PORT TIMING DIAGRAM OF SINGLE CYLINDER TWO STROKE SPARK IGNITION ENGINE

AIM:
To draw the port timing diagram of a two stroke spark ignition engine.

APPARATUS REQUIRED:

BRIEF THEORY OF THE EXPERIMENT:
The port timing diagram gives an idea about how various operations are taking place in an engine cycle. The two stroke engines have inlet and transfer ports to transfer the combustible air fuel mixture and an exhaust port to transfer exhaust gas after combustion. The sequence of events such as opening and closing of ports are controlled by the movements of piston as it moves from TDC to BDC and vice versa. As the cycle of operation is completed in two strokes, one power stroke is obtained for every crankshaft revolution. Two operations are performed for each stroke both above the piston (in the cylinder) and below the piston (crank case). When compression is going on top side of the piston, the charge enters to the crank case through inlet port. During the downward motion, power stroke takes place in the cylinder and at the same time, charge in the crank case is compressed and taken to the cylinder through the transfer port. During this period exhaust port is also opened and the fresh charge drives away the exhaust which is known scavenging. As the timing plays major role in exhaust and transfer of the charge, it is important to study the events in detail. The pictorial representation of the timing enables us to know the duration and instants of opening and closing of all the ports. Since one cycle is completed in one revolution i.e. 360 degrees of crank revolution, various positions are shown in a single circle of suitable diameter.

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PROCEDURE
1. Mark the direction of rotation of the flywheel. Always rotate only in clockwise direction when viewing in front of the flywheel.
2. Mark the Bottom Dead Center (BDC) position on the flywheel with the reference point when the piston reaches the lowermost position during rotation of the flywheel.
3. Mark the Top Dead Center (TDC) position on the flywheel with the reference point when the piston reaches the top most position during the rotation of flywheel.
4. Mark the IPO, IPC, EPO, EPC, TPO, and TPC on the flywheel observing the following conditions.
5. Inlet port open (IPO) when the bottom edge of the piston skirt just opens the lower most part of the inlet port during its upward movement.
6. Inlet port close (IPC) when the bottom edge of the piston fully reaches the lower most part of the inlet port during its downward movement.
7. Transfer port open (TPO) when the top edge of the piston just open the top most part of the transfer port during its downward movement.
8. Transfer port close (TPC) when the top edge of the piston fully reaches the upper most part of the transfer port during its upward movement.
9. Exhaust port open (EPO) when the top edge of the piston just opens the top most part of the exhaust port during its downward movement.
10. Exhaust port close (EPC) when the top edge of the piston fully reaches the upper most part of the exhaust port during its upward movement.
11. Measure the circumferential distance of the above events either from TDC or from BDC whichever is nearer and calculate their respective angles.
12. Draw a circle and mark the angles.
FORMULA:

\[ \text{Angle} = \frac{L}{X} \times 360 \]

Where, \( L \) – Distance from nearest dead center in mm
\( X \) – Circumference of the Flywheel in mm

OBSERVATION TABLE:

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Description</th>
<th>Distance in mm</th>
<th>Angle in degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IPO before TDC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>IPC after TDC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>EPO before BDC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>EPC after BDC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>TPO before BDC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>TPC after BDC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RESULT: The given two-stroke petrol engine is studied and the Port timing diagram is drawn for the present set of values.

REVIEW QUESTIONS:

1. What is the difference 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 for larger exhaust port diameter than the transfer port.

5. What do you mean by scavenging?

6. What is the pressure developed in crank case?

7. What are the problems associated with two stroke engines?

8. What are the advantages of two stroke engines?

9. How are two stroke engines lubricated? Give the name.

10. Define compression ratio. Give the range of compression ratio for petrol and diesel engines.
VALVE TIMING DIAGRAM OF A SINGLE CYLINDER FOUR STROKE COMPRESSION IGNITION ENGINE

AIM:
To draw the valve timing diagram of the four stroke compression ignition engine.

REQUIREMENTS:
1. Experimental engine
2. Measuring tape
3. Chalks

BRIEF THEORY OF THE EXPERIMENT:
The valve timing diagram gives an idea about how various operations are taking place in an engine cycle. The four stroke diesel engines have inlet valve to supply air inside the cylinder during suction stroke and an exhaust valve to transfer exhaust gas after combustion to the atmosphere. The fuel is injected directly inside the cylinder with the help of a fuel injector. The sequence of events such as opening and closing of valves which are performed by cam-follower-rocker arm mechanism in relation to the movements of the piston as it moves from TDC to BDC and vice versa. As the cycle of operation is completed in four strokes, one power stroke is obtained for every two revolution of the crankshaft. The suction, compression, power and exhaust processes are expected to complete in the respective individual strokes. Valves do not open or close exactly at the two dead centers in order to transfer the intake charge and the exhaust gas effectively. The timing is set in such a way that the inlet valve opens before TDC and closes after BDC and the exhaust valve opens before BDC and closes after TDC. Since one cycle is completed in two revolutions i.e 720 degrees of crank rotations, various events are shown by drawing spirals of suitable diameters. As the timing plays major role in transfer of the charge, which reflects on the engine performance, it is important to study these events in detail.

