Department of Mechanical Engineering

III Year- V Semester - Mechanical Engineering

ME8512 Thermal Engineering Laboratory

LAB MANUAL

(2017 Regulation)

ME8512 THERMAL ENGINEERING LABORATORY **L T P C 0 0 4 2**

OBJECTIVES:

- To study the value timing-V diagram and performance of IC Engines
- To Study the characteristics of fuels/Lubricates used in IC Engines
- To study the Performance of steam generator/ turbine
- To study the heat transfer phenomena predict the relevant coefficient using implementation
- To study the performance of refrigeration cycle / components

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

1. Study on Steam Generators and Turbines.
2. Performance and Energy Balance Test on a Steam Generator.
3. Performance and Energy Balance Test on Steam Turbine.

HEAT TRANSFER LAB:

1. Thermal conductivity measurement using guarded plate apparatus.
2. Thermal conductivity measurement of pipe insulation using lagged pipe apparatus.
3. Determination of heat transfer coefficient under natural convection from a vertical cylinder.
4. Determination of heat transfer coefficient under forced convection from a tube.
5. Determination of Thermal conductivity of composite wall.
6. Determination of Thermal conductivity of insulating powder.
7. Heat transfer from pin-fin apparatus (natural & forced convection modes)
8. Determination of Stefan – Boltzmann constant.
9. Determination of emissivity of a grey surface.
10. Effectiveness of Parallel / counter flow heat exchanger.

REFRIGERATION AND AIR CONDITIONING LAB

1. Determination of COP of a refrigeration system
2. Experiments on Psychrometric processes
3. Performance test on a reciprocating air compressor
4. Performance test in a HC Refrigeration System
5. Performance test in a fluidized Bed Cooling Tower.

TOTAL: 60 PERIODS

OUTCOMES:

Upon the completion of this course the students will be able to

CO1 conduct tests on heat conduction apparatus and evaluate thermal conductivity of materials.

CO2 conduct tests on natural and forced convective heat transfer apparatus and evaluate heat transfer coefficient.

CO3 conduct tests on radiative heat transfer apparatus and evaluate Stefan Boltzmann constant and emissivity.

CO4 conduct tests to evaluate the performance of parallel/counter flow heat exchanger apparatus and reciprocating air compressor.

CO5 conduct tests to evaluate the performance of refrigeration and air conditioning test rigs.

CONTENTS

Study No: 01
Date :

STUDY OF INTERNAL COMBUSTION ENGINES

AIM:

To study the classification of internal combustion engines, their components and terminologies used in internal combustion engines.

INTERNAL COMBUSTION ENGINES

The internal combustion engine is an engine in which the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber. In an internal combustion engine the expansion of the high temperature and pressure gases, which are produced by the combustion, directly applies force to a movable component of the engine, such as the pistons or turbine blades and by moving it over a distance, generate useful mechanical energy.

CLASSIFICATION OF IC ENGINES:

a) Type of Ignition process:
i) Spark Ignition or SI engine,
ii) Compression Ignition or CI engine,
iii) Hot spot ignition engine

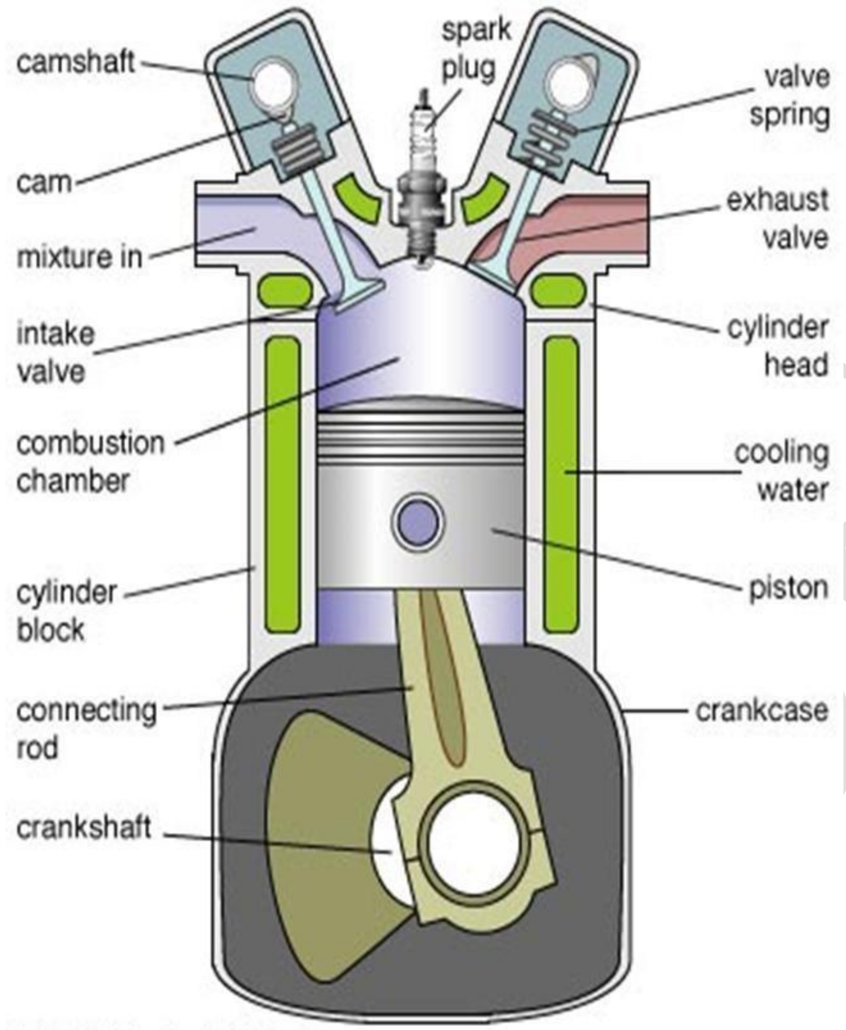
b) Type of Fuel used:
i) Petrol/Gasoline engine,
ii) Diesel engine,
iii) Gas engine

c) Number of Strokes per cycle:
i) Four stroke engine,
ii) Two stroke engine.

d) Type of cooling system:
i) Air cooled engine,
ii) Water cooled engine,
iii) Evaporative cooling engine.

e) Cycle of Operation:
i) Otto cycle engine,
ii) Diesel cycle engine,
iii) Dual cycle engine.

f) Method of fuel injection:
i) Carburettor engine,
ii) Air injection engine,
iii) Airless or solid injection engine.


camshaft
spark plug
valve spring
cam
exhaust valve
mixture in
intake valve
cylinder head
combustion chamber
cooling water
cylinder block
piston
connecting rod
crankcase
crankshaft

g) Arrangement of Cylinders:

i) Vertical engine,
ii) Horizontal engine,
iii) Radial engine,
iv) V engine,
v) Opposed cylinder engine,
vi) Opposed piston engine.

h) Application fields:

i) Stationary engine,
ii) Automotive engine,
iii) Marine engine,
iv) Aircraft engine,
v) Locomotive engine.

i) Valve Locations:

i) Over-head valve engine,
ii) Side valve engine.

j) Speed of the engine:

i) Slow speed engine,
ii) Medium speed engine,
iii) High speed engine.

k) Method of Governing:

i) Hit and Miss governed engine,
ii) Qualitatively governed engine,
iii) Quantatively governed engine.

COMPONENTS OF INTERNAL COMBUSTION ENGINES:

1. Cylinder: It is a cylindrical block having cylindrical space inside for piston to make reciprocating motion. Upper portion of cylinder which covers it from the top is called cylinder head. This is manufactured by casting process and materials used are cast iron or alloy steel.

2. Piston and Piston rings: Piston is a cylindrical part which reciprocates inside the cylinder and is used for doing work and getting work. Piston has piston rings tightly fitted in groove around piston and provides a tight seal so as to prevent leakage across piston and cylinder wall during piston‟ s reciprocating motion. Pistons are manufactured by casting or forging process. Pistons are made of cast iron, aluminium alloy. Piston rings are made of silicon, cast iron, steel alloy by casting process.

3. Combustion space: It is the space available between the cylinder head and top of piston when piston is at farthest position from crankshaft (TDC).

4. Intake manifold: It is the passage/duct connecting intake system to the inlet valve upon cylinder. Through intake manifold the air/air-fuel mixture goes into cylinder.

5. Exhaust manifold: It is the passage/duct connecting exhaust system to the exhaust valve upon cylinder. Through exhaust manifold burnt gases go out of cylinder.

6. Valves: Engine has both intake and exhaust type of valves which are operated by valve operating mechanism comprising of cam, camshaft, follower, valve rod, rocker arm, valve spring etc. Valves are generally of spring loaded type and made out of special alloy steels by forging process.

7. Spark plug: It is the external igniter used for initiating combustion process. Spark plug is activated by electrical energy fed by electrical system with engine. It delivers spark with suitable energy to initiate combustion at appropriate time for suitable duration. It is present in spark ignition engines.

8. Bearing: Bearings are required to support crank shaft. Bearings are made of white metal leaded bronze.

9. Connecting rod: It is the member connecting piston and crankshaft. It has generally I section and is made of steel by forging process.

10. Crank: It is the rigid member connecting the crankshaft and connecting rod. Crank is mounted on crankshaft. Crank transfers motion from connecting rod to crankshaft as it is linked to connecting rod through crank pin.

11. Crankshaft: It is the shaft at which useful positive work is available from the piston-cylinder arrangement. Reciprocating motion of piston gets converted into rotary motion of crankshaft. Crankshaft is manufactured by forging process from alloy steel.

12. Crankcase: Crankcase actually acts like a sump housing crank, crankshaft, and connecting rod and is attached to cylinder. These are made of Aluminium alloy, steel, cast iron etc. by casting process.

13. Gudgeon pin: It is the pin joining small end of the connecting rod and piston. This is made of steel by forging process.

14. Cams and Camshafts: Cams are mounted upon camshaft for opening and closing the valves at right timings and for correct duration. Camshaft gets motion from crankshaft through timing gears.

15. Carburetor: Carburetor is device to prepare the air fuel mixture in right proportion and supply at right time.

16. Fuel injector: It is present in the compression ignition engine. It injects fuel into the combustion chamber at the end of compression stroke in finely atomized state.

TERMINOLOGIES:

Bore: The inside diameter of the cylinder is known as bore. It is always measured in mm.

Stroke: The distance travelled by the piston from one of its dead center positions to the other dead center position.

Dead centers: They correspond to the positions occupied by the piston at the end of its stroke where the center lines of the connecting rod and crank are in the same straight line.

TDC: The top most position of the piston towards the cover end side of the cylinderof a vertical engine is called Top Dead Center or TDC.

BDC: The lowest position of the piston towards the crank end side of the cylinder of a vertical engine is known as BDC.

Crank throw/ crank radius: The distance between the center of main shaft and center of crank pin is known as Crank Throw or Crank Radius. This distance will be equal to half the stroke length.

Piston displacement/ swept volume: It is the volume through which the piston sweeps for its one stroke. Swept Volume is represented by Vs and it is equal to cross- sectional area of the piston x stroke length.

Clearance volume: It is the volume included between the piston and the cylinder head when it is at TDC (for vertical engines) or IDC (for horizontal engine). The piston can never enter this portion of the cylinder during its travel. Clearance volume (V_c) is generally expressed as percentage of the swept volume and is denoted by Vc.

Compression ratio: It is the ratio of the total cylinder volume to the clearance volume. For petrol engine it varies from 5:1 to 9:1 and for diesel engines from 14: 1 to 22: 1.

Piston speed: It is the distance travelled by piston in one minute. If rpm of engine shaft is (N) and length of stroke is (L), then piston speed will be 2LN m/min.

RESULT:

Thus the study of internal combustion engines and their classifications with terminologies are studied.

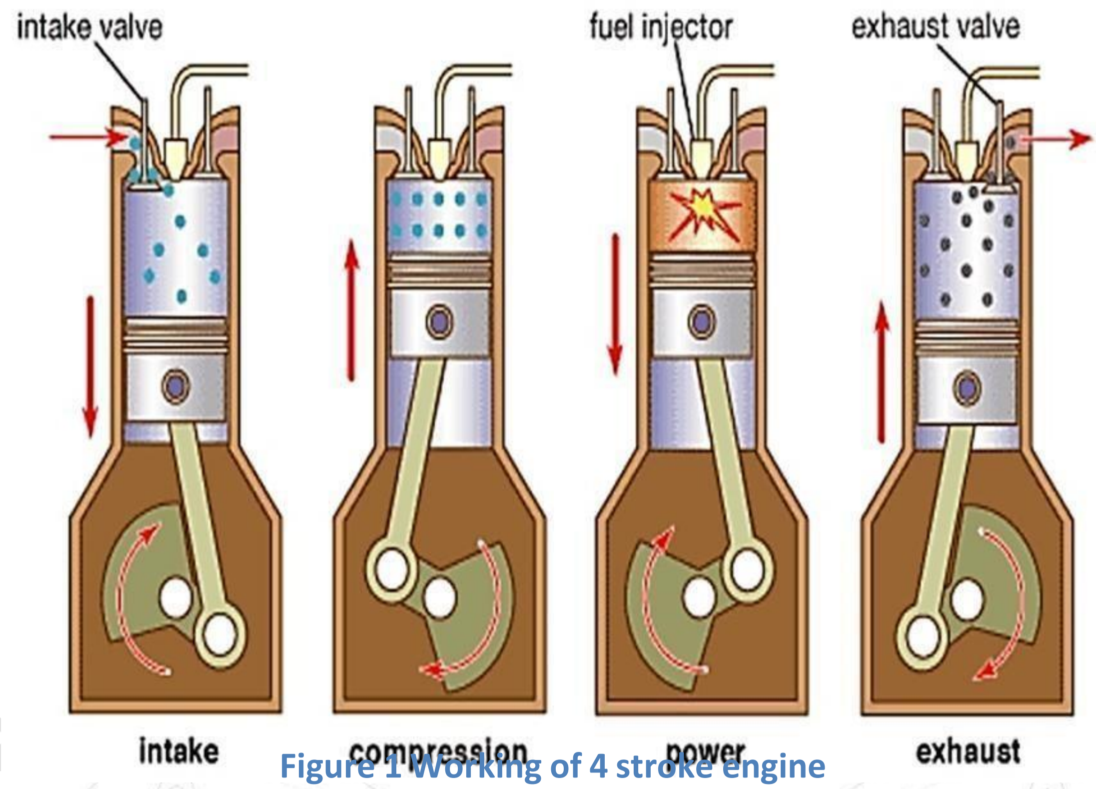


Figure 1 Working of 4 stroke engine

Study No: 02 **STUDY OF WORKING OF 2-STROKE/4-STROKE ENGINES**
Date :

Aim:

To study the working principle of 2-stroke / 4-stroke spark ignition and compression ignition engine.

FOUR STROKE SI ENGINE:

1. First Stroke: *Intake Stroke or Induction* The piston travels from TDC to BDC with the intake valve open and exhaust valve closed. This creates an increasing volume in the combustion chamber, which in turn creates a vacuum. The resulting pressure differential through the intake system from atmospheric pressure on the outside to the vacuum on the inside causes air to be pushed into the cylinder. As the air passes through the intake system, fuel is added to it in the desired amount by means of fuel injectors or a carburetor.

2. Second Stroke: *Compression Stroke* When the piston reaches BDC, the intakevalve closes and the piston travels back to TDC with all valves closed. This compresses the air-fuel mixture, raising both the pressure and temperature in the cylinder. The finite time required to close the intake valve means that actual compression doesn't start until sometime after BDC. Near the end of the compression stroke, the spark plug is fired and combustion is initiated.

3. Combustion: Combustion of the air-fuel mixture occurs in a very short but finite length of time with the piston near TDC (i.e., nearly constant-volume combustion). It starts near the end of the compression stroke slightly before TDC and lasts into the power stroke slightly after TDC. Combustion changes the composition of the gas mixture to that of exhaust products and increases the temperature in the cylinder to a very high peak value. This, in turn, raises the pressure in the cylinder to a very high peak value.

4. Third Stroke: *Expansion Stroke or Power Stroke* With all valves closed, the high pressure created by the combustion process pushes the piston away from TDC. This is the stroke which produces the work output of the engine cycle. As the piston travels from TDC to BDC, cylinder volume is increased, causing pressure and temperature to drop.

