the}}$ = __________ W/m²K.
2. Experimental heat transfer co-efficient is $\mathbf{h_{exp}}$ = __________ W/m²K.

HEAT TRANSFER FROM A PIN- FIN APPARATUS

AIM:

To calculate the value of heat transfer coefficient from the fin for forced convection.

INTRODUCTION:

Extended surfaces of fins are used to increase the heat transfer rate from a surface to a fluid wherever it is not possible to increase the value of the surface heat transfer coefficient or the temperature difference between the surface and the fluid.

The use of this is variety of shapes. Circumferential fins around the cylinder of a motor cycle engine and fins attached to condenser tubes of a refrigerator are a few familiar examples.

It is obvious that a fin surface sticks out from the primary heat transfer surface. The temperature difference with surrounding fluid will steadily diminish as one move out along the fin. The design of the fins therefore required knowledge of the temperature distribution in the fin. The main objective of this experimental set up is to study temperature distribution in a simple pin fin.

APPARATUS:

A brass fin of circular cross section in fitted across a long rectangular duct. The other end of the duct is connected to the suction side of a blower and the air floes past the fin perpendicular to the axis. One end of the fin projects outside the duct and is heated by a heater. Temperature at five points along the Length of the fin. The air flow rate is measured by an orifice meter fitted on the delivery side of the blower.

EXPERIMENTAL PROCEDURE:

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

FORCED CONVECTION**:**

1. Stat heating the fin by switching ON the heater and adjust dimmer stat voltage 80 to 100 volts.
2. Start the blower and adjust the difference of level in the manometer with the help of gate valve.
3. Note down the thermocouple reading (1) to (5) at a time interval of 5 minutes.
4. When the steady state is reached, record the final reading (1) to (5) and also record the ambient temperature reading (6).

5. Repeat the experiment with different manometer readings.

RESULT FROM EXPERIMENTAL:

FORCED CONVECTION:

1. Plot the temperature distribution along the length of the fin from observed readings
2. Calculate the value of m and obtain the temperature at various locations along the length of fin by using equation and plot them.
3. Calculate Re and Pr and obtain Nu from equation
4. Calculate the value of heat transfer rate from the fin and fin effectiveness by using equation.
5. Repeat the same procedure for all other sets of observations.

Specification:

❖ fin material		= brass	
❖ Length of the fin	(L_f)	=150mm	= 0.15m
❖ diameter of the fin	(d_f)	=12mm	= 0.012m
❖ diameter of the pipe	(d_p)	=38mm	=0.038m
❖ diameter of the orifice	(d_o)	=20mm	= 20mm
❖ with of the duct	(w)	= 150mm	=0.15m
❖ breath of the duct	(b)	= 100mm	=0.1m
❖ co- efficient of discharge	(c_d)	= 0.62	
❖ density of water	(ρ_w)	=1000 Kg/m^3	
❖ density of Air	(ρ_a)	=1.165 Kg/m^3	

1. **HEAT CONVECTIVE TRANSFER CO-EFFICIENT (h_c):**

$$h_c = \frac{Nu.k}{D} \quad \text{W/m}_2\text{ K}$$

Where,

Nu =Nusselt number

K = thermal conductivity of air in W/mK

D = diameter of the fin in m

A. **NUSSELT NUMBER (Nu):**

$$Nu = C.Re^n.Pr^{1/3}$$

Where

Re = 0.4 to 4.0	C = 0.989 & n = 0.33
Re = 4 to 40	C = 0.911 & n = 0.385
Re = 40 to 4000	C = 0.683 & n = 0.466
Re = 4000 to 40000	C = 0.293 & n = 0.618
Re = 40000 to 400000	C = 0.27 & n = 0.805