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PROCEDURE:
1. Mark the direction of rotation of the flywheel. Always rotate only in clockwise direction when viewing in front of the flywheel.
2. Mark the Bottom Dead Center (BDC) position on the flywheel with the reference point when the piston reaches the lowermost position during rotation of the flywheel.
3. Mark the Top Dead Center (TDC) position on the flywheel with the reference point when the piston reaches the top most position during the rotation of flywheel.
4. Identify the four strokes by the rotation of the flywheel and observe the movement of inlet and exhaust valves.
5. Mark the opening and closing events of the inlet and exhaust valves on the flywheel.
6. Measure the circumferential distance of the above events either from TDC or from BDC whichever is nearer and calculate their respective angles.
7. Draw the valve timing diagram and indicate the valve opening and closing periods.

FORMULA:

\[
\text{Angle} = \frac{L}{X} \times 360 \text{ degrees}
\]

Where, 
L – Distance from nearest dead center in mm
X- Circumference of the Flywheel in mm

OBSERVATIONS:
RESULT:
The given four stroke compression ignition engine is studied and the valve timing diagram is drawn for the present set of values.

REVIEW QUESTIONS:
1. How the valves are different 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. Explain the lubrication system of four stroke engines.
5. What do you mean by valve overlap? What are their effects in SI engines?
6. How the cylinder numbers assigned in multi-cylinder I.C. engines?
7. Give firing order for a four and six cylinder engines.
8. Explain how the correct direction of rotation is found before starting the valve timing experiment.
9. How do you identify an engine is working on two stroke or four stroke principle?
10. How do you identify whether it is petrol or diesel engine?
DIESEL ENGINE TEST RIG
(Performance Test on Two Cylinder Four Stroke Diesel Engine (KIRLOSKAR))

AIM:
To perform a load test on the given engine and to draw the performance characteristic curves.

APPARATUS REQUIRED:
1. The engine test rig
2. Stop-watch
3. Hand tachometer

SPECIFICATIONS

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Name</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TYPE</td>
<td>4-Stroke, 2-Cylinder Diesel Engine (Water Cooled), Compression Ignition.</td>
</tr>
<tr>
<td>2</td>
<td>MAKE</td>
<td>Kirloskar.</td>
</tr>
<tr>
<td>3</td>
<td>RATED POWER OUTPUT</td>
<td>10 HP, 1500 RPM.</td>
</tr>
<tr>
<td>4</td>
<td>BORE &amp; STROKE</td>
<td>87.5mm x 110mm.</td>
</tr>
<tr>
<td>5</td>
<td>COMPRESSION' RATIO</td>
<td>17.5 : 1</td>
</tr>
<tr>
<td>6</td>
<td>CYLINDER CAPACITY</td>
<td>1322cc.</td>
</tr>
<tr>
<td>7</td>
<td>STARTING</td>
<td>By Hand Cranking</td>
</tr>
</tbody>
</table>

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FUEL PROPERTIES:
Specific gravity of Diesel = 0.83 g/cc
Calorific value = 42,000 kJ/kg

BRIEF THEORY OF THE EXPERIMENT:
A load test on an engine provides information regarding the performance characteristics of the engine. Engine performance varies with both load on the engine as well as the engine speed. However the stationary engine used in this experiment operate at a constant speed. The performance characteristics of such engines are obtained by varying the load on the engine.

EXPERIMENTAL SETUP:
The compact and simple engine test rig consisting of a four stroke double cylinder, water cooled, constant speed diesel engine coupled to an alternator by flexible coupling. The engine is started by hand cranking using the handle by employing the decompression lever. The engine is loaded using electrical load. The loading arrangement consists of a set of switches on the panel board. A voltmeter and an ammeter are used to record the load on the alternator. A burette is connected with the fuel tank through a control valve for fuel flow measurement. Provision is made to circulate water continuously through the engine jacket.

STARTING THE ENGINE:
1. Keep the decompression lever in the vertical position
2. Insert the starting handle in the shaft and rotate it
3. When the flywheel picks up speed bring the decompression lever into horizontal position and remove the handle immediately.
4. Now the engine will pick up.
STOPPING THE ENGINE: 1. Cut off the fuel supply by keeping the fuel governor lever in the other extreme position. (For Diesel Engine)

PROCEDURE:
1. Start the engine at no load and allow idling for some time till the engine warm up.
2. Note down the time taken for 10cc of fuel consumption using stopwatch and fuel measuring burette.
3. After taking the readings open the fuel line to fill burette and supply fuel to run the engine from the fuel tank again.
4. Now load the engine gradually to the desired valve. This may be done by switching on the load switches.
5. Allow the engine to run at this load for some time in order to reach steady state condition and note down the time taken for 10 cc of fuel consumption.
6. Note down the voltmeter and ammeter readings for the above conditions.
7. Repeat the experiment by switch ON additional load switches.
8. Release the load by switching OFF the load switches slowly one by one and stop the engine.
10. Tabulate the readings as shown and calculate the result.