5. Exhaust Blowdown: Late in the power stroke, the exhaust valve is opened and exhaust blow down occurs. Pressure and temperature in the cylinder are still high relative to the surroundings at this point, and a pressure differential is created through the exhaust system which is open to atmospheric pressure. This pressure differential causes much of the hot exhaust gas to be pushed out of the cylinder and through the exhaust system when the piston is near BDC. This exhaust gas carries away a high amount of enthalpy, which lowers the cycle thermal efficiency. Opening the exhaust valve before BDC reduces the work obtained during the power stroke but is required because of the finite time needed for exhaust blowdown.

6. Fourth Stroke: *Exhaust Stroke* By the time the piston reaches BDC, exhaust blowdown is complete, but the cylinder is still full of exhaust gases at approximately atmospheric pressure. With the exhaust valve remaining open, the piston now travels

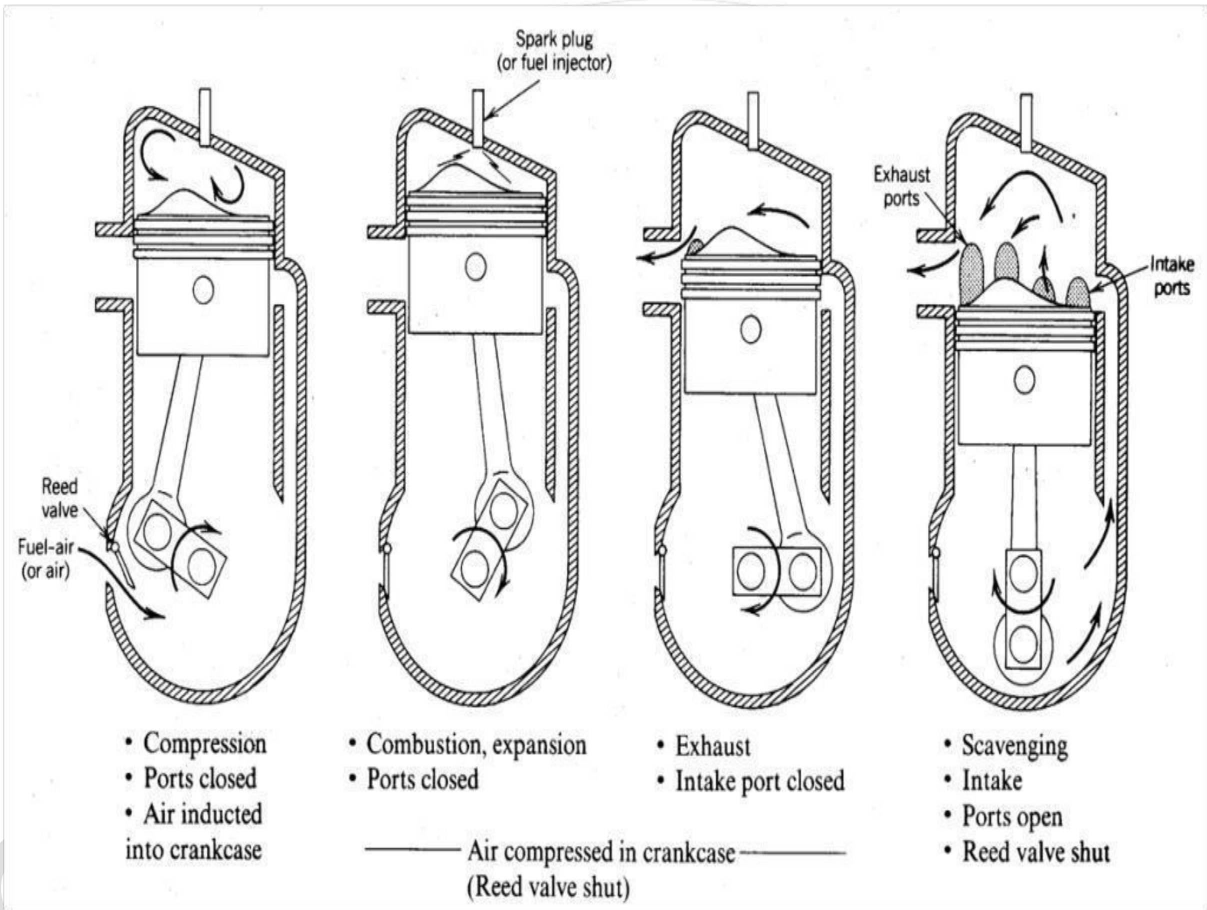


Figure 2 Working of 2 stroke cycle engine

from BDC to TDC in the exhaust stroke. This pushes most of the remaining exhaust gases out of the cylinder into the exhaust system at about atmospheric pressure, leaving only that trapped in the clearance volume when the piston reaches TDC. Near the end of the exhaust stroke before TDC, the intake valve starts to open, so that it is fully open by TDC when the new intake stroke starts the next cycle. Near TDC the exhaust valve starts to close and finally is fully closed sometime after TDC. This period when both the intake valve and exhaust valve are open is called valve overlap.

FOUR-STROKE CI ENGINE CYCLE

1. First Stroke: *Intake Stroke* The same as the intake stroke in an SI engine with one major difference: no fuel is added to the incoming air.

2. Second Stroke: *Compression Stroke* The same as in an SI engine except that only air is compressed and compression is to higher pressures and temperature. Late in the compression stroke fuel is injected directly into the combustion chamber, where it mixes with the very hot air. This causes the fuel to evaporate and self-ignite, causing combustion to start.

3. Combustion: Combustion is fully developed by TDC and continues at about constant pressure until fuel injection is complete and the piston has started towards BDC.

4. Third Stroke: *Power Stroke* The power stroke continues as combustion ends and the piston travels towards BDC.

5. Exhaust Blowdown Same as with an SI engine.

6. Fourth Stroke: *Exhaust Stroke* same as with an SI engine.

TWO-STROKE SI ENGINE CYCLE

1. Combustion: With the piston at TDC combustion occurs very quickly, raising the temperature and pressure to peak values, almost at constant volume.

2. First Stroke: *Expansion Stroke or Power Stroke* Very high pressure created by the combustion process forces the piston down in the power stroke. The expanding volume of the combustion chamber causes pressure and temperature to decrease as the piston travels towards BDC.

3. Exhaust Blowdown: At about 75° before BDC, the exhaust valve opens and blowdown occurs. The exhaust valve may be a poppet valve in the cylinder head, or it may be a slot in the side of the cylinder which is uncovered as the piston approaches BDC. After blowdown the cylinder remains filled with exhaust gas at lower pressure.

4. Intake and Scavenging: When blowdown is nearly complete, at about 50° before BDC, the intake slot on the side of the cylinder is uncovered and intake air-fuel enters under pressure. Fuel is added to the air with either a carburetor or fuel injection. This incoming mixture pushes much of the remaining exhaust gases out the open exhaust valve and fills the cylinder with a combustible air-fuel mixture, a process called scavenging. The piston passes BDC and very quickly covers the intake port and then the exhaust port (or the exhaust valve closes). The higher pressure at which the air enters the cylinder is established in one of two ways. Large two stroke cycle engines generally have a supercharger, while small engines will intake the air through the crankcase. On these engines the crankcase is designed to serve as a compressor in addition to serving its normal function.

5. Second Stroke: *Compression Stroke* With all valves (or ports) closed, the piston travels towards TDC and compresses the air-fuel mixture to a higher pressure and temperature. Near the end of the compression stroke, the spark plug is fired; by the time the piston gets to IDC, combustion occurs and the next engine cycle begins.

TWO-STROKE CI ENGINE CYCLE

The two-stroke cycle for a CI engine is similar to that of the SI engine, except for two changes. No fuel is added to the incoming air, so that compression is done on air only. Instead of a spark plug, a fuel injector is located in the cylinder. Near the end of the compression stroke, fuel is injected into the hot compressed air and combustion is initiated by self – ignition.

RESULT:

Thus the working principle of two stroke and four stroke cycle engine of both spark ignition and compression ignition engine was studied.

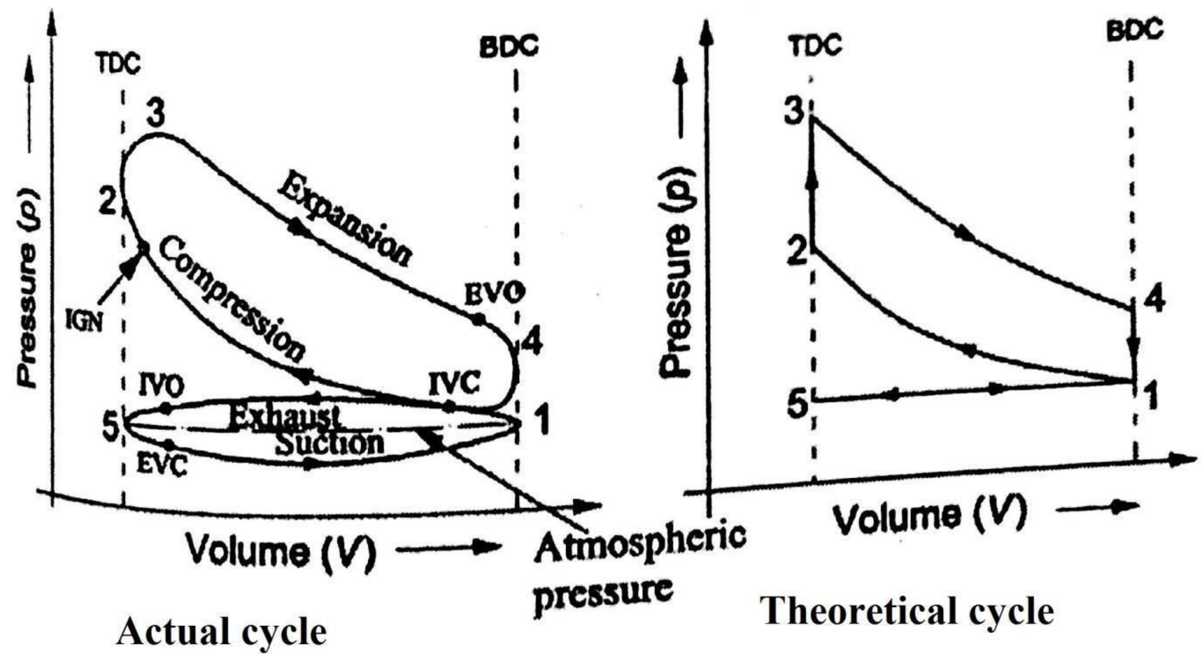


Figure (a)

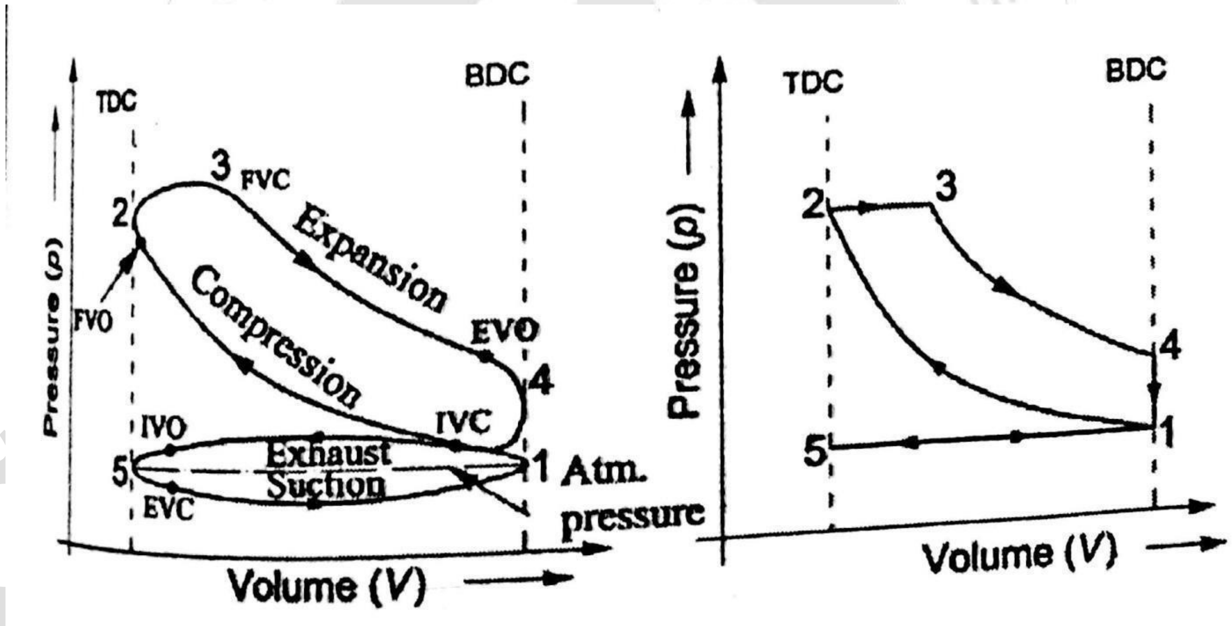


Figure (b)

Study No: 03
Date :

ACTUAL P-V DIAGRAMS OF IC ENGINES

AIM:

To study the actual p-v diagrams of four stroke and two stroke engines of CI and SI engines.

ACTUAL CYCLE FOR 4-STROKE CYCLE IN SI ENGINE:

The comparison of actual cycle and theoretical cycle for 4-stroke cycle in SI engine was shown in fig. (a). The line 5-1 represents the suction stroke in which the charge enters into the cylinder. The suction of mixture is possible only, if the pressure inside the cylinder is below atmospheric pressure. So, the suction line lies below the atmospheric pressure line.

The burnt gases are pushed out only when the pressure inside the cylinder is above atmospheric pressure. This process is represented by line 1-5. The above two process (5-1 and 1-5) gives the area in the form of small loop which is called as "pumping losses".

The compression stroke is shown by line 1-2 which shows that the inlet valve closes (IVC) a little beyond 1. At the end of this stroke, there is an increase in pressure inside the engine cylinder.

Shortly, before the end of compression stroke, the charge is ignited with the help of a spark plug. Thus, both pressure and temperature of the cylinder increase. But the volume remains constant as shown by line 2-3.

Expansion stroke is shown by line 3-4. The exhaust valve opens (EVO) little before 4. Then, the burnt gases are exhausted to atmosphere.

Also, the actual pressure in such an engine is only about half the theoretical value. The corners are rounded off because both inlet and exhaust valve do not open and they suddenly close.

ACTUAL CYCLE FOR 4-STROKE CYCLE IN CI ENGINE:

The comparison of actual cycle and theoretical cycle for 4-stroke cycle in CI engine was shown in fig (b). The line 5-1 represents the suction stroke in which the air enters into the cylinder. The suction of air is possible only, if the pressure inside the cylinder is below atmospheric pressure. So, the suction line 5-1 lies below the atmospheric pressure line.

The burnt gases are pushed out only when the pressure inside the cylinder is above atmospheric pressure. This process is represented by line 1-5.

The air is adiabatically compressed in cylinder during 1-2 process which takes place after the inlet valve closed (IVC).

Shortly, before the end of compression stroke, the fuel valve opens and fuel is injected into the cylinder. The fuel is ignited due to temperature of highly compressed air inside the cylinder.