B. **REYNOLDS NUMBER (Re):**

$$Re = \frac{V_a\, d_f}{v}$$

Where,

V_a = velocity of air in duct in m/s d_f = diameter of fin in m

v = kinematic viscosity m^2/s

C. **Velocity of air in duct (V_a):**

$$V_a = \frac{V_0 \times \frac{\pi}{4} \times d_0^2}{w \times b}\ \text{m/s}$$

Where,

V_o=velocity at orifice

d_0 = dia of orifice

D. **Velocity at orifice (V_0):**

$$V_0 = c_d \times \sqrt{2gh\left(\frac{\rho_w - \rho_a}{\rho_a}\right)} \times \left(\frac{1}{\sqrt{1-\beta^4}}\right) \text{m/s}$$

Where,

$$\beta = \frac{d_0}{d_p} = \frac{\text{dia of orifice}}{\text{dia of pipe}}$$

E. **Mean temperature T_m:**

$$T_m = \frac{T_s + T_a}{2}\ ^\circ C$$

F. **surface temperature T_S:**

$$T_s = \frac{T_1 + T_2 + T_3 + T_4 + T_5}{5}\ ^\circ C$$

NOTE

The following air properties data should be taken from the HMT Data book for surface temperature (T_s)

Pr = Prandtl number of air

K = Thermal conductivity of air N

= Kinematic viscosity

ρ = density of air

1. *To find m*

$$m=\sqrt{\frac{h_c \times p}{K \times A}}$$ from HMT D.B.Pg.No:50

Where,

h_c= convective heat transfer co-efficient in W/m^2 K

p =perimeter = $\pi \times d_f$

k=110.7 W/m^2 K (brass)

A= cross section area of fin = $\pi/4 \times d_f^2$

2. Effectiveness of fin (S)

$$S=\sqrt{\frac{K \times P}{h_c \times A}} \tan h \, mL$$

3. Efficiency of fin (η)

$$\eta=\frac{\tanh (m(L-x))}{K \times A} \times 100 \%$$

4. Temperature distribution:

$$\frac{T-T_a}{T_b-T_a} = \frac{\cosh (m(L-x))}{\cosh (m x L)}$$

Where,

Ta- Ambient Temperature °C

T_b- base temperature °C

TEMPERATURE DISTRIBUTION:

Given thermocouple distance:

S.NO	Experimental temperature °C	Calculated Temperature °C	Distance of the thermo couple 'm'
1	T_1=		0.02
2	T_2=		0.05
3	T_3=		0.08
4	T_4=		0.11
5	T_5=		0.14

`	Heat Input ‘W’			Fin Temperature °C						Manometer Reading ‘m’			Ambient Temperature °C	Effectiveness (E)	Efficiency (η)
	V	I	Q	T_1	T_2	T_3	T_4	T_5	T_{AVG}	h_1	h_2	H	T_a		

RESULT:

Heat transfer co-efficient, effectiveness and efficiency are calculated

1. Heat transfer co-efficient ______________________________ W/m^2 K
2. Effectiveness of the fin ______________________.
3. Efficiency of the fin ______________________%

STEFAN – BOLTZMANN APPARATUS

AIM:

To find value of Stefan – Boltzmann constant for radiation heat transfer.

STEFAN – BOLTZMANN LAW:

Stefan – Boltzmann law state that the total emissive power of a perfect black body is proportional to fourth power of the absolute temperature.

$$E_b = \sigma T^4$$

- σ - Stefan – Boltzmann constant

SPECIFICATIONS:

- Material of the disc & hemisphere = Copper
- Diameter of the disc = 20 mm
- Mass of the disc = 5 grams $=5\times10^{-3}$ Kg
- Specific heat capacity of the copper = 383 J/ Kg K

PROCEDURE:

1. Switch on the heater; heat the water in the tank about 80 °C.
2. Allow the hot water to flow through the hemisphere and allow the hemisphere to reach a steady temperature.
3. Note down the temperature $\mathbf{T_1}$ and $\mathbf{T_2}$. Average of these temperatures is the hemisphere temperature **($\mathbf{T_{avg}}$)**
4. Refit the disc at the bottom of the hemisphere and start the stop clock.
5. The raise in temperature $\mathbf{T_3}$ with respect to time is noted.