The combustion takes place at constant pressure as shown by the line 2-3. Actually, the combustion at constant pressure is not possible as fuel will not burn

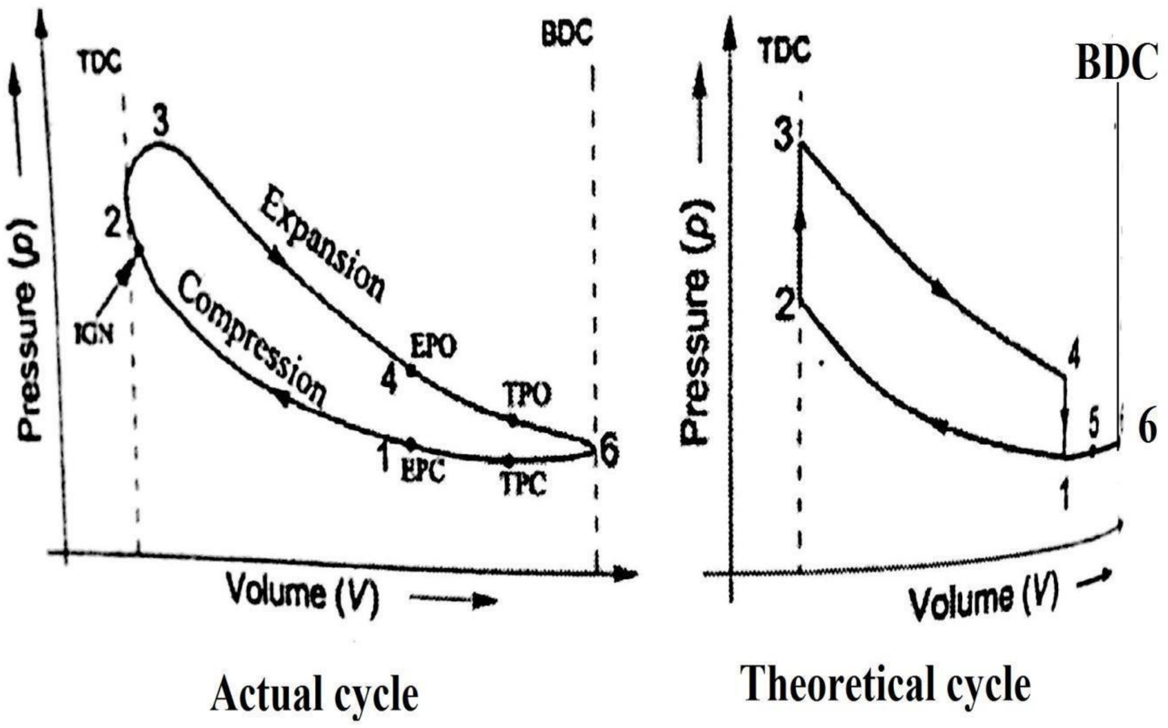

TDC
BDC
3
2
IGN
Expansion
Compression
4
EPO
TPO
1
EPC
TPC
6
Pressure (p)
Volume (V)
Actual cycle
TDC
BDC
3
2
4
5
6
1
Pressure (p)
Volume (V)
Theoretical cycle

Figure (c)

completely as it is introduced into the cylinder.

Then the charge is adiabatically expanded in the cylinder as shown by line 3-4. At the end of expansion stroke and little before BDC, the exhaust valve is opened (EVO).

Theoretically, both compression and expansion are adiabatically followed. But in actual cycle it is not so because of heat and pressure losses. Actual area on p-V diagram per cycle is less than the theoretical because of lower pressure rise and pumping losses.

ACTUAL CYCLE FOR 2-STROKE CYCLE IN SI ENGINE:

The comparison of actual cycle and theoretical cycle for 2-stroke cycle in SI engine was shown in fig (c). The suction stroke is carried out from transfer port open (TPO) and transfer ports close (TPC). During half of the suction stroke, the exhaust port is also opened. Now, the volume of air fuel mixture is entered into the cylinder. It happens as the piston moves from TDC to BDC. During the second half of the suction stroke (i.e., BDC to TPC), the air fuel mixture is compressed and burnt gases are pushed out. A little beyond TPC, the exhaust port closes (EPC) at 1. These processes are represented in theoretical cycle as 1-5-6 and 6-5-1.

Now, the air fuel mixture is isentropically compressed in the cylinder. This process is shown by line 1-2. Before the end of compression, the charge is ignited (IGN) with the help of a spark plug. The combustion of air-fuel mixture increases the pressure and temperature of the products of combustion. During this process, the volume remains constant. This is represented by line 2-3.

The expansion process is shown by line 3-4. At the end of the expansion stroke, the exhaust port opens (EPO) at 4 and burnt gases are pushed out in the atmosphere. During this, the pressure falls suddenly to the atmospheric pressure.

As the piston moves towards BDC, the volume of burnt gases increases from 4 to 5. At point 5, the transfer port opens (TPO) and the suction stroke starts.

ACTUAL CYCLE FOR 2-STROKE CYCLE IN CI ENGINE:

The comparison of actual cycle and theoretical cycle for 2-stroke cycle in CI engine was shown in fig (d). The suction stroke was carried out from transfer port open (TPO) to transfer port closes (TPC). During half of the suction stroke, the exhaust port is also opened. The volume of air is entered into the cylinder. It happensas the piston moves from TPO to BDC. During the second half of the stroke (i.e. BDC to TPC), the air is compressed and burnt gases are pushed out. Beyond TPC, the exhaust port closes (EPC) at 1. Now, the air is compressed isentropically in the cylinder. This process is shown by line 1-2.

Before the end of compression, the fuel is admitted into the cylinder by means of a fuel injector (INJ). The combustion of fuel increases the pressure and temperature of the products of combustion. During this process, the pressure remains constant. This is represented by line 2-3.

The expansion process is shown by line 3-4. At the end of the expansion

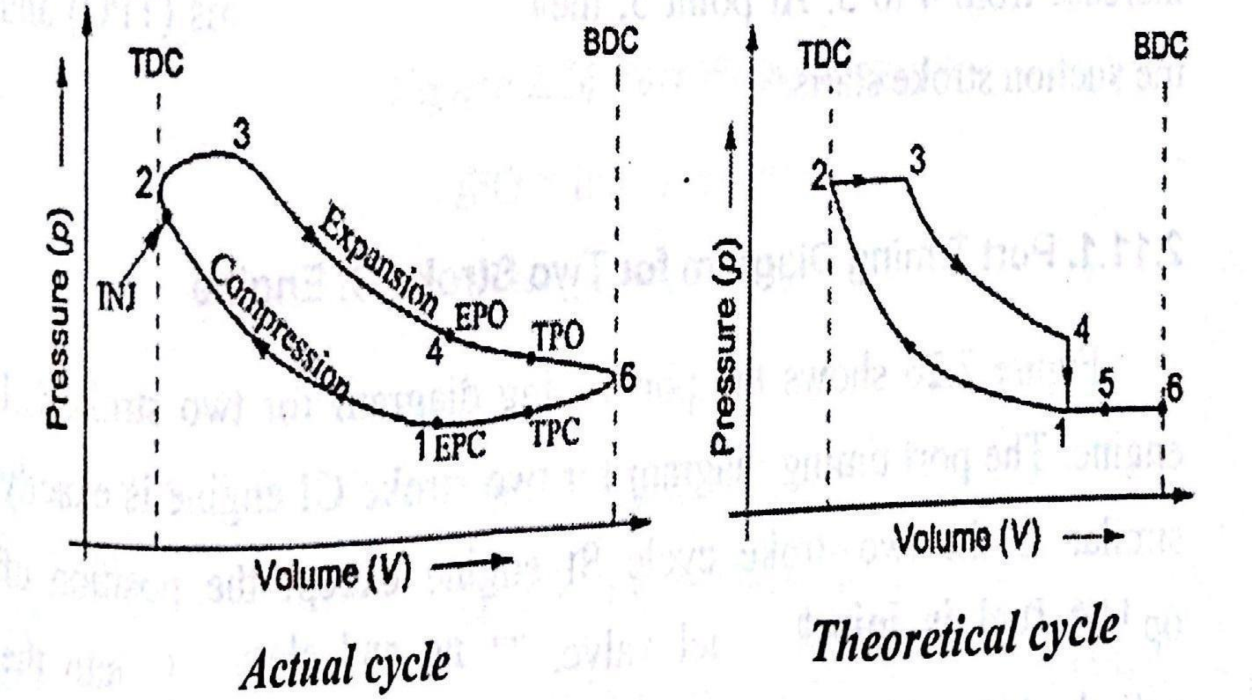

TDC
BDC
Pressure (p)
Volume (V)
2
3
INJ
Expansion
Compression
EPO
TPO
4
6
1 EPC
TPC
Actual cycle
5
Theoretical cycle

Figure (d)

stroke, the exhaust port opens (EPO) at 4 and burnt gases are pushed out into the atmosphere. During this, the pressure falls suddenly to atmospheric pressure.

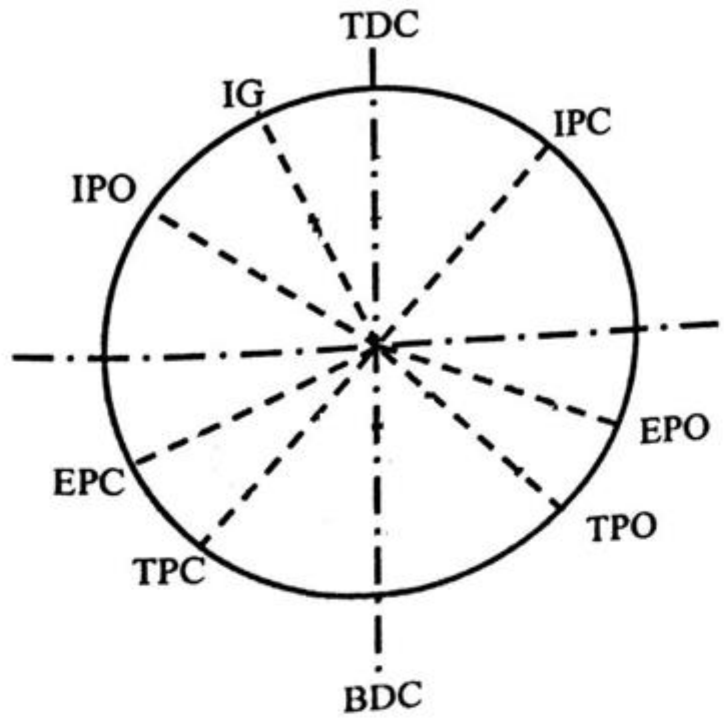
As the piston moved towards BDC, the volume of burnt gases increase from 4 to 5. At point 5, the transfer port opens (TPO) and the suction stroke starts.

RESULT:

Thus the actual p-v diagrams for 4-stroke and 2-stroke SI and CI was drawn and studied.

TABULATION:

Circumference of the flywheel =___________cm



θ

S.No	Events	Position with respect to the nearest dead centre	Distance from nearest dead center (cm)	Angle in degrees
1.	EPO			
2.	EPC			
3.	TPO			
4.	TPC			
5.	IPO			
6.	IPC			

Ex. No:01

Date :

PORT TIMING DIAGRAM

AIM:

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

APPARATUS USED:

Cut section model of two stroke petrol engine.
Chalk
Paper
String.

FORMULA:

$$\text{Angle } Q = \frac{\text{Distance from nearest dead center}}{\text{Circumference of the flywheel}} \times 360 \text{ degrees}$$

PROCEDURE:

1. The TDC and BDC positions of the piston are marked on the flywheel.
2. The flywheel is rotated in a clockwise direction.
3. Move the piston on the flywheel against the marking, when the exhaust port slightly gets opened. Thus piston is marked as EPO.
4. Further clockwise rotation of flywheel result the complete covering of exhaust port. This position is marked as EPG on flywheel.
5. The above procedure is repeated for transport.
6. The angle between the markings EPO, EPC, TPO, TPC, IPO and IPC from their nearest dead center can be directly from the attached on the flywheel.The readings are tabulated, and port timing diagram are drawn.

Model calculation:

RESULT:

Thus a port timing diagram of a two stroke petrol engine was drawn.

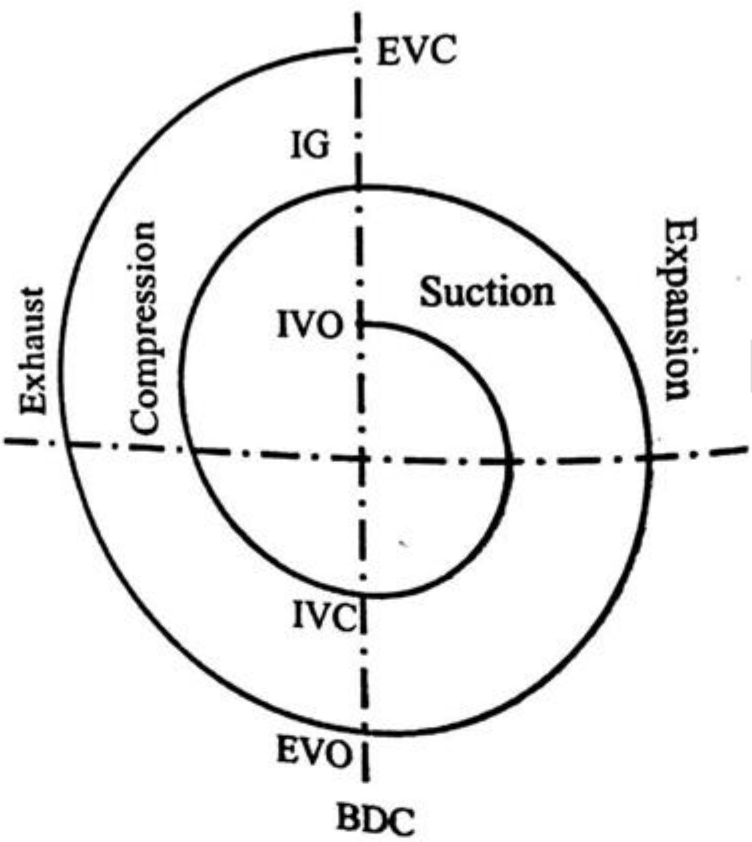
VIVA-VOCE QUESTIONS:

1. What are the differences between valves and ports?
2. How does the opening and closing of ports happen in two stroke engines?
3. What is the use of transfer port?
4. Give reason why exhaust port has larger diameter than the transfer port?
5. What do you mean by scavenging?
6. What are the advantages of two stroke engines?
7. How are two stroke engines lubricated? Give the name.
8. Give the ranges of compression ratio for petrol and diesel engine.
9. Define compression ratio.
10. What are the problems associated with two stroke engines?

TABULATION:

Circumference of the flywheel =___________cm

θ



S.No	Events	Position with respect to the nearest dead center	Distance from nearest dead center (cm)	Angle in degrees
1.	IVO			
2.	IVC			
3.	EVO			
4.	EVC			

Ex. No: 02
Date :

VALVE TIMING DIAGRAM

AIM:

To draw the valve timing diagram of the given four stroke engine.

APPARATUS REQUIRED:

1. Cut section model of 4 stroke diesel engine.
2. Chalk
3. Paper
4. String.

FORMULA:

$$\text{Angle } Q = \frac{\text{Distance from nearest dead center}}{\text{Circumference of the flywheel}} \times 360 \text{ degrees}$$

PROCEDURE:

1. The position of the Top dead centre and the Bottom dead centre are marked on the flywheel by rotating it in the current direction.
2. The paper is inserted between the inlet valve stem and roller arm.
3. The flywheel is rotated in the given direction of rotation where the paper string is slightly slipped.
4. The flywheel is slipped at the instant and the position against the arrow on the flywheel is moved as IVO (Inlet valve opening)
5. Thus the flywheel is rotated in the same direction until the paper is released.
6. At the instance, position against the arrow is moved as IVC (Inlet valve closing.)
7. The same step is repeated for exhaust valve also.
8. The distance of marking IVO, IVC, EVO and EVC are measured from their nearest dead centre and tabulated.
9. The distance are covered into respective angle and plotted in diagram.

Model calculation:

RESULT:

Thus a valve timing diagram of the given four stroke diesel engine was drawn.

VIVA-VOCE QUESTIONS:

1. How the valves differ from ports?
2. What are the advantages of four stroke engines over two stroke engines?
3. Why four stroke engines are more fuel efficient than two stroke engines?
4. What do you mean by valve overlap? What are their effects in SI engines?
5. How to identify, whether it is petrol or diesel engine?

TABULATION:

Given sample: ______________________

Temperature °C	Observations

Ex. No: 03 **DETERMINATION OF FLASH POINT AND FIRE POINT**
Date :

AIM:

To determine the flash point and fire point of the given fuel/lubricating oil.

APPARATUS REQUIRED:

Candle, Oil sample, Thermometer (0-360°C) and Cleveland open cup apparatus.

FLASH POINT:

It is the lowest temperature at which the fuel will flash when an external source of fire is brought in contact with the vapour over its surface.

FIRE POINT:

Fire point is the lowest temperature at which the formation of combustible gases from the oil is enough to maintain a steady combustible gas fire after it is ignited.

PRECAUTIONS:

Using a rheostat regulate the heating range to sufficiently low rate to avoid errors provide adequate heating.

PROCEDURE:

1. First of all, oil cups cleared well.
2. The given lubricating oil, sample is poured inside the oil cup up to the mark level.
3. Thermometer is placed inside the oil cup such that the bulb of the thermometer doesn" t touch the surface of the oil cup.
4. The candle is ignited inside, by using a stick the fire is taken to the lubricating oil reaches; the flash is produced in the oil and by this time the temperature is noted which gives the flash point.
5. When the oil cup is continuously heated the oil catches fire at a point, which is the fire point of the lubricating oil.
6. The procedure is repeated for various lubricating oil and readings were noted.

RESULT:

Observation:

Diameter of brake drum D = m

Diameter of rope d = m

Diameter of bore = m

S.No	Dead weight W(kg)	Spring balance reading S(kg)	Time Taken for 10cc of fuel consumption sec	Water temperature °C		Exhaust temperature °C T_4	BP kW	MFC kg/s	FuP kW	SFC kg/kW-hr	IP kW	η_{mech} %	η_{bth} %	η_{ith} %
				In T_2	Out T_3									

Ex. No: 04 **PERFORMANCE TEST ON 4 – STROKE DIESEL ENGINE**
Date :

AIM:

To conduct a performance test on the four stroke single cylinder diesel engine with mechanical rope brake loading.

DESCRIPTION:

The mechanical brake drum is fixed to the engine fly wheel and the engine mounted on the M.S. channel chase and further mounted on anti-vibro mounts. A separate panel board is used to fix burette with 3way cock, digital temperature indicator & rpm indicator, temperature selector switch, U-tube manometer.

APPARATUS REQUIRED:

Four stroke diesel engine test rig
Tachometer
Stop watch

SPECIFICATION:

Engine	
Bhp	
Speed (N)	
Fuel	
No of cylinder	
Bore	
Stroke length	
Starting	
Working cycle	
Method of cooling	
Method of ignition	

Maximum load applied to the engine:

1. **Brake power**

   $$BP = \frac{2\pi N (W-S) * 9.81 (D+d)}{2*60} \quad KW$$

   Where, N= RPM of the engine
   S= Speing balance reading in kg
   W= dead weights in kg
   D= diameter of brake drum in mm
   D= diameter of rope in mm

2. **Mass of fuel consumed:**

   $$MFC = \frac{X \times 0.82}{1000 \times T} \ kg/s$$

   Where, X = burette reading in cc
   0.82 = density of diesel in gram / cc
   T = time taken in seconds.

(Multiply by 3600 for getting unit in kg/hr)

PRECAUTIONS:

1. Check the fuel level in the fuel tank and open the fuel knob.
2. Check lubrication oil level in the crankcase.
3. Ensure cooling water supply to engine before starting the engine.
4. Ensure cooling water supply to brake drum before loading the engine.
5. Engine should be started on no load condition.
6. Load should be added or removed gradually by adjusting the speed of the engine to its rated value by screwing in or out of the governor nut.
7. Engine should stopped only at no load condition
8. During starting the engine, handle is used on the crank shaft to start the engine, should be removed immediately once the engine is started
9. Decompression lever should not be used to stop the engine.
10. Do not over load the engine beyond ten percent more than the full load capacity.

PROCEDURE:

1. Determine the maximum load that can be applied to the engine.

   $$BP = \frac{2\pi NT}{60 * 1000}$$

   (Take brake power from specification)
   For rope brake loading, $T = W_{max}.R_e$
   Where R_e is effective radius of brake drum.

   $$W_{max} = \frac{T}{R_e}$$

(N)

2. Start the engine and allow it to stabilized rated speed.
3. Now load the engine in steps of $^1/_4$, $^1/_2$, ¾, full load & 10% over load and allow the engine to stabilize at each load.
4. Record all the required parameters indicated on the digital indicators which are mounted on the panel board like,
    a. Speed of the engine from digital RPM indicator
    b. Load from the spring balance,
    c. Fuel consumption from burette,
    d. Quantity of airflow from manometer,
    e. Different temperatures from Temperature indicator.
5. Load the engine step by step.
6. Note down the corresponding parameters.
7. Turn off the fuel knob provided on the panel after the test.

3. **Fuel power** (FuP) = mfc * CV

4. **Specific fuel consumption :**

SFC = MFC/BP .... kg/kW hr

5. **Frictional power** (FP) = Calculate from Willian‟ s graphical method (MFC in kg/hr Vs BP in kW)

6. **Indicated power** (IP) = BP + FP kW

7. **Mechanical efficiency** (η_{mech}) $= \frac{BP}{IP} * 100$

8. Brake thermal efficiency(η_{bth}):

$$\eta_{bth} = \frac{BP * 100}{mfc * CV}$$

9. Indicated thermal efficiency(η_{ith}):

$$\eta_{ith} = \frac{IP}{FuP} * 100$$

Graph:

1. η_{mech} vs BP
2. η_{bth}vs BP
3. η_{ith} vs BP

TABULATION:

S.No	Working cylinders	Loading				Brake Power in KW	Indicated Power
		W_1 kg	W_2 kg	$W = (W_1 - W_2)$ kg	Net Load W in „N‟		
1.	**1-2-3-4**						
2.	**2-3-4**						
3.	**1-3-4**						
4.	**1-2-4**						
5.	**1-2-3**						

RESULT:

Thus the performance test on single cylinder diesel engine with mechanical brake loading was conducted.

VIVA-VOCE QUESTIONS:

1. Define brake power.
2. What is specific fuel consumption? How it is varies according with load?
3. What are the methods used to determine the friction power?
4. List the various ways of expressing fuel consumption.
5. How brake power is measured?
6. Define indicated thermal efficiency.
7. Define relative efficiency.
8. Define mechanical efficiency.
9. Define brake thermal efficiency.
10. What is calorific value of diesel fuel?

Ex. No: 05 **MORSE TEST ON MULTI-CYLINDER PETROL ENGINE**
Date :

AIM:

To determine the mechanical efficiency of the four cylinders petrol engine by conducting the Morse test.

APPARATUS REQUIRED:

Multi-cylinder petrol engine test rig
Tachometer

Power	
Speed	
Bore	
Number of strokes	
Stroke length	
Fuel	
Calorific value	

FORMULA USED:

Brake Horse power (BP) : $(WN / 2000) \times 0.736$ kW

W – Weight applied in N. N - Speed in rpmIndicated

power of I cylinder (IP) : $(B.P)_{all} - (B.P)_{234}$ kW

I.P of II cylinder : $(B.P)_{all} - (B.P)_{134}$ kW

I.P of III cylinder : $(B.P)_{all} - (B.P)_{124}$ kW

I.P of IV cylinder : $(B.P)_{all} - (B.P)_{123}$ kW

I.P of all cylinder : $(I.P)_1 + (I.P)_2 + (I.P)_3 + (I.P)_4$

Frictional power of engine (FP) : $(I.P)_{all} - (B.P)_{all}$ in kW

Mechanical efficiency η_{mech} : $(BP/IP) \times 100\%$ where IP = BP+FP

Model calculation:

PROCEDURE:

1. Determine the maximum load that can be applied to the engine.

$$BP = \frac{2\pi NT}{60 * 1000}$$

(Take brake power from specification)
For rope brake loading, $T = W.R_e$
Where R_e is effective radius of brake drum.
$W = \frac{T}{R_e}$ (N)

2. Check the engine for fuel availability, lubricant and cooling water connections.
3. Release the load completely on the engine and start the engine in no load conditions and allow the engine to run for few minutes to attain the rated speed.
4. Apply the load and increase the load up to maximum load. (All four cylinders should be in working). Now note the load on the engine and speed of the engine say the speed is „N‟ rpm
5. Cut-off the ignition of first cylinder, now the speed of engine decreased. Reduce the load on the engine and bring the speed of the engine to „N‟ rpm. Now note the load on the engine.
6. Bring the all four cylinders are in working conditions and cut off the 2nd , 3rd and 4th cylinder in turn and adjust the load to maintain same „N‟ rpm and note the load .

RESULT:

Thus the Morse test is conducted on a four stroke petrol engine at a constant speed of 1500 rpm.

VIVA-VOCE QUESTIONS:

1. Define indicated power.
2. What is firing order of 4-cylinder engine?
3. Why Morse test is carried out?
4. Why multi-cylinder engine have smaller flywheel?
5. Which type of ignition system is used in this equipment?

S.No	Applied load (rounded off)			Time for 10cc of fuel consumption t (sec)	Cooling water temperature (°C)		Mass flow rate of water (m_w) kg/sec	Exhaust gas temp (T_{g2}) °C	Manometer reading $h_w = h_1 - h_2$ (m)		
	V	A	VA		T_{w1}	T_{w2}			h_1	h_2	h_w

Ex. No: 06 **HEAT BALANCE TEST ON 4-STROKE DIESEL ENGINE**
Date :

AIM:

To conduct a heat balance test for a single cylinder four stroke diesel engine by electrical loading with different loads at constant speed.

APPARATUS REQUIRED:

Stopwatch

ENGINE SPECIFICATION:

Engine Make	
Power (BP)	
Speed (N)	
Bore (B)	
Stroke (SL)	
Calorific value of fuel CV	
Orifice diameter d	
Alternator efficiency η_g	

PROCEDURE:

1. Calculate maximum load to be applied for a selected engine.

   BP is taken from specification.
2. Check the fuel supply, water circulation in the water system and lubricating oil in the oil sump.
3. Ensure no load condition.
4. The engine is started and allowed to run on idle speed for a few minutes.
5. Gradually the engine is loaded with electrical dynamometer and the speed is maintained constant.
6. Load the engine in steps of 0%, 25%, 50% , 75% & 100% of the maximum load to be applied
7. Note the corresponding readings of voltmeter, ammeter, mass flow rate of water, fuel consumption, manometer reading, water inlet and outlet temperature, exhaust gas temperature, etc.
8. After taking the readings, unload the engine, allow it to run for few minutes and then stop the engine.

Model calculation:

Maximum Load applied to the engine:

Total Fuel Consumption (TFC) = (X / t) * (Specific gravity /1000) kg/s

Heat input to the engine Q_i = TFC * CV kW

Brake Power BP = (V x A) / (η_g x 1000) kW

Useful heat Q_u = BP kW

Heat carried away by engine cooling water Q_w = $m_w C_{pw} (T_{w2} - T_{w1})$ kW

Height of air column h_a =(ρ_w / ρ_a)* h_w (m)

Volume of air (i.e.) takenat RTP = A C_d $(2gh_a)^{0.5}$ m^3/s

where A = Area oforifice in m^2

Mass of air = V * ρ_a

Mass of exhaust gas= m_a + TFC

Heat carried away by exhaust gas Q_g = m_g $C_{pg} (T_{g2} - T_{g1})$ kW

Heat unaccounted $Q_{ua} = Q_i - (Q_u + Q_w + Q_g)$ kW

Percentage of heat unaccounted $\%Q_{ua} = (Q_{ua} / Q_i) * 100$

Percentage of equivalentof useful work done= $(Q_u / Q_i) * 100$
Percentage of heat carriedaway by cooling water= $(Q_w / Q_i) * 100$
Percentage of heat carriedaway by exhaust gas = $(Q_g / Q_i) * 100$

Heat balance sheet:

Sl. No.	CREDIT	DEBIT							
	Heat input Q_i	**Useful heat (Q_u)**		**Cooling water loss (Q_w)**		**Exhaust gas loss (Q_g)**		**Unaccounted loss (Q_{ua})**	
	kW	**kW**	**%**	**kW**	**%**	**kW**	**%**	**kW**	**%**
1									
2									
3									
4									
5									

RESULT:

The heat balance test is conducted for a single cylinder four-stroke diesel engine by electrical loading with different loads at constant speed and the results are tabulated.

VIVA-VOCE QUESTIONS:

1. What is meant by heat balance sheet?
2. What are various ways heat is lost from the engines?
3. List some unaccounted heat losses.
4. How mass flow rate of air is calculated?
5. What are the precautions needed before starting the engine?
6. How the speed of engine is measured?

Observation table:

S.No	No load condition		Half load condition	
	Drop in speed (rpm)	Time, t_2 (sec)	Drop in speed (rpm)	Time, t_3 (sec)

Ex. No: 07
Date :

RETARDATION TEST ON 4-STROKE DIESEL ENGINE

AIM:

To conduct a retardation test and determine the frictional power of the single cylinder diesel engine at a given speed.

APPARATUS REQUIRED:

1. Stopwatch
2. Tachometer

SPECIFICATIONS:

4-stroke, vertical, water cooled, single cylinder, slow speed diesel engine.

Type of loading	: Brake drum dynamometer
Make	: Anil
Bore	: 114.3 mm
Stroke	: 139.7 mm
Cubic capacity	: 1433 cc
Speed	: 850 rpm
Power	: 8 HP
Compression ratio	: 16:1
Fuel	: High speed diesel oil
Calorific value	: 44,000 kJ/kg
Specific gravity of fuel	: 0.8275

DESCRIPTION:

This test involves the method of retarding the engine by cutting the fuel supply. The engine is made to NO load condition and at the rated speed. When the engine is running under steady operating conditions the supply of fuel is cut-off and simultaneously the time of fall in speeds say 20%, 40%, 60%, 80% of the rated speed is recorded. This tests is repeated with 50% load on the engine.

PROCEDURE:

1. Check the fuel level.
2. Check the lubricating oil level.
3. Open the three way cock, so that the fuel flows to the engine.
4. Supply cooling water through the inlet pipe.
5. Start the engine.
6. Adjust the speed by screwing and unscrewing the governor nut.
7. Allow cooling water in the brake drum.
8. Adjust cooling water to the engine to the required value.

FORMULAE:

1. Maximum load, $(W - S)_{max} = \frac{T}{R*9.81}$ kg

   Where $T = \frac{BP*60*100}{2\pi N}$ N-m
   BP = 8 * 0.736 kW
   N = Engine speed = 850 rpm.
   W = Dynamometer load $(w + w_h)$
   w = Dead load (kg)
   w_h = Hanger weight = 1 kg
   R = Equivalent radius of brake drum = 0.21 m
   S = Spring balance reading (kg)

2. Brake power at half load, BP = kW

   Where N-m

3. Frictional power, FP = BP * kW

   Where t_2 and t_3 are time take for fall of speed at No load and Half load conditions taken from graph connecting time of fall in speed in x-axis and speed in y-axis.

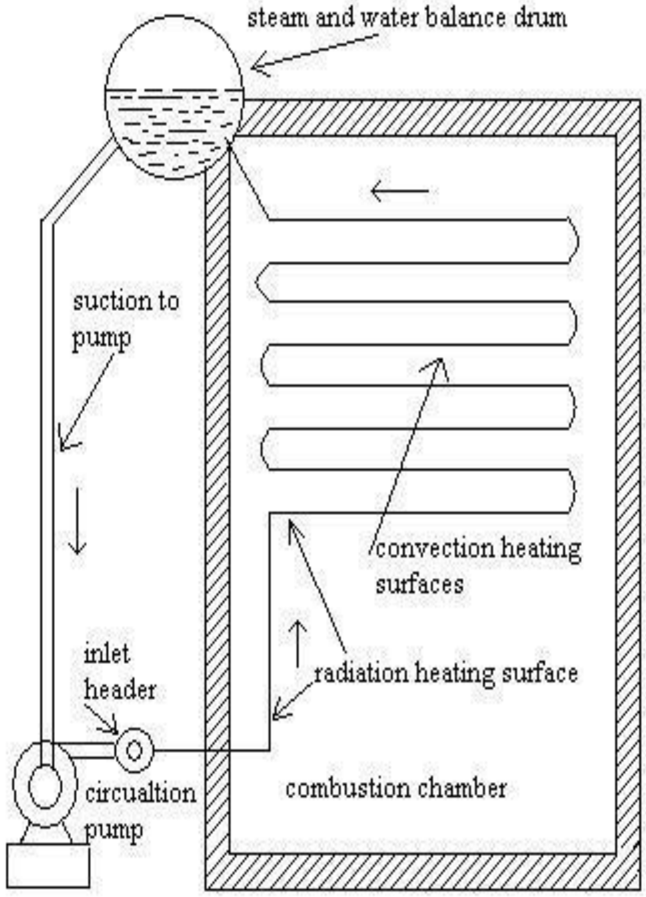
4. Indicated power, IP = BP + FP kW
5. Mechanical efficiency, η_{mech} = (BP/IP)*100

RESULT:

The retardation test was conducted on a single cylinder 4-stroke diesel engine and the frictional power was found.