FORMULAE:

Heat Equation:

Rate of Change of Heat Capacity of the Disc = Net Energy Radiated on the Disc

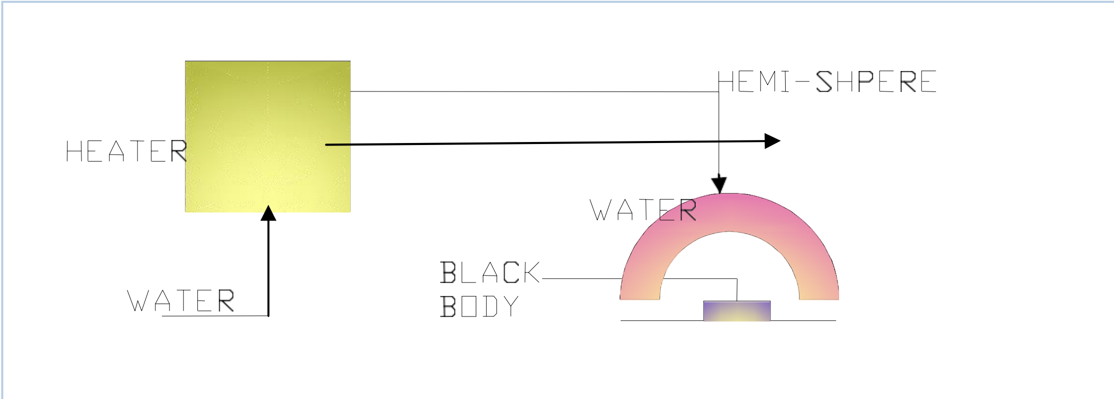
$$1.\ m \times C_p \frac{dT}{dt} = \sigma A_D \left(T_{avg}^4 - T_D^4\right)$$

$$2.\ \sigma = \frac{m \times C_p \frac{dT}{dt}}{A_D \left(T_{avg}^4 - T_D^4\right)} \quad \left(\mathbf{W/m^2\ K^4}\right)$$

3. $T_{avg} = (T_1+T_2+T_3)/3$ (K)

Specification:

- σ - Stefan – Boltzmann constant
- m - Mass of the disc in kg
- C_P - Specific heat capacity of the copper = 383 J/ Kg K
- dT -Change in Temperature in (K)
- dt - Change in Temperature in seconds
- A_D - Area of the disc
- T_{avg} - Average Temperature
- T_D - Temperature of the disc before inserting into the plate



TABULATION:

STEFAN – BOLTZMANN APPARATUS

Temperature of the disc before inserting into the plate T_D =

S.no	Hemisphere (Left side) **(T_1)** °C	Hemisphere (Right side) **(T_2)** °C	hot water Temperature **(T_4)** °C	Avg. temperature of hemisphere **(T_{avg})** K	Stefan – Boltzmann constant $W/m^2\ K^4$

Temperature Time Responses:

Time (sec) **t**	Temperature of the disc ($\mathbf{T_3}$) **°C**	Temperature in **K**
0		
20		
30		
40		
60		
80		
100		

GRAPH:

dT vs dt

RESULT:

Stefan – Boltzmann constant is found to be ------------------------------ $W/m^2 K^4$.

DETERMINATION OF EMISSIVITY OF TEST SURFACE

AIM:

To measure the emissivity of the test plate surface

DESCRIPTION OF APPARATUS:

An ideal block surface is one, which absorbs the radiation falling on it. Its reflectivity and transivity is zero. The radiation emitted per unit time per unit area from the surface of the body is called emissive power.

The emissive power of a body to the emissive power of black body at the same temperature is known as emissivity of that body.

For a black body absorbvity is 1, emissivity depends on the surface temperature and the nature of the surface.