VIVA-VOCE QUESTIONS:

1. What is the other name of retardation test?
2. How retardation is take place in the engine?
3. List the limitations of deceleration method.
4. Explain the method of measuring deceleration in the engine.
5. Name the two losses occur in the engine.



Schematic diagram of La Mont Boiler

Study No: 04
Date :

STUDY OF STEAM GENERATORS

AIM:
To study the working of various types of steam generator (steam boilers).

STEAM GENERATORS:

INTRODUCTION:
A steam boiler is a closed vessel which boiler generator steam by transferring heat produced by burning of fuel to water. The steam boiler produced is used for power generation or process heating.

SELECTION OF STEAM GENERATORS:
The selection of type & size of a steam generator depends on the following factors.
1. The power required & working pressure.
2. The geographical position of power house.
3. The fuel & water available.
4. The probable load factor.

CLASSIFICATION OF BOILERS:
The steam boilers are classified according to the following basic:

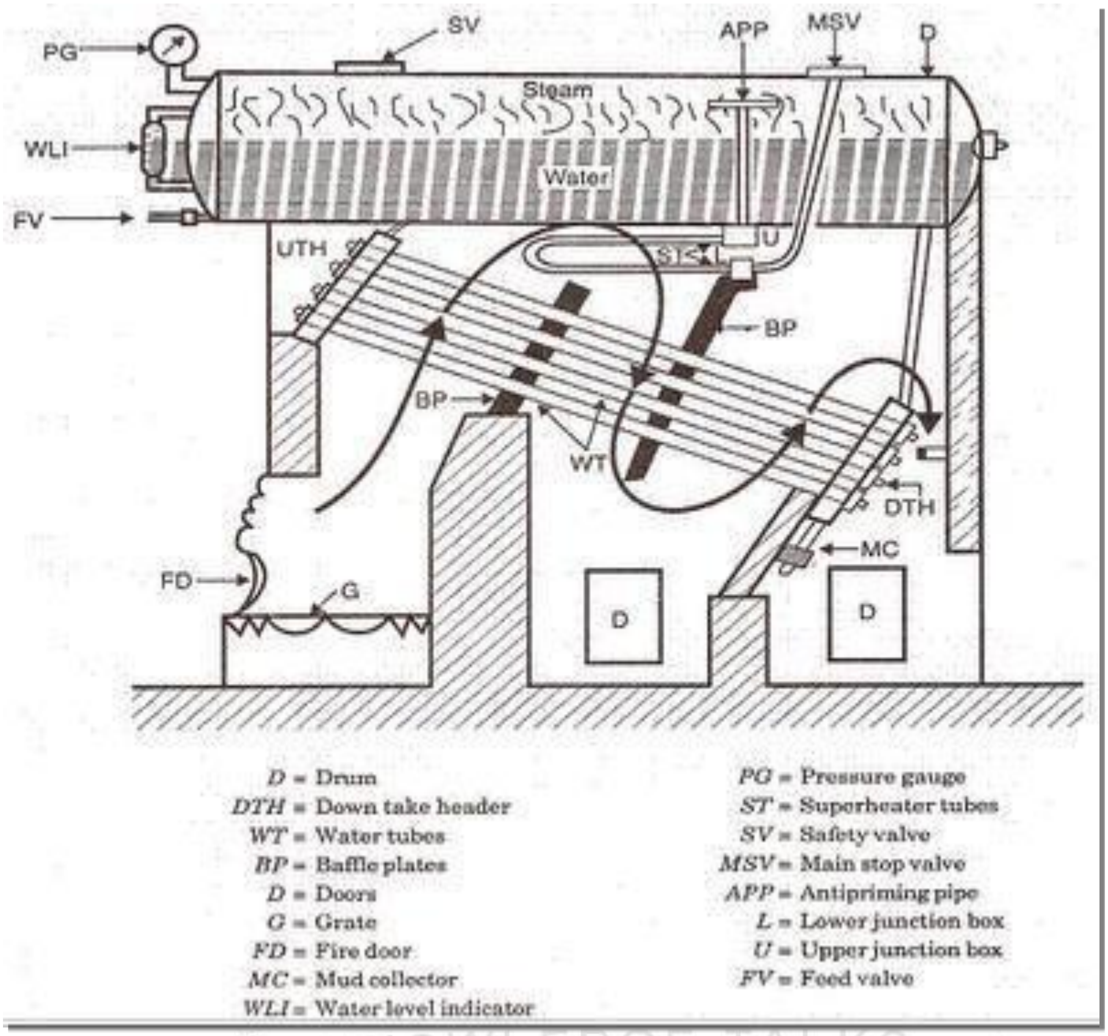
1. Flow of water & heat gases
   a. Fire tube boiler
   b. Water Tube boiler

2. Method of firing
   a. Internally fired
   b. Externally fired

3. Method of water circulation
   a. Natural circulation
   b. Forced circulation

4. Pressure developed
   a. Low pressure boiler
   b. High pressure boiler

5. Nature of service
   a. Stationary boiler
   b. Mobile boiler



Babcock & Wilcox boiler

6. Design of gas passage
a. Single phase
b. Multi-phase

HIGH PRESSURE BOILERS:
Modern high pressure boilers generate steam at a pressure more than 75 bar.
Example: Babcock & Wilcox boiler, Lamont boiler, BHEL boiler.

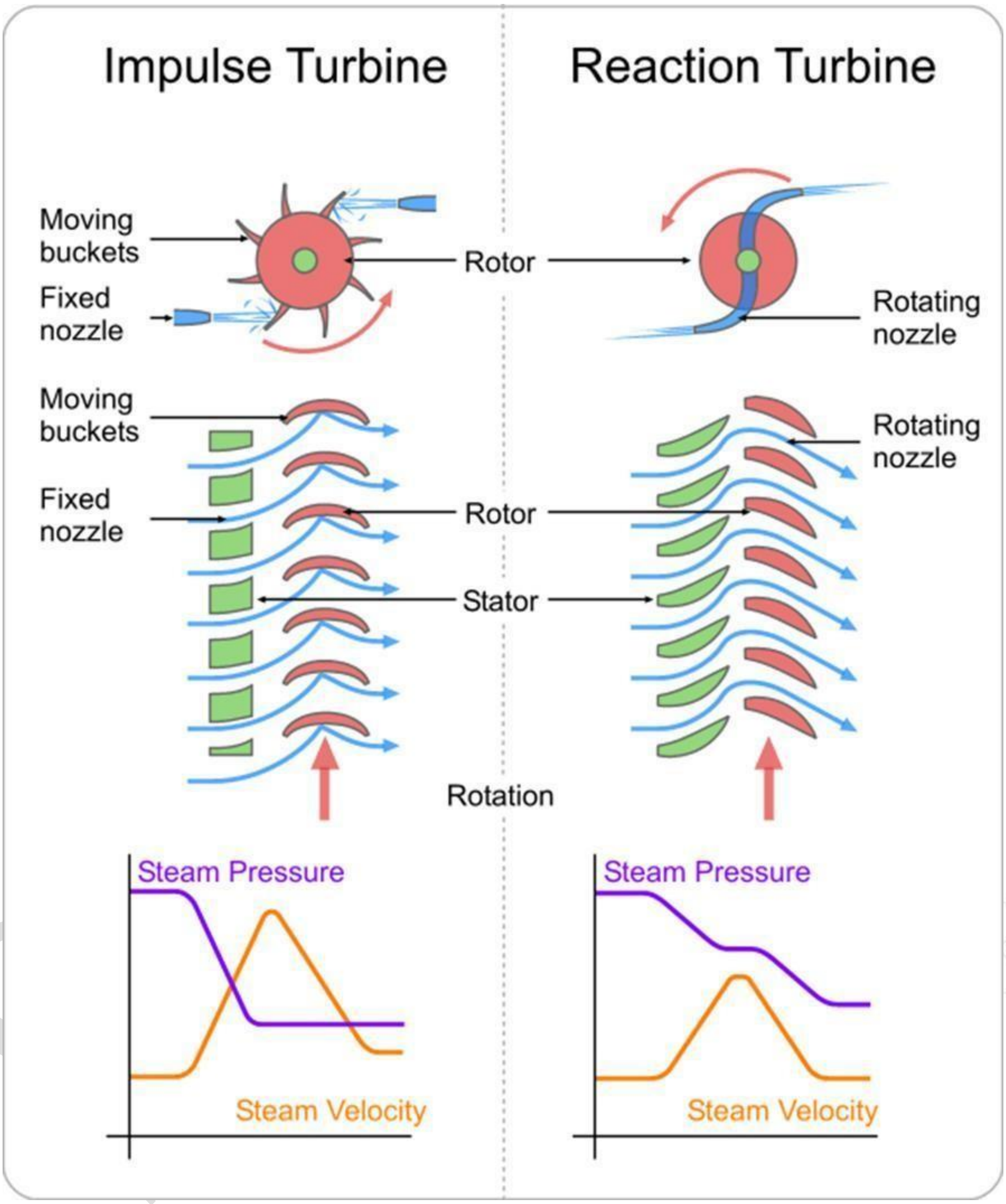
LAMONT BOILER:
A forced circulating boiler was first introduced in 1725 by Camont. The arrangement is shown in the figure. The most of sensible heat is supplied to the feed water passing through the Economizer. A centrifugal pump circulates the water equal to 8 to 10 times the weight of steam evaporated tubes and the part of water supplied drum. The large quantity of water circulated prevents the tubes from being overheated.
To secure the uniform flow of feed water through each of parallel boilers circuits a choke is fitted all the enhance to each circuits.

BHELL BOILERS:
It consists of feed pump, a economizer a boiler drum , radiant & connective super heaters , FD fan , air pre heaters 1 & 2 .Electro static precipitator 1D fan & chimney .

The feed water from the hot well is pumped with the help of a feed pump to boiler from the through economy .In boiler drawn the fed water is circulated to number of valves in the furnaces with fuel is burnt. The feed water is evaporated into wet steam and the wet steam flows back to boiler drawn. In this it is s supplied to prime mover through steam outlet.

The hot blue gases from the furnace pars over radiant & connective super heaters to super heat the steam. Then it passes through the pre heaters economizer and pre heater .Then the blue gases passes through the electrostatic precipitator.

RESULT:
Thus the working of various types of steam generator (steam boilers) was studied.


Impulse Turbine
Reaction Turbine
Moving buckets
Fixed nozzle
Rotor
Rotating nozzle
Moving buckets
Fixed nozzle
Rotor
Rotating nozzle
Stator
Rotation
Steam Pressure
Steam Velocity
Steam Pressure
Steam Velocity

Study No: 05
Date :

STUDY OF STEAM TURBINES

AIM:

To study the working and classification of steam turbines.

WORKING OF STEAM TURBINE:

A steam turbine has basically nozzle and ring of moving blades mounted on a shaft called rotor. The shaft motion of turbine depends solely upon the dynamic action of steam. Steam is injected through nozzles over to the ring of moving blades. Thermal energy of steam is partly converted into kinetic energy due to static pressure drop in nozzle. High velocity steam leaving nozzle enters the moving blade and the direction of steam flow gets changed from inlet to exit. This change in direction of steam flow causes change of momentum, which results in dynamic force acting as driving thrust for rotation of shaft.

Steam turbine can be impulse turbine or reaction turbine based on mechanismof driving thrust creation.

If the static pressure drop occurs principally in stationary nozzle with little or no static pressure drop occurring in rotor blade passage, then turbine is called an „impulse turbine‟ .

If the substantial static pressure drop occurs in stationary nozzle and rotor blade passage both then turbine is called „reaction turbine‟ .

Thus in case of impulse turbine driving thrust is available due to change in momentum because of change in velocity direction while moving across the blade from inlet to exit.

In case of reaction turbine the static pressure drop in rotor blade passagecauses further conversion of thermal energy into kinetic energy and hence generation of resultant reactive force. Driving thrust in reaction turbine comprises of reactive force and force associated with change in momentum due to change in direction of velocity.

Impulse Turbine has basically following components which are also described.

COMPONENTS:

Stationary nozzle**:** Impulse turbine has stationary passage comprising of one or more stationary nozzles in which steam at high static pressure and low velocity is expanded so as to increase velocity of steam at exit of nozzle. High velocity stream leavesnozzle so as to deliver steam with correct direction for smooth entry into movingblade.

Moving blades: Moving blades are fixed around the circumference of a rotor shaft with top of blades connected together for rigidity by means of a blade shroud ring. Blades actually cause change in direction of steam and so the momentum change occurs and thus impulse is generated. Steam turbine blades are made of alloy steel and manufactured by machining from bar stock. Typical blade material called nickel based super alloy may have Ni, Co, W, Cr, Al, Tn, Ti, Hf, Fe, Mo, C, Si, Mn, Cu, Za,B, S, Pb in percentage by weight of 59, 10, 10, 9, 5.5, 2.5, 1.5, 1.5, 0.25, 0.25, 0.15, 0.1, 0.1, 0.05, 0.05, 0.015, 0.008 and 0.0005 respectively.

Guide blades: Turbine rotor has guide blades prior to moving blades so as to guide steam in proper direction for smooth entry into moving blade. Guide blades are stationary guides mounted between the rotor blade rings. Guide blades perform function of reversing the direction of steam leaving the preceding moving blade rowso that direction of steam entering moving blade rows is similar.

Casing: Casing refers to the outer enclosure housing nozzles and fixed blades. Casing is also referred to as shell or cylinder. Casing confines steam to flow passages and also provides the structural frame. Casings of large steam turbines are normally horizontally split for convenience of repair and inspection. For high pressures and temperatures casings are made of cast carbon steel while low pressure turbine casings are made from rolled flat steel plate. For very high temperatures stainless steel casings are good.

Shaft: Shaft or rotor or spindle refers to the rotating member upon which moving blade ring is mounted.

Ring or Wheel: Wheel refers to the ring upon which moving blades are mounted. Wheel is keyed on to the shaft. This ring is also called disc.

Diaphragm: Diaphragm is attached to the casing containing the nozzles and performs function of confining steam flow to nozzle passage.

Packing: Packing is provided for preventing the leakage across the annular space between the diaphragm and shaft, casing and shaft. Packing is provided in the form of carbon rings or labyrinth glands. Carbon rings present an effective seal against shaft leakage in small turbines and are extensively used with labyrinth and water seals for preventing shaft leakage in larger turbines. Carbon ring consists of a ring of carbon rectangular in cross section and usually divided into four segments. Rings snugly fit into a recess in casing and are kept tight against shaft by means of garter spring. Labyrinth seals consist of series of thin strips fixed to the casing or other stationary member and arranged so as to maintain the smallest possible clearance with the shaft. The labyrinth seals have small restrictions that increase the velocity of leaking fluid only to have it dissipated in the pockets, thereby throttling the fluid. The tips of the strips are extremely thin so that if rubbing occurs the tip gets worn away without damaging the shaft. These labyrinth seals do not prevent complete leakage of fluid.

These are effective in only reducing leakage. Complete leakage prevention is done in association with other seals as carbon seals described earlier.

Steam chest: This is the steam supply chamber which houses steam before being supplied to nozzles.

Exhaust hood: The portion of casing which collects and delivers the exhaust steam to exhaust pipe or condenser is called exhaust hood.

Throttle valve: Throttle valve, also called stop valve is located in steam supply line of the steam turbine. Throttle valve may be manually operated or hydraulically operated for regulating steam flow during start and stop of turbine.

Governor: Governor is also provided in steam turbine for controlling the steam mass flow so as to maintain constant speed with load fluctuations. An over speed governor with trip mechanism is also provided to shut off the supply of steam.

Bearings: Turbine has main bearings to support the shaft. Along with these thrust bearings are also provided to support the axial thrust.

Turning gear: Turning gear is generally used with large turbines and consists of a gear integral with turbine shaft driven by electric motor through necessary speed reduction. Turning gear is used so as to keep the turbine shaft rotating at about 1−20 rpm in order to avoid springing of shaft occurring due to unequal expansions and contractions during warming and cooling of turbine.

Trip mechanism: Steam turbine is provided with a trip mechanism operating through an over speed governor to shut off supply of steam to turbine. Trip mechanism is actually safety device which gets activated upon number of other adverse operating conditions of turbine such as loss of lubricating oil pressure or condenser vacuum or excessive axial thrust etc.

Ex. No: 08 **THERMAL CONDUCTIVITY APPARATUS-GAURDED HOT PLATE METHOD**

Date:

AIM:

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

DESCRIPTION OF APPARTUS:

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

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

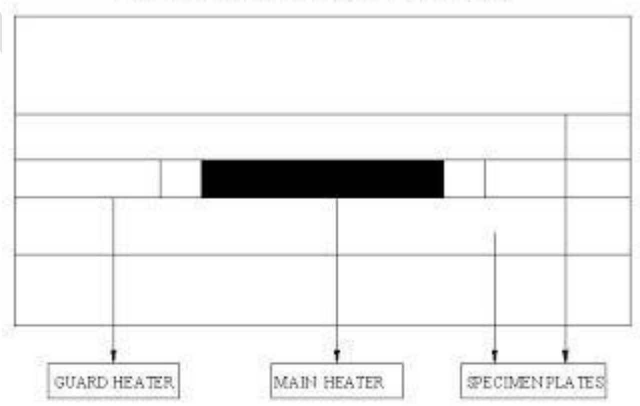
The whole assembly is kept in an enclosure with heat insulating material filled all around to minimize the heat loss.

SPECIFICATION:

Thickness of specimen = 2.5mm

Diameter of specimen (d) = 20cm

THERMAL CONDUCTIVITY APPARATUS



PROCEDURE:

1. Connect the power supply to the unit. Turn the regulator knob clockwise to power the main heater to any desired value.

2. Adjust the guard heater's regulator so that the main heater temperature is less than or equal to the guard heater temperature.

3. Allow water through the cold plate at steady rate. Note the temperatures at different locations when the unit reaches steady state. The steady state is defined, as the temperature gradient across the plate remains same at different time intervals.

4. For different power inputs is in ascending order only the experiment may by repeated and readings are tabulated as below.

TABULATION:

Inner heater				Outer heater				Cooling plate	
V	I	T_1	T_2	V	I	T_3	T_4	T_5	T_6

MODEL CALCULATIONS:

FORMULA USED:

Since the guard heater enables the heat flow in uni direction

q = KA dT/dx

Where A = surface area of the test plate considered for heat flow = m2

dx = thickness of the specimen plate = m

dt = average temperature gradient across the specimen = c

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

Tavg1 = T1 + T2 / 2 ; Tavg2 = T3 +T4 / 2

Q = V.I. Watts

Q = K1 A. dT / dx (for lower side)

Q = K1. πd2/4 (Tavg1 – T5)/dx

Where dx = 2.5mm = 0.0025m

Diameter of specimen

d = 20cm = 0.2m

Q = K2 πd2/4 . (Tavg2 –T6)/dx (for upper side)

KAvg = (K1 + K2)/ 2

Calculation:

RESULT:

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

Ex. No:09 **THERMAL CONDUCTIVITY OF INSULATING MATERIAL - LAGGED PIPE**
Date:
AIM:

To find the thermal conductivity of different insulating material.

DESCRIPTION OF APPARATTUS:

The insulation defined as a material, which retards the heat flow with reasonable effectiveness. Heat is transferred through insulation by conduction, convection and radiation or by the combination of these three. There is no insulation, which is 100% effective to prevent the flow of heat under temperature gradient.

The experimental set up in which the heat is transferred through insulation by conduction is under study in the given apparatus.

The apparatus consisting of a rod heater with asbestos lagging. The assembly is inside as MS pipe. Between the asbestos lagging and MS pipe saw dust is filled. The set up as shown in the figure. Let r1 be the radius of the heater, r2 be the radius of the heater with asbestos lagging and r3 be the inner radius of the outer MS pipe.

Now the heat flow through the lagging materials is given by

$Q = K1\ 2\ \Pi L(\Delta t) / (In(r2)/r1)$ or

$= K2\ 2\ \Pi L(\Delta t) / (In(r3)/r2)$

Where Δt is the temperature across the lagging.

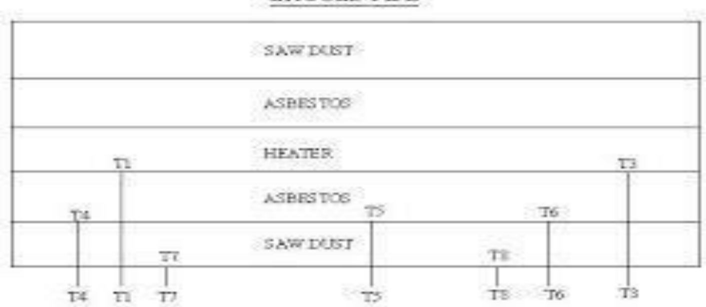
K1 is the thermal conductivity of asbestos lagging material and

K2 is the thermal conductivity of saw dust.

L is the length of the cylinder.

Knowing the thermal conductivity of one lagging material the thermal conductivity of the other insulating material can be found.

LAGGED PIPE



d1 - HEATER DIA = 20 mm d2 - HEATER WITH ASBESTOS DIA = 40 mm d3 - ASBESTOS & SAW DUST DIA = 80 mm LENGTH = 500mm

PROCEDURE:

1. Switch on the unit and check if all channels of temperature indicator showing proper temperature.
2. Switch on the heater using the regulator and keep the power input at some particular value.
3. Allow the unit to stabilize for about 20 to 30 minutes. Now note down the ammeter, voltmeter reading which given the heat input.
4. Temperatures 1, 2 and 3 are the temperature of heater rod, 4,5 and 6 are the temperatures on the asbestos layer, 7 and 8 are temperatures on the sawdust lagging.
5. The average temperature of each cylinder is taken for calculation. The temperatures are measured by thermocouple (Fe/Ko) with multi point digital temperature indicator.
6. The experiment may be repeated for different heat inputs.

The readings are tabulated as below:

TABULATION:

S.No	Heat temperature				Asbestos temperature				Sawdust temperature			Volts (V)	Amps (A)	K W/mK
	1	2	3	avg	4	5	6	avg	7	8	avg			

SPECIFICATION:

Diameter of heater rod = 20mm

Diameter of heater rod with asbestos lagging = 40mm

Diameter of heater with asbestos lagging and saw dust = 80mm

The effective length of the above set up of cylinders = 500mm

CALCULATION:

RESULT :

Thermal conductivity of

(i) Asbestas --------------W/mK

(ii) Sawdust --------------- W/mK

Ex. No:10 **HEAT TRANSFER BY FREE CONVECTION**

Date:

AIM:

To find the heat transfer coefficient under natural convection environment.

DESCRIPTION OF APPARATUS:

Convection is a mode of heat transfer where by a moving fluid transfers heat from a surface. When the fluid movement is caused by density differences in the fluid due to temperature variations, it is called **FREE** or **NATURAL CONVECTION**.

This 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 it to rise. This in turn gives rise to a continuous flow of air upwards in the duct. The instrumentation provided gives the heat input and the temperature at different points on the heated cylinder.

SPECIFICATION:

Length of cylinder = 50 cm

PROCEDURE:

1. Switch on the unit and adjust the regulator to provide suitable power input.
2. Allow some time for the unit to reach steady state condition.
3. Note the temperature of inlet air, outlet air and temperatures along the heater rod.
4. Note ammeter and voltmeter readings.
5. For different power inputs the experiments may be repeated.

The readings are tabulated as below: -

Voltmeter (V)	Ammeter (A)	Q (W)	Temperature								$\frac{T_2 + \ldots\ldots + T_8}{7}$ In C°
			T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	

FORMULA USED:

The power input to heater = V X A = hAΔt

Where A = Area of heat transfer = χdl

D = Dia. Of heater rod = 40mm

L = Length of heater rod = 500mm

Δt= Avg. temp. Of heater rod – Avg. temp. of air.

H = Overall heat transfer co-efficient.

THEORETICAL METHOD

Using free convection correlations for vertical cylinders.

Nu = hl / K = 0.53$(GrPr)^{1/4}$ for GrPr < 10^5

Nu = hl / K = 0.56$(GrPr)^{1/4}$ for 10^5< GrPr < 10^8

Nu = hl / K = 0.13$(GrPr)^{1/3}$ for 10^8< GrPr < 10^{12}

Characteristic length is the height of the cylinder (l)

K = Thermal conductivity of air

P = Prandtl number of air

$G_r = ßgl^3 \Delta t / \upsilon^2$

ß = 1 / Mean temp. of air + 273 K

The properties of air at mean temperature = $(T_1+T_2+T_3+\ldots+T_8)/ 8$

Hence h can be evaluated.

Calculation:

RESULT:

The heat transfer coefficient is found to be ----------------------------W/m^2K

Ex. No:11 **FORCED CONVECTION**

Date:

AIM:

To find the heat transfer coefficient under forced convection environment.

DESCRIPTION OF APPARATUS:

The important relationship between Reynolds number, Prandtl number and Nusselt number in heat exchanger design may be investigated in this self-contained unit.

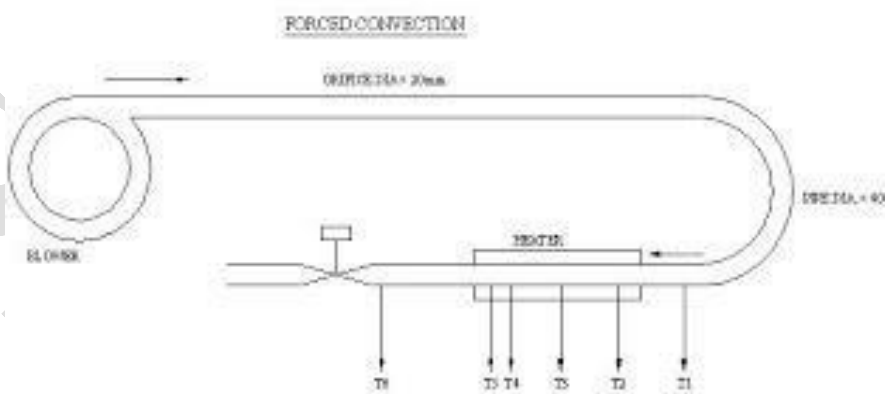
The experimental set up (see sketch) consists of a tube through which air is sent in by a blower. The test section consists of a long electrical surface heater on the tube which serves as a constant heat flux source on the flowing medium. The inlet and outlet temperatures of the flowing medium are measured by thermocouples and also the temperatures at several locations along the surface heater from which an average temperature can be obtained. An orifice meter in the tube is used to measure the airflow rate with a 'U' tube water manometer.

An ammeter and a voltmeter is provided to measure the power input to the heater.

A power regulator is provided to vary the power input to heater.

A multi-point digital temperature indicator is provided to measure the above thermocouples input.

A valve is provided to regulate the flow rate of air.



PROCEDURE:

1. Switch on the mains.
2. Switch on the blower.
3. Adjust the regulator to any desired power input to heater.
4. Adjust the position of the valve to any desired flow rate of air.
5. Wait till steady state temperature is reached.
6. Note manometer readings h_1 and h_2.
7. Note temperatures along the tube. Note air inlet and outlet temperatures
8. Note volt meter and ammeter reading.
9. Adjust the position of the valve and vary the flow rate of air and repeat the experiment.
10. For various valve openings and for various power inputs and readings may be taken to

The heat input Q = h A L M T D = m cp (temp. of tube – temp. of air)

M = mass of air. cp = specific heat of air.

LMTD=(Avg Temp Of tube – outlet air temp) – (Avg. temp of tube – inlet air temp.)

1n x (Avg. temp of tube – outlet temp. of air)

(Avg. temp of tube – inlet temp. of air)

H= heat transfer co-efficient. A = area of heat transfer = T1d1

From the above the heat transfer co-efficient 'h' can be calculated. These experimentally determined values may be compared with theoretical values.

Calculate the velocity of the air in the tube using orifice meter / water manometer. The volume of air flowing through the tube (Q) = $(cd^2{}_1{}^2{}_2\sqrt{2gh_0}) / (\sqrt{a_1^2 - a_2^2})$ m^3 / sec.

h_o= heat of air causing the flow. = $(h_1 - h_2)\rho w/\rho a$

$h_1$and h_2 are manometer reading in meters.

a_1= area of the tube.

a_2 = area of the orifice.

Hence the velocity of the air in the tube $V = Q / a_1$ m/sec heat transfer rate and flow rates are expressed in dimension less form of Nusselt number and Reynolds number which are defined as

$Nu = h D/k$ $\quad\quad$ $Re = Dv/ \upsilon$

D = Dia. Of the pipe

V = Velocity of air

K = Thermal conductivity of air.

The heat transfer co-efficient can also be calculated from Dittus-Boelter correlation.

$Nu = 0.023\ Re^{0.8}\ Pr^{\ 0.4}$

Where Pr is the Prandtl number for which air can be taken as 0.7. The Prandtl number represents the fluid properties. The results may be represented as a plot of Nu exp/ Nu corr. Vs Re which should be a horizontal line.

TABULATION:

Voltage In Volts(v)	Ammeter In Amps(A)	Inlet Temp (T_1)	Outlet Temp (T_6)	Temperature						H In W/m^{2}K
				T_2	T_3	T_4	T_5	H_1 in CM	H_2 in CM	

Calculation:

RESULT:

The heat transfer coefficient is found to be ---------------- W/m^2K

Ex. No:12 **HEAT TRANSFER FROM FINS**

Date:

AIM:

To determine the temperature distribution of a PIN-FIN for natural convection and FIN efficiency.

DESCRIPTION OF APPARATUS:

Consider a PIN-FIN having the shape of rod whose base is attached to a wall at a surface temperature Ts, the fin is cooled along the axis by a fluid at temperature TAMB. The fin has a uniform cross sectional area Ao is made of material having a uniform thermal conductivity K and the average heat transfer co-efficient between the surfaces to the fluid. We shall assume that transverse temperature gradients are so small so that the temperature at any cross section of the fin is uniform.

The apparatus consists of a Pin-fin placed inside an open duct, (one side open) the other end of the duct is connected to the suction side of a blower; the delivery side of a blower is taken up through a gate valve and an orifice meter to the atmosphere. The airflow rate can be varied by the gate valve and can be measured on the U tube manometer connected to the orifice meter. A heater is connected to one end of the pin-fin and seven thermocouples are connected by equal distance all along the length of the pin and the eight thermocouple is left in the duct.

The panel of the apparatus consists of voltmeter, ammeter and digital temperature indicator. Regulator is to control the power input to the heater. U tube manometer with connecting hoses.

SPECIFICATIONS:

Duct width	b	=	150 mm
Duct height	w	=	100 mm
Orifice dia.	do	=	20 mm
Orifice co-efficient	cd	=	0.6
Fin length	L	=	14.5cm
Fin diameter	df	=	12mm
(Characteristic length)			

PROCEDURE:

Connect the three pin plug to a 230V, 50Hz, 15A power and switch on the unit.

Keep the thermocouple selector switch in first position.

Turn the regulator knob to clockwise and set the power to the heater to any desired value by looking at the voltmeter and ammeter.

Allow the unit to stabilize.

Switch OFF the blower.

Set the airflow rate to any desired value looking at the difference in U tube manometer limb levels.

Note down the temperatures indicated by temperature indicator.

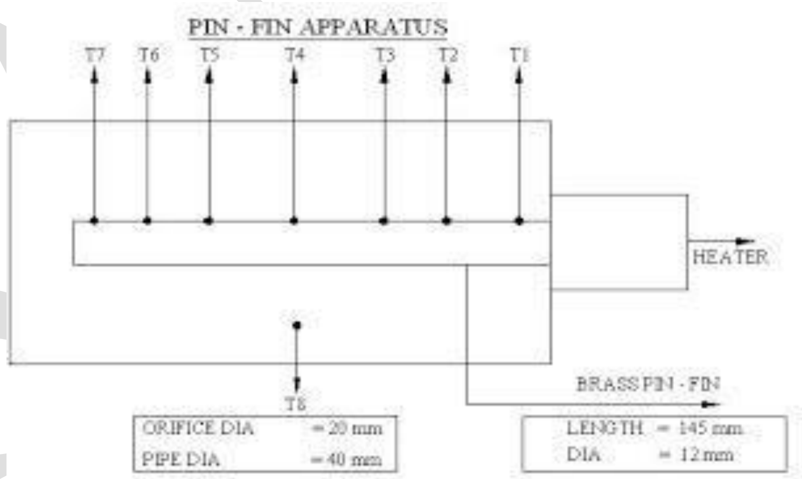
Repeat the experiment by

a. Varying the airflow rate and keeping the power input to the heater constant.

b. Varying the power input to the heater and keeping the air flow rate constant.