The experimental set up consists of two circular aluminum plates identical in size and is provided with heating coils at the bottom. The plates are mounted on thick asbestos sheet and kept in an enclosure so as to provide undisturbed natural convection surrounding. The heat input to the heaters is varied by two regulators and is measured by an ammeter and voltmeter. The temperatures of the plates are measured by thermocouples. Each plate is having three thermocouples; hence an average temperature may be taken. One thermocouple is kept in the enclosure to read the chamber temperature.

One plate is blackened by a layer of enamel of black paint to from the idealized black surface whereas the other plate is the test plate. The heat dissipation by conduction is same in both cases.

SPECIFICATION:

- Diameter of test plate and black surface = 150mm

PROCEDURE:

1. Connect the unit to the supply and switch on the unit.
2. Keep the thermocouple selector switch in first position.
3. Keep the toggle switch in position (1.**power will be feed to block plate &** position 2. **power will be feed to test surface plate) allow** the unit to stabilize. Ascertain the power inputs to the block and test surfaces are at set values i.e. equal.
4. Turn the thermocouples selector switch clockwise step by step note down the temperatures indicated by the temperature indicator from channel 1 to 7.
5. Tabulate the readings for various power inputs repeat the experiment.
6. After the experiment is over turn off both the energy regulations 1&2.

FORMULAE:

1. **HEAT INPUT**:

$$q = V \times I \text{ in watts}$$

Where,

Voltmeter = V volts
Ammeter = I amps

2. **AVERAGE BLACK BODY TEMPERATURE:**

$$T_b = \frac{T1+T2+T3}{3} \; °C$$

3. *AVERAGE TEST SURFACE TEMPERATURE:*

$$T_t = \frac{T4+T5+T6}{3} \; °C$$

4. *EMISSIVITY OF TEST SURFACE:*

Heat input to block surface=heat input to test surface

$$q = E_b \times A_b \times (T_b^4 - T_a^4) = E_t \times A_t \times (T_t^4 - T_a^4)$$

Since the power input is same for both block and test surface is also same, knowing the Sb=1

$$E_t = E_b \frac{(T_b^4 - T_a^4)}{(T_t^4 - T_a^4)}$$

Where,

- S_t =emissivity of block surface
- S_b =emissivity of block surface=1
- T_b = Average block body temperature in K
- T_t = Average test surface temperature in K

TABULATION:

DETERMINATION OF EMISSIVITY OF TEST SURFACE

Sl.No	Heat Input 'W'			Black Body Temperature °C				Test Body Temperature °C				Ambient Temperature °C	Emissivity Of Test Surface
	V	I	Q	T_1	T_2	T_3	T_B	T_4	T_5	T_6	T_T	Ta	E_t

RESULT:

The emissivity of a test surface is -- --.

EFFECTIVENESS OF PARALLEL AND COUNTER FLOW HEAT EXCHANGER

AIM:

To determine LMTD, the effectiveness and the overall heat transfer co-efficient for parallel and counter flow heat exchange.

Apparatus required:

- ❖ Heat exchange test rig
- ❖ Supply of hot and cold water
- ❖ Stop watch
- ❖ Measuring jar

Specification:

1. Inner tube material – copper
   - Inner diameter, d_i = 9.5mm
   - Outer diameter, d_o = 12.5mm
2. Outer tube material – galvanized iron
   - Inner diameter, D_i = 28.5mm
   - Outer diameter, D_o = 32.5mm
3. Length of heat exchanger L = 1500mm

Formula:

1. **HEAT TRANSFER FROM HOT WATER:**

$$q_b = m_h \times C_{ph} \times (T_{hi} - T_{ho}) \text{ in W}$$

Where,

- ➢ M_h = mass flow rate of hot water
- ➢ C_{ph} = specific heat of water = 4187 J/kg K
- ➢ T_{ho} = hot water outlet temperature K
- ➢ T_{hi} = hot water inlet temperature K