Tabulate the readings and calculate for different conditions.

After all the experiment is over, put off the blower switch, turn the energy regulator knob anti clockwise, put off the main switch and disconnect the power supply.



TABULATION:

S.No.	Voltage (V)	Ammeter (A)	Manometer reading		Fin surface temp in C^0					Amb. Temp in T_6 in C^0
			h1	h2	T1	T2	T3	T4	T5	

Formula used:

Volume of air flowing through the duct

Vo = cd a1a2 √2gha / √a12 a22

Where cd = co-efficient of orifice = 0.6

g = gravitational constant = 9.81 m/sec2

ha = heat of air = (lw /la)h

a1 = area of the pipe.

a2 = area of the orifice.

h = manometer differential head.

Velocity of air in the duct = Vo / (W X B)

Where W = width of the duct.

D = breadth of the duct.

REYNOLD'S NUMBER OF AIRFLOW:

Reynolds's number Re = (L X Va X Pa) / µa

Where Va = Velocity of air in the duct.

Pa = density of air in the duct.

µa = Viscosity of air at to C.

L = length of fin.

PRANDTL NUMBER OF AIRFLOW

Prandtl number = (cpa X μa) / ka

Where cpa = specific heat of air.

μa = viscosity of air

ka = thermal conductivity of air.

HEAT TRANSFER CO-EFFICIENT CALCULATIONS

NUSSELT NUMBER (Nu)

For 40 <NRe< 4000

Nnu = 0.683 (NRe) 0.466 (NPr) 0.333

For 1 <NRe< 4

Nnu = 0.989 (NRe)0.33 (NPr)0.333

For 4 <NRe< 40

Nnu = 0.911 (NRe)0.385 (NPr)0.333

For 4000 <NRe< 40000

Nnu = 0.193 (NRe)0.618 (NPr)0.333

For NRe> 40000

Nnu = 0.0266 (NRe)0.805 (NPr)0.333

Heat transfer co-efficient h = Nnu X (Ka / L)

Ka = thermal conductivity of air

L = length of fin.

Efficiency of the pin-fin = actual heat transferred by the fin / (Heat which would have been transferred if entire fin where at the base temperature)

= Tan Hyperbolic ML/ML

Where, h = heat transfer co-efficient

L = length of the fin

M = √hp/(kb X A)

P = perimeter of the fin (π X dia of the fin)

A = cross sectional area of the fin.

kb = thermal conductivity of brass rod.

Temperature distribution = Tx = [cosh M (L-X) /cosh ML (To - Ta)] + Ta

X = distance between thermocouple and heater.

EVALUATION OF THE HEAT TRANSFER CO-EFFICIENT (h)

Natural convection (blower off)

Nuav = (hd)/k = 1.1 (Gr Pr)1/6 for 1/10 < Gr Pr< 104

Nuav= 0.53 (Gr Pr)1/4 for 104 < Gr Pr< 109

Nuav= 0.13 (Gr Pr)1/3 for 109 < Gr Pr< 1012

Where Nuav = average Nusselt number

= (hD) / k

D = Dia. of fin

K = thermal conductivity of air.

Gr = Grashof number = gβ ΔT D3 / r2

Where, β = 1/ (Tav + 273)

ΔT= (Tav – Tamb)

Pr = Prandtl Number = (μ Cp) / K

Calculation:

RESULT:

The efficiency of the fin is found to be ----------------------

Ex. No:13 **HEAT TRANSFER FROM FINS**

AIM:

To determine the temperature distribution of a PIN-FIN for forced convection and FIN efficiency.

DESCRIPTION OF APPARATUS:

Consider a PIN-FIN having the shape of rod whose base is attached to a wall at a surface temperature Ts, the fin is cooled along the axis by a fluid at temperature TAMB. The fin has a uniform cross sectional area Ao is made of material having a uniform thermal conductivity K and the average heat transfer co-efficient between the surfaces to the fluid. We shall assume that transverse temperature gradients are so small so that the temperature at any cross section of the fin is uniform.

The apparatus consists of a Pin-fin placed inside an open duct, (one side open) the other end of the duct is connected to the suction side of a blower; the delivery side of a blower is taken up through a gate valve and an orifice meter to the atmosphere. The airflow rate can be varied by the gate valve and can be measured on the U tube manometer connected to the orifice meter. A heater is connected to one end of the pin-fin and seven thermocouples are connected by equal distance all along the length of the pin and the eight thermocouple is left in the duct.

The panel of the apparatus consists of voltmeter, ammeter and digital temperature indicator. Regulator is to control the power input to the heater. U tube manometer with connecting hoses.

SPECIFICATIONS:

Duct width	b	=	150 mm
Duct height	w	=	100 mm
Orifice dia.	do	=	20 mm
Orifice co-efficient	cd	=	0.6
Fin length	L	=	14.5cm
Fin diameter	df	=	12mm
(Characteristic length)			

PROCEDURE:

Connect the three pin plug to a 230V, 50Hz, 15A power and switch on the unit.

Keep the thermocouple selector switch in first position.

Turn the regulator knob to clockwise and set the power to the heater to any desired value by looking at the voltmeter and ammeter.

Allow the unit to stabilize.

Switch ON the blower.

Set the airflow rate to any desired value looking at the difference in U tube manometer limb levels.

Note down the temperatures indicated by temperature indicator.

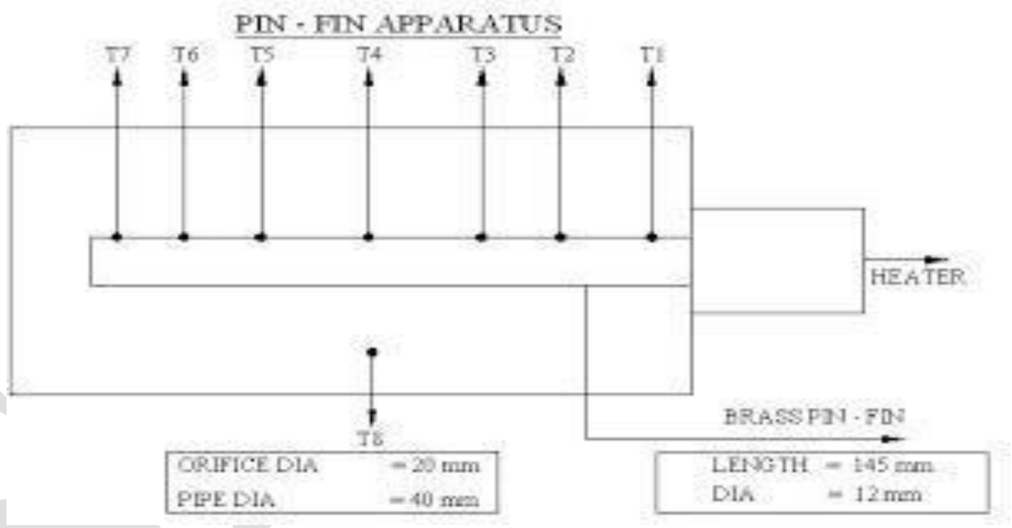
Repeat the experiment by

a. Varying the airflow rate and keeping the power input to the heater constant.

b. Varying the power input to the heater and keeping the air flow rate constant.

Tabulate the readings and calculate for different conditions.

After all the experiment is over, put off the blower switch, turn the energy regulator knob anti clockwise, put off the main switch and disconnect the power supply.



TABULATION:

S.No.	Voltage (V)	Ammeter (A)	Manometer reading		Fin surface temp in C^0					Amb. Temp in T_6 in C^0
			h1	h2	T1	T2	T3	T4	T5	

CALCULATION:

Volume of air flowing through the duct

Vo = cd a1a2 √2gha / √a12 a22

Where cd = co-efficient of orifice = 0.6

g = gravitational constant = 9.81 m/sec2

ha = heat of air = (lw /la)h

a1 = area of the pipe.

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h = manometer differential head.

Velocity of air in the duct = Vo / (W X B)

Where W = width of the duct.

D = breadth of the duct.

REYNOLD'S NUMBER OF AIRFLOW:

Reynolds's number Re = (L X Va X Pa) / µa

Where Va = Velocity of air in the duct.

Pa = density of air in the duct.

µa = Viscosity of air at to C.

L = length of fin.

PRANDTL NUMBER OF AIRFLOW

Prandtl number = (cpa X μa) / ka

Where cpa = specific heat of air.

μa = viscosity of air

ka = thermal conductivity of air.

HEAT TRANSFER CO-EFFICIENT CALCULATIONS

NUSSELT NUMBER (Nu)

For 40 <NRe< 4000

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For NRe> 40000

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Heat transfer co-efficient h = Nnu X (Ka / L)

Ka = thermal conductivity of air

L = length of fin.

Efficiency of the pin-fin = actual heat transferred by the fin/

(Heat which would have been transferred if entire fin where at the base temperature)

= Tan Hyperbolic ML/ML

Where, h = heat transfer co-efficient

L = length of the fin

M = √hp/(kb X A)

P = perimeter of the fin (π X dia of the fin)

A	=	cross sectional area of the fin.
kb	=	thermal conductivity of brass rod.

Temperature distribution = Tx = [cosh M (L-X) /cosh ML (To - Ta)] + Ta

X	=	distance between thermocouple and heater.

EVALUATION OF THE HEAT TRANSFER CO-EFFICIENT (h)

Natural convection (blower off)

Nuav = (hd)/k = 1.1 (Gr Pr)1/6 for 1/10 < Gr Pr< 104

Nuav= 0.53 (Gr Pr)1/4 for 104 < Gr Pr< 109

Nuav= 0.13 (Gr Pr)1/3 for 109 < Gr Pr< 1012

Where Nuav = average Nusselt number

= (hD) / k

D	=	Dia. of fin
K	=	thermal conductivity of air.

Gr = Grashof number = gβ ΔT D3 / r2

β = 1/ (Tav + 273)

ΔT= (Tav – Tamb)

Pr = Prandtl Number = (μ Cp) / K

RESULT:

The efficiency of the fin is found to be ----------------------

Ex. No: 14 **STEFAN – BOLTZMANN APPARATUS**

Date:

AIM:

To find Stefan-Boltzmann constant.

DESCRIPTION OF APPARATUS:

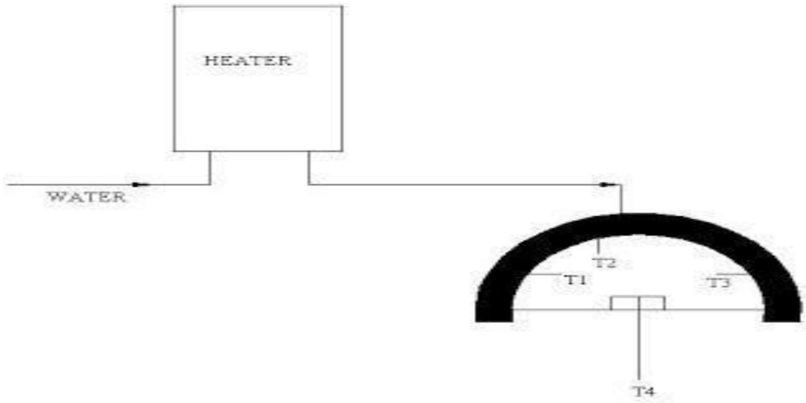
Stefan – Boltzmann law which establishes the dependence of integral hemispherical radiation on temperature. We can verify this phenomenon in this unit. The experimental set up consisting of concentric hemispheres with provision for the hot water to pass through the annulus. A hot water source is provided. The water flow may be varied using the control valve provided, thereby to control the hot water temperature. A small disk is placed at the bottom of the hemisphere, which receives the heat radiation and can be removed (or) refitted while conducting the experiment. A multi-point digital temperature indicator and thermocouples (Fe/Ko) are provided to measure temperature at various points on the radiating surface of the hemisphere and on the disc.

SPECIFICATIONS:

1. Mass of the disc = 0.005 kg.
2. Dia. of the disc = 0.020 m.
3. Material of the disc = copper
4. C_p = 381 J/KgK

PROCEDURE:

1. Allow water to flow through the hemisphere. Remove the disc from the bottom of the hemisphere. Switch on the heater and allow the hemisphere to reach a steady temperature.
2. Note down the temperatures T1, T2 and T3.The average of these temperatures is the hemisphere temperature (T_h).
3. Refit the disc at the bottom of the hemisphere and start the stop clock.
4. The raise in temperature T4 with respect to time is noted. Also note down the disc temperature at T4 when steady state is reached (Td).



TABULATION:

Sl.No.	T1	T2	T3	T4	Avg.temp. of hemisphere Th	Ts	Steady temp. of the disc. Td

FORMULA USED:

$Q = \sum\sigma (T_h^4 - T_d^4) A.$

$\sigma = Q / \sum(T_h^4 - T_d^4) A$ and $\sum=1.$

CALCULATION:

RESULT:

Stefan Boltzman constant is found to be------------W/m^2K^4

Ex. No: 15 **TEST ON EMISSIVITY APPARATUS**
Date:
Aim:

To measure the emissivity of the test plate surface.

DESCRIPTION OF APPARATUS:

An ideal black 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 absorptivity is 1 and by Kirchhoff's law its emissivity is also 1.Emissivity depends on the surface temperature and the nature of the surface.

The experimental sets up consists of two circular aluminum plates identical in size and are provided with heating coils at the bottom. The plates or mounted on thick asbestos sheet and kept in an enclosure so as to provide undisturbed natural convection surroundings. 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 Ir/Con 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 black paint to form 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:

a) Connect the three pin plug to the 230V, 50Hz, 15 amps main supply and switch on the unit.

b) Keep the thermocouple selector switch in first position. Keep the toggle switch in position 1. By operating the energy regulator 1 power will be fed to black plate. Now keep the toggle switch in position 2 and operate regulator 2 and feed power to the test surface.

c) Allow the unit to stabilize. Ascertain the power inputs to the black and test surfaces are at set values. I.e. equal.

d) Turn the thermocouple selector switch clockwise step by step and note down the temperatures indicated by the temperature indicator from channel 1 to 7.

e) Tabulate the readings and calculate.

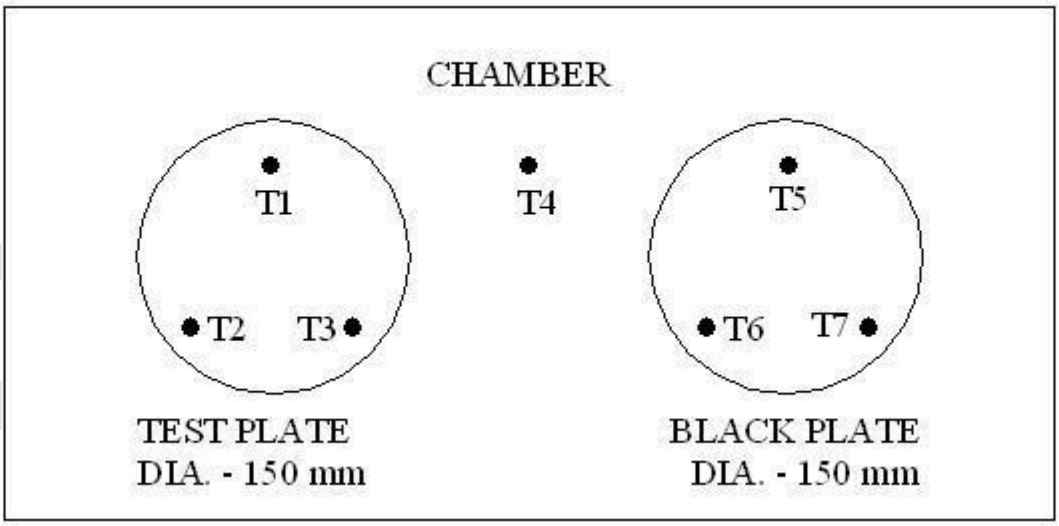
f) After the experiment is over turn both the energy regulators 1 & 2.

g) For various power inputs repeat the experiment.

TABULATION:

s.no	Plate	Volts (v)	Amps (I)	T_1 C^0 (T_b)	T_2 C^0(T_g)	T_3 C^0(T_a)	Emissivity(E_b)
1	Black Test						
2	Black Test						

EMISSIVITY APPARATUS



CALCULATION:

Temperature of the black body in absolute unit T ba = T b + 273

Temperature of the polished body in absolute unit T pa = T p + 273

Temperature of the chamber in absolute unit Tca = T 7 + 273

Emissivity $\varepsilon p = \varepsilon b$ X T4 ba - T4 ca / T4 pa - T4 ca

Where εb, emissivity of black body which is equal to 1.

RESULT:

Emissivity of the specimen is found to be ---------------

Ex. No: 16 **HEAT EXCHANGER TEST – PARALLEL FLOW AND COUNTERFLOW**
DATE:
Aim:

To find the overall heat transfer co-efficient in parallel flow and counter flow.

DESCRIPTION OF APPARATUS:

Heat exchangers are devices in which heat is transferred from one fluid to another. Common examples of the heat exchangers are the radiator of a car, condenser at the back of domestic refrigerator etc. Heat exchangers are classified mainly into three categories. 1. Transfer type 2. Storage type 3. Direct contact type.

Transfer type of heat exchangers are most widely used. A transfer type of heat exchanger is one in which both fluids pass simultaneously through the device and head is transferred through separating walls. Transfer type of exchangers are further classifies as

1. Parallel flow type in fluids flow in the same direction.
2. Counter flow type in fluids flow in the opposite direction.
3. Cross flow type in which fluids flow at any angle to each other.

A simple heat exchanger of transfer type can be in the form of a tube arrangement. One fluid flowing through the inner tube and the other through the annulus surrounding it. The heat transfer takes place across the walls of the inner tube.

SPECIFICATIONS:

Length of the heat exchanger L = 1650mm
Inner copper tube ID = 10.5mmInner
copper tube OD = 12.5mm
Outer GI tube ID = 27.5mm
Outer GI tube OD = 33.8mm

PROCEDURE:

1. Connect water supply at the back of the unit. The inlet water flows through geyser and inner pipe of the heat exchanger and flows out.

Also the inlet water flows through the annulus gap of the heat exchanger and flows out.

2. For parallel flow open valve V_2 , V_4 and V_5.

   For counter flow open valve V_3, V_1 and V_5.

3. Control the hot water flow approximately 2 lit./min. and cold water flow approximately 5 lit./min.

4. Switch ON the geyser. Allow the temperature to reach steady state.

5. Note temperatures T_1 and T_2 (hot water inlet and outlet temperature Respectively).

6. Under parallel flow condition T_3 is the cold-water inlet temperature and T_4 is the cold water outlet temperature. Note the temperatures T_3 and T_4.Under counter flow condition T_4 is the cold-water inlet temperature T_3 is the cold-water outlet temperature.

7. Note the time for 1 liter flow of the hot and cold water. Calculate mass flow rate Kg/sec.

8. Change the water flow rates and repeat the experiment.

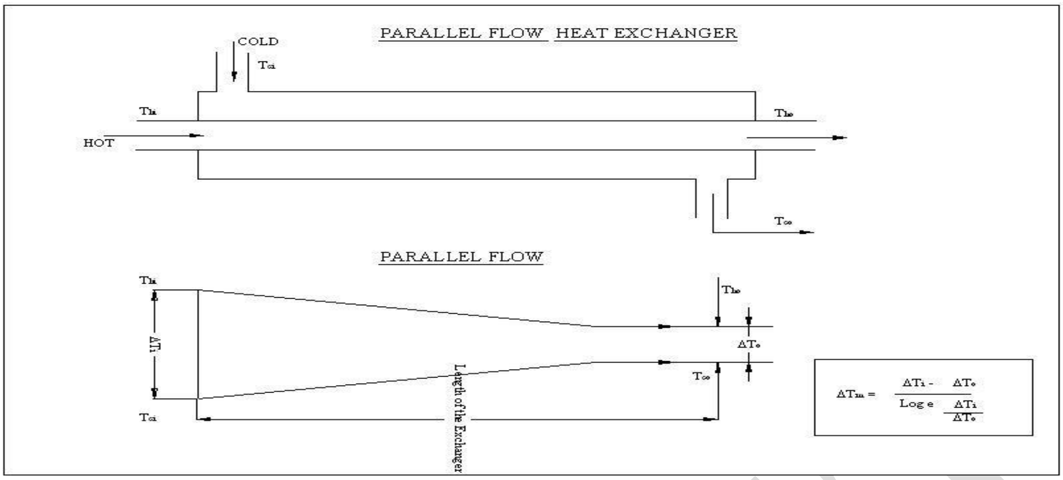
TABULATION :

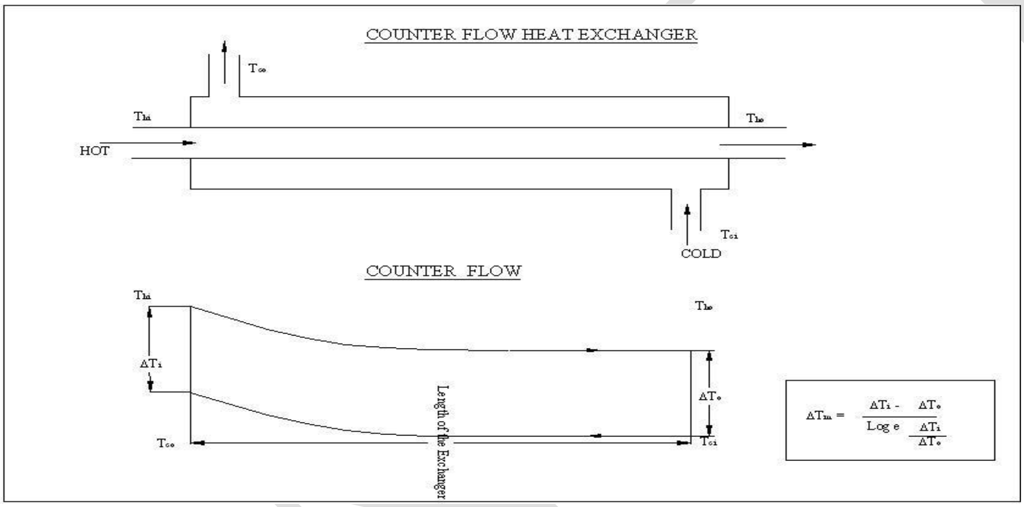
FOR PARALLEL FLOW

Hot water			Cold water		
Time of water (sec)	Inlet temperature (T1)	Outlet temperature (T2)	Time for Water (sec)	Inlet temperature (T3)	Outlet temperature (T4)

FOR COUNTER FLOW

Hot water			Cold water		
Time of water (sec)	Inlet temperature (T1)	Outlet temperature (T2)	Time for Water (sec)	Inlet temperature (T4)	Outlet temperature (T3)





CALCULATIONS:

Refer drawing and find

LMTD (Δtm) = $\Delta t_1 - \Delta t_o / l_n (\Delta t_1 / \Delta t_o)$

Please not Δt_1 and $\Delta t_o$to be calculated as per drawing for Parallel flow and Counter flow.

Q_h = A U L M T D

Hence the overall Heat transfer co-efficient

U = q_h / A L M T D

Where $q_h = m_h c_p (T_{hi} - T_{ho})$

c_p= specific heat of water (j/kgc)

A = Outer area of hot water pipe.

M_h= mass of hot water (kg/sec)

Effectiveness of Heat exchanger

= Actual heat transfer/ Max. possible heat transfer

= $(t_{co} - t_{ci}) / (t_{hi} - t_{ci})$

THEORETICAL METHOD:

The overall Heat transfer co-efficient

$1/U = (1/h_o) + (1/h_1)$

Neglecting the thickness of inner tube and film resistance where h_o and h_1 are the co-efficient of heat transfer of hot and cold side respectively.

h_1 = Inside Heat transfer co-efficient (from hot to inner surface of the inner tube)

h_o = Outside heat transfer co-efficient (from outer wall of the inner tube to the cold fluid).

R_e = hot water flow = $D\upsilon / \upsilon$

υ = Velocity of hot water.

Knowing the mass flow rates (υ) may be calculated for hot and cold water.

$N_u = 0.023 (R_e)^{0.8} (P_r)^{0.3} = (h_i D) / K$

K = Thermal conductivity of water.

PARALLEL FLOW CALCULATION:

COUNTER FLOW CALCULATION:

RESULT:

(i) Parallel flow

Overall heat transfer coefficient by theoretical method ------------ W/ m^2 K

Overall heat transfer coefficient by practical method -------------- W/ m^2 K

Efficiency -----------

(i) Counter flow

Overall heat transfer coefficient by theoretical method ------------ W/ m^2 K

Overall heat transfer coefficient by practical method -------------- W/ m^2 K

Efficiency ----------

Ex. No: 17 PERFORMANCE TEST ON A REFRIGERATION SYSTEM

DATE:

AIM:

To determine the COP, Refrigerant flow rate and capacity of a given refrigerant system and its control where throttling of the refrigerant is accomplished in a

i. A capillary tube.
ii. A thermostatic expansion valve

APPARATUS REQUIRED:

1. Refrigeration System.

PROCEDURE:

1. Select the thermostatic expansion valve line by opening the shut off valve on this line and closing the one on the capillary line. The solenoid manual switch is switched ON.
2. Start the compressor and run for some time so that the hilled water temperature t_5 is lowered to about 5^0C.
3. Note down the time (t_h & t_c) taken for a n revolutions of energy meter disc.
4. Note down the cooling coil temperature, voltage and current.
5. Measure temperature and presser at different points.
6. Calculation is done using the refrigeration relations.
7. Repeating the experiment by selecting the capillary tube as the expansion device and the solenoid manual switch is OFF.
8. Experiment may be repeated for different heat input.

FORMULA:

$$Work\ done\ by\ compressor = \frac{3600 \times n}{1200 \times t_c} \quad \frac{KJ}{Sec}$$

$$2. Heat\ remove = refrigerating\ effect = \frac{3600 \times n}{1200 \times t_h} \quad \frac{KJ}{Sec}$$

$$3. Actual\ COP(Refrigerator) = \frac{heat\ removed}{work\ done\ by\ the\ compressor}$$

$$4. Theoretical\ COP(Refrigerator) = \frac{h_1 - h_4}{h_2 - h_1}$$

h_1, h_2, h_3, h_4 *are taken from* $R - 12$ *chart*

where, n = *number of revolutions of energy meter disc*

t_h = *time take for n revolutions of energy meter disc of heater unit*

t_c = *time take for n revolutions of energy meter disc of compressor unit*

$$5. Refrigeration\ flow\ rate = \frac{Refrigerant\ capacity}{work\ done\ by\ compressor}$$

where, $Refrigerant\ capacity = m(h_1 - h_2)$

m = *mass flow rate of the refrigerant* $\frac{Kg}{Sec}$

$$Relative\ COP = \frac{Actual\ COP}{Theoretical\ COP}$$

Tabulation

Time for 5 rev of energy meter disc		Ammeter reading (Amps)	Voltmeter reading (Volts)	T^0				Pressure(bar)			
Heater t_h	Compressor t_c			T1	T2	T3	T4	P1	P2	P3	P4

Result:

Actual COP =

Ex. No: 18 PERFIRMANCE TEST ON AN AIR-CONDITIONING SYSTEM

DATE:

AIM:

To conduct COP test on a given air-conditioning test rig.

APPARATUS REQUIRED:

1. Air-conditioning system.

PROCEDURE:

1. Switch ON the heater first and then after some time switch on the whole air- conditioning system.
2. Measure the dry bulb and wet bulb temperature at four stages and note down the readings.
3. Tabulate the cooling coil temperature in ^{0}C.
4. Measure the time taken for a 5 revolutions of energy meter disc for heater and compressor.
5. Tabulate the values and calculate the coefficient of performance of the given air-Conditioning test rig.

FORMULA:

1. $By - Pass\ factor = \frac{T_4 - T_c}{T_3 - T_c}$

$where, T_3\ and\ T_4 = Temperature\ before\ and\ after\ cooling\ process$

$T_c = Temperature\ of\ cooling\ water\ coil$

2. $Refrigeration\ effect = m \times C_p \times \Delta T$

$where, m = \frac{q_a}{Q_H}$

3. $q_a = \frac{3600 \times 5}{600 \times t_c}$

4. $Q_H = h_2 - h_1 + h_{w1-2}$

$where, t_c = Time\ taken\ for\ 5\ revolution\ of\ energy\ meter\ disc$

$h_1, h_2 = Enthalpy\ of\ the\ system\ 1\ \&\ 2\ (\frac{KJ}{Kg})$

5. $\Delta SH = SH_3 - SH_4$

6. $Refrigeration\ effect = m \times Q_c$

7. $Power\ input = \frac{3600\times5}{600\times t_h}$

8. $COP = \frac{Refrigerating\ effect}{Power\ input}$

Tabulation:

Dry bulb temperature ^0C				Wet bulb temperature ^oC				Sp. Humidity (J/KgK)				Enthalpy (Kj/Kg)				Cooling coil temperature tc	Te (Secs)	th (Secs)
T 1	T 2	T 3	T 4	T W 1	T W 3	T W 3	T W 4	SH 1	SH 2	SH 3	SH 4	h 1	h 2	h 3	h 4			

Result:

Thus the COP of a given Air-conditioning system is =

Ex. No: 19 **PERFORMANCE TEST ON A RECIPROCATING AIR COMPRESSOR**

DATE:

AIM:

To conduct load test on two stage reciprocating air compressor and determine

1. Load factor of intercooler
2. Input power/ kg of air
3. Compression index
4. Volumetric efficiency
5. Isothermal efficiency

APPARATUS REQUIRED:

2. Two stage air compressor

PROCEDURE:

1. Note Barometer reading and room temperature
2. Start the compressor motor; open outlet receiver
3. Now note down the reading
   a) Manometer reading
   b) LP delivery gauge reading
   c) HP delivery gauge reading
   d) Temperature at HP outlet
   e) Temperature at HP inlet
   f) Spring balance reading

4. Close delivery valve partially and repeat procedure
5. Stop the compressor motor and release the air pressure in receiver and drain the water drops.

FORMULA:

1. $Electrical\ energy\ input\ to\ the\ motor = \frac{n_{pulse} \times 3600}{t \times EC}\ kW$

2. $Mechanical\ power = \frac{2\pi NT}{60}$

3. $T = Wight\ \times Arm\ distance$

4. $Density\ of\ air, \rho_a = \frac{P_a}{T_a}$

5. $Change\ in\ pressure, \Delta p = \rho_w \times g \times h \quad \frac{N}{m^2}$

6. $Actual\ volume\ of\ air\ intake = C_d \times A_0 \times \sqrt{2\Delta p \rho_a}$ m³/s

7. $Swept\ volum\ per\ sec = \frac{\pi}{4} D_{LP}{}^2 \times L_{LP} \times \frac{N}{60}$ m³/s

8. $Volumetric\ efficiency = \frac{V_a}{V_s} \times 100$

9. $Compressor\ output = \rho_a \times h_{hp} \times V_a$

$$h_{hp} = \frac{p_3}{\rho_a}$$

$$\eta_{overall} = \frac{compressor\ output}{Electrical\ input}$$

$$\eta_{cooling} = \frac{T_2 - T_3}{T_2 - T_1}$$

$$Isothermal\ workdone = mRT_1 \ln \frac{p_3}{p_1}$$

$$\eta_{isothermal} = \frac{Isothermal\ workdone}{Actual\ workdone}$$

Tabulation:

S.No	Delivery Pressure, kgf/cm²	Spring Balance reading of meter, kgf	Meter speed, rpm	Manometer reading		Manometer reading, $L=L_1-L_2$	Time taken for 5 rev of energy (sec)
				Right (L_1)cm	Left (L_2)cm		
1							
2							
3							
4							

Calculation:

Result:

Thus the load test on two stage reciprocating air compressor is conducted and various Parameters are found out.