2. **HEAT GAINED BY COLD WATER:**

$$q_c = m_c \times C_{pc} \times (T_{co} - T_{ci}) \text{ in W}$$

Where,

- **Mc** = mass flow rate of cold water
- C_{ph} = specific heat of water = 4187 J/kg K
- T_{co} = temperature of cold water outlet in K
- T_{ci} = temperature of cold water inlet in K

3. **AVERAGE HEAT TRANSFER(Q_{AVG}):**

$$q_{avg} = (q_c + q_h)/2 \quad \text{in W}$$

4. **LOGARITHMIC MEAN TEMPERATURE DIFFERENCE (LMTD):**

$$LMTD = \frac{(\phi_1 - \phi_2)}{\ln\left(\frac{\phi_1}{\phi_2}\right)} \quad \text{in K}$$

Where,

$\phi_1 = T_{hi} - T_{ci}$, $\phi_2 = T_{ho} - T_{co}$, **for parallel flow.**

$\phi_1 = T_{hi} - T_{co}$, $\phi_2 = T_{ho} - T_{ci}$, **for counter flow**.

5. **OVER ALL HEAT TRANSFER CO-EFFICIENT BASED ON OUTSIDE SURFACE AREA OF INNER TUBE:**

$$U_O = \frac{(q_{avg})}{(A_O \times LMTD)} \text{ in } (W/m^2K)$$

Where,

$$A_O = \pi d_o l \quad \text{in } m^2$$

6. **EFFECTIVENESS:**

a) $$E = \left(\frac{(m_h \times C_h)}{C_{min}}\right)\left(\frac{(T_{hi} - T_{ho})}{(T_{hi} - T_{ci})}\right)$$

For $m_h \times C_h = C_{min}$

b) $$E = \left(\frac{(m_c \times C_c)}{C_{min}}\right)\left(\frac{(T_{co} - T_{ci})}{(T_{hi} - T_{ci})}\right)$$

For $m_c \times C_c = C_{min}$

Tabulation I: Parallel Flow

S.No	Hot water collect for 20 sec ‘ml’	Cold water collect for 20 sec ‘ml’	Temperature of hot Water ° C		Temperature of cold Water ° C		Logarithmic mean Temperature Difference (LMTD) (K)	Over all heat transfer co-efficient (W/m^2K)	Effectiveness
			Inlet T_{hi} (T_1) °C	Outlet T_{ho} (T_2) °C	Inlet T_{ci} (T_3) °C	Outlet T_{co} (T_4) °C			

Tabulation II: Counter Flow

S.No	Hot water collect for 20 sec ‘ml’	Cold water collect for 20 sec ‘ml’	Temperature of hot Water ° C		Temperature of cold Water ° C		Logarithmic mean Temperature Difference (LMTD) (K)	Over all heat transfer co-efficient (W/m^2K)	Effectiveness
			Inlet T_{hi} (T_1) °C	Outlet T_{ho} (T_2) °C	Inlet T_{ci} (T_4) °C	Outlet T_{co} (T_3) °C			

****NOTE****

‘a’ can be used $(m_h \times C_h) < (m_c \times C_c)$

‘b’ can be used $(m_h \times C_h) > (m_c \times C_c)$

Result:

LMTD, Effectiveness and the overall heat transfer co-efficient of parallel & counter flow are calculated.

Flow type	**Logarithmic mean temperature difference (LMTD)** **‘(K)’**	**Over all heat transfer co-efficient based on outside surface area of inner tube** **‘(W/m^2K)’**	**Effectiveness**
Parallel flow			
Counter flow			

REFRIGERATION AND

AIR CONDITIONING LAB

EXPERMENTS ON REFRIGERATION SYSTEM

Aim:

To determine the (i) Experimental COP, (ii) Carnot COP, (iii) Relative COP of a refrigeration system.

Apparatus required:

1. Refrigeration test rig
2. stop watch

Procedure:

1. Switch on the mains and switch on the fan motor and then compressor motor.
2. Allow the plant to run to reach steady conditions. Take readings for every 5 minutes to know the steady state.
3. Observe the readings in compressor motor energy meter. Pressure gauges and thermocouple and record it is tubular form.
4. Switch off the plant after experiment is over by switching off the compressor motor first. Allow the fan motors to run for 10 minutes and then switch off.

Abbreviation and notation:

P_1= pressure of the refrigerant before the compressor. P_2= pressure of the refrigerant after the compressor.
P_3= pressure of the refrigerant before the expansion valve. P_4= pressure of the refrigerant after the expansion valve.

T_1=temperature of the refrigerant before compression.
T_2=temperature of the refrigerant after compression.
T_3=temperature of the refrigerant before expansion.
T_4=temperature of the refrigerant after expansion.

Conversion:

Convert all the pressure in PSIG to bar (multiply the value in PSIG by 0.06894 and add 1.013 to convert to bar abs)

FOR EXAMPLES:

P1 = (25×0.06894) +1.0134 =2.736 bar
P2 = (195×0.06894) +1.0134 =14.456 bar
P3 = (150×0.06894) +1.0134 =11.354 bar
P4 = (20×0.06894) +1.0134 =2.391 bar

FORMULA USED:

1. *Experimental COP:*

$$\text{Experimental COP} = \frac{\text{Actual Refrigeration effect}}{\text{work done}}$$

A. Actual Refrigeration effect **(RE) =** $m_w \times C_p \times \Delta T / \Delta t$ in KW

Where,

- m_w =mass of water in kg
- C_p =specific heat of water =4.186 KJ/ kg K
- ΔT =Temperature drop in the water
- Δt = Time for fall in temperature of water 5 minutes (or)water after decreasing 5°C
- Work done = Energy consumed by the compressor motor to be found out from the energy meter

B. *Input energy (or) work done:*

$$\textbf{Work done} = \frac{N \times 3600}{t \times x} \text{ KW}$$

Where,

X=energy meter constant=3200 impulse/KW hr.

t= time taken in sec. for 10 flickering of energy meter reading

2. *CARNOT COP*

$$\textbf{Carnot COP} = \frac{T_L}{T_H - T_L}$$

Where,

T_L=Lower temperature to be maintained in the evaporator in absolute units °k T_L= p_{min}= (P_1+P_4)/2;

T_H=Higher temperature to be maintained in the Condenser in absolute units °k T_H= p_{max} = (P_2+P_3)/2;

3. *Relative COP*

$$\text{Relative COP}=\frac{\text{Actual €OP}}{\text{€arnot €OP}}$$

EXPERMENTS ON REFRIGERATION SYSTEM

TABULATION I:

S.No	Quantity of Water in Tank ‘Kg’	Initial Temperature of Water T_{5i} ^{O}C	Final Temperature of Water T_{5f} ^{O}C	Temperature ^{O}C				Pressure PSI				Time taken for 5º falling Temperature T ^{O}C	Number of flickering in Energy meter light ‘N’	Time taken for N flickering t_f
				T_1	T_2	T_3	T_4	P_1	P_2	P_3	P_4			

TABULATION II:

Actual COP	Carnot COP	Relative COP

Result:

The COP of the Refrigeration system are determined and tabulated.

1. Experimental (Actual) COP = ________________________.
2. Relative COP = __________________________.
3. Carnot COP = _________________________

DETERMINATION OF COP OF AIR CONDITIONING SYSTEM

Aim:

To conduct performance test on Air conditioning test rig to determine the co-efficient of performance.

Apparatus required:

1. Air conditioning test rig
2. Stop watch

Specification:

- Orifice diameter = 50mm
- Refrigerant R =22
- Energy meter constant = 3200 impulse/KW hr
- Density of air = 1.184 at 25°C

Procedure:

1. Switch on the mains.
2. Switch on the conditioning unit.

Note down the following:

a) Pressure p_1, p_2, p_3 and p_4 from the respective pressure gauge.
b) Note the corresponding temperature T_1, T_2, T_3, and T_4 at the respective state points.
c) Monometer readings.
d) DBT and WBT of atmosphere air.
e) DBT and WBT of the conditioned air.

Abbreviation and notation:

P_1= pressure of the refrigerant before the compressor. P_2= pressure of the refrigerant after the compressor.
P_3= pressure of the refrigerant before the expansion valve. P_4= pressure of the refrigerant after the expansion valve.

T_1=temperature of the refrigerant before compression.
T_2=temperature of the refrigerant after compression.
T_3=temperature of the refrigerant before expansion.
T_4=temperature of the refrigerant after expansion.

DBT = Dry bulb temperature
WBT=Wet bulb temperature

FORMULA USED:

1.COP OF AIR CONDITIONER:

$$\text{Cop of air conditioner} = \frac{\text{Refrigeration effect}}{\text{input energy}}$$

A. Refrigeration effect by Air Conditioner (RE):

$$(RE) = m \times (h_1 - h_2) \text{ in KW}$$

Where,

- h_1= enthalpy of air at ambient condition
- h_2= enthalpy of conditioned air
- h_1&h_2 are calculated using DBT. WBT in psychometric chart
- m- Mass flow rate of air

B. Mass flow rate of air:

$$m = C_d \times \rho \times Q \quad \text{'kg/sec'}$$

Where,

- Q=volume flow rate of air = A×V m^3/sec
- ρ = density of air = 1.162 kg/m^3
- C_d= 0.65

C. Volume flow rate of air:

$$Q = A \times V$$

Where,

A- Area of orifice = $\pi/4 \times d_o^2$

v- Air velocity =$\sqrt{2gH_a}$

$$H_{a} = \left(\frac{q_w - q_a}{q_a}\right) \times H_m$$

ρ_{air}=1.165 refer HMT Data Book

H_m=Manometer pressure difference

D. Input energy or work done by the compressor:

$$\text{Input energy} = \frac{N \times 3600}{t \times x} \text{ kW}$$

Where,

- X=energy meter constant=3200 impulse/ kW hr.
- t= time taken in sec for 10 revolutions of energy meter reading

2. CAPACITY OF THE AIR CONDITIONER

Capacity=refrigeration effect/3.5

3. CARNOT COP

$$\textbf{Carnot COP} = \frac{T_L}{T_H - T_L}$$

Where,

- T_L=Lower temperature to be maintained in the evaporator in absolute units °K
- $T_L = p_{min} = (P_1+P_4)/2$;
- T_H=Higher temperature to be maintained in the Condenser in absolute units °K
- $T_H = p_{max} = (P_2+P_3)/2$;

Tabulation:

Expansion Valve:

S.No	Pressure PSI				Manometer Reading 'mm'			Atmospheric Air ^{O}C		Conditional Air ^{O}C		Time take for 10 Impulse in Energy meter 't'	COP	
	P_1	P_2	P_3	P_4	h_1	h_2	H	T_{1D} DBT	T_{1W} WBT	T_{2D} DBT	T_{2W} WBT		ACTUAL	CARNOT

Capillary tube:

S.No	Pressure PSI				Manometer Reading 'mm'			Atmospheric Air ^{O}C		Conditional Air ^{O}C		Time take for 10 Impulse in Energy meter 't'	COP	
	P_1	P_2	P_3	P_4	h_1	h_2	H	T_{1D} DBT	T_{1W} WBT	T_{2D} DBT	T_{2W} WBT		ACTUAL	CARNOT

Calculations:

Result:

The COP of the Air Conditioning system are determined and tabulated.

EXPANSION VALVE:

1. Experimental (Actual) COP ________________________.
2. Capacity Of the Air Conditioner____________________ tone
3. Carnot COP ________________________.

CAPILLARY TUBE:

1. Experimental (Actual) COP ________________________.
2. Capacity Of the Air Conditioner____________________ tone
3. Carnot COP ________________________.

TEST ON RECIPROCATING AIR COMPRESSOR

Aim:

To conduct performance test on a two stage reciprocating air compressor to determine the volumetric and isothermal efficiency.

Apparatus required:

The test unit consisting of an air reservoir on air intake tank with an orifice and a **U** tube manometer, the compressor having pressure gauge.

Specification:

Compressor Modal: 2 stage reciprocating

Diameter of low pressure cylinder D_L	=101.6 mm
Diameter of high pressure cylinder D_H	=63.5 mm
Stroke length L	=69.85 mm
Speed of the compressor	=65 rpm
Diameter of orifice	=8.5 mm
Co-efficient of discharge of orifice (C_d)	=0.65
Tank capacity	=250 lit
Motor capacity	=3 HP

Procedure:

1. Close the outlet valve.
2. Fill up the manometer with water up to half level.
3. Start the compressor and observe the pressure developing slowly.
4. At a particular test, pressure outlet valve is opened slowly and adjuster so that pressure in tank and maintained constant.
5. Note down the reading as the observation table.

Formula used:

1. *Volumetric efficiency*

$$\eta_{vol} = \frac{V_a}{V_t} \times 100 \quad \%$$

Where,

V_a=actual volume of air compressed

V_t= Theoretical volume of air compressed

A. Actual volume of air compressed (V_a):

$$V_a = C_d \times A \times \sqrt{2gH} \ \ m^3/sec$$

Where,

C_d= Co-efficient of discharge of orifice =0.65

A = orifice Area in m^2= (π/4) ×d^2

H= Air head causing flow

B. Air head causing flow (H):

$$H = h \times \frac{(\rho_w - \rho_a)}{\rho_a} \quad \text{in m}$$

Where,

h = head of water =h_1-h_2 in m

ρ_w =density of water =1000 kg/m^3

ρ_a =density of air =1.165 kg/m^3

C. Theoretical volume of air compressed (V_T):

$$V_T = \frac{G D_h^2 L N}{4 \times 60} \quad m^3/sec$$

Where,

D_h =Diameter of high pressure cylinder =63.5 m^3/sec

L = Stroke length =69.85mm

N = Speed of the compressor =65 rpm

2. Isothermal efficiency:

$$\eta_{Isothermal} = \frac{\text{Isothermal workdone}}{\text{Actual workdone}} \times 100 \quad \%$$

D. Iso thermal workdone

$=P_a \times V_a \times \ln(r)$ in Nm/sec (or) Watts

Where,

P_a =Atmospheric pressure =1.01325 × 10^5 N/m^2

Va = actual volume of air compressed in m^3/sec

$$r = \frac{P_a + P_g}{P_a}$$

P_g =delivery pressure (available in kg/cm^2 should be converted in to N/m^2)

E. Actual workdone =HP of the motor=3 HP

NOTE

$1 Kg/cm^2 = 0.9814$ bar

1 bar $= 1 \times 10^5$ N/m^2

Kg/cm^2 to N/m^2

$1 Kg/cm^2 = 98 \times 10^5$ N/m^2

1HP =745.699watts take it as 1HP=746watts

Tabulation:

TEST ON RECIPROCATING AIR COMPRESSOR

S.No	Delivery Pressure or Gauge Pressure P_g Kg/m^3	Tank Pressure P_r Kg/m^3	U-tube manometer reading				Volumetric efficiency η_{vol}	Isothermal efficiency $\eta_{isothermal}$
			h_1 'cm'	h_2 'cm'	$h = (h_1-h_2)$ 'cm'	$h = (h_1-h_2)$ 'm'		

RESULT:

Thus performance test on a two stage reciprocating air compressor is conducted

1. Volumetric efficiency_________________________%
2. Isothermal efficiency_________________________%