DETERMINATION OF MAXIMUM LOAD:

\[ I = \frac{Brakepower \times AlternatorEfficiency}{\sqrt{3V \cos \phi}} \text{ kW} \]

SPECIMEN CALCULATIONS:

1. Total fuel consumption = \( \frac{X}{Time} \times \text{specific gravity of fuel} \times \frac{3600}{1000} \text{ kg/hr} \)

Where
\( X \) – quantity of fuel consumed in cc
Specific gravity of fuel = 0.85 gm/cc
2. Brake power = \( \frac{\sqrt{3}VI \cos \phi}{\text{AlternatorEfficiency}} \) kW

Where
\( \cos \phi = \text{power factor} \)

3. Specific fuel consumption = \( \frac{TFC}{BP} \) kd/kW-hr

From the graph between brake power and total fuel consumption, the frictional power is found by extrapolation method.

4. Frictional power = \( \) kW

5. Indicated power = brake power + frictional power kW

6. Mechanical efficiency = \( \frac{\text{BrakePower}}{\text{IndicatedPower}} \times 100\% \)

7. Brake thermal efficiency = \( \frac{\text{BrakePower}}{TFC \times \text{CalorificValue}} \times 100\% \)

GRAPHS:
- B.P. Vs T.F.C.
- B.P. Vs S.F.C.
- B.P. Vs Mechanical efficiency
- B.P. Vs Brake Thermal efficiency

PRECAUTIONS:
1. The engine should be checked for no load condition.
2. The cooling water inlet for engine should be opened.
3. The level of fuel in the fuel tank should be checked.
4. The lubrication oil level is to be checked before starting the engine.

RESULT: Load test on the given engine is performed and performance characteristic curves are drawn. From the graph drawn between B.P and T.F.C, friction power is calculated by willian’s line method.

REVIEW QUESTIONS:
1. How to start and stop the CI engine?
2. What is the purpose of a decompression lever?
3. How the speed of the engine is maintained constant at all loads?
4. What is the function of a governor in a constant speed engine? Where it is normally located?
5. What is normal fuel injection pressure in a C I. engine?
6. What is the speed ratio between a cam shaft and a crank shaft?
7. What is the type of dynamometer employed?
8. Give reasons for valve timing greater than 180º?
9. What is the type of cooling employed?
10. How do you ensure the lubrication pump is effective?
<table>
<thead>
<tr>
<th>Electrical load connected in watts</th>
<th>Engine speed in rpm</th>
<th>Fuel consumption for 10ml insec</th>
<th>Air flow reading in mm of water</th>
<th>Energy meter reading time for no of revolutions</th>
<th>Alternator Voltage in volts</th>
<th>Alternator current in amps</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Engine speed in rpm</th>
<th>Total fuel consumption</th>
<th>Brake power</th>
<th>Specific fuel consumption</th>
<th>Indicated power</th>
<th>Mechanical efficiency</th>
<th>Brake thermal efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
MORSE TEST

AIM:
To study and conduct Morse test on the two cylinder four stroke diesel engine.

APPARATUS:
Two cylinder four stroke diesel engine
Stopwatch

THEORY:
Morse Test is used to find a close estimate of Indicated Power (IP) of a Multi cylinder Engine. In this test, the engine is coupled to a suitable dynamometer and the brake power is determined by running the engine at the required speed. The fuel flow in first cylinder is now cut off by closing the fuel injector of the first cylinder in the diesel engine.

As a result of cutting out the first cylinder, the engine speed will drop. Load on the engine is now removed so that the original speed is attained. The brake power under this load is determined and recorded (BP1). The first cylinder operation is restricted normal and the second cylinder is fuel injector is cut-out. The engine speed will again vary. By adjusting the load on the engine, speed brought to original speed and the new BP is recorded (BP2).

PROCEDURE:
Start set up and run the engine at no load for some time for warming up the engine.
Gradually increase the load on the engine by loading it.
Increase the engine throttle to any desired position and simultaneously load the engine to obtain desired speed for which frictional power is to be calculated.
Wait for few minutes till steady state is achieved, note engine speed and load.
Cut off the fuel flow in the first cylinder. The engine speed will decrease, at this state decrease the load and bring the engine speed to the original state.
Wait for steady state and tabulate the readings.
Repeat the procedure for the second cylinder and tabulate the readings.

OBSERVATIONS TABLE:

<table>
<thead>
<tr>
<th>SI. No.</th>
<th>Cylinder Condition</th>
<th>Engine Speed N (rpm)</th>
<th>Load W(kgs)</th>
<th>Brake Power (BP)</th>
<th>Indicated Power (IP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>All cylinders are firing</td>
<td></td>
<td></td>
<td>(BP) =</td>
<td>(IP)</td>
</tr>
<tr>
<td>2.</td>
<td>First cylinder is cut-off</td>
<td></td>
<td></td>
<td>(BP1) =</td>
<td>(IP1)</td>
</tr>
<tr>
<td>3.</td>
<td>Second cylinder is cut-off</td>
<td></td>
<td></td>
<td>(BP2) =</td>
<td>(IP2)</td>
</tr>
</tbody>
</table>
CALCULATIONS:

1. Total Brake Power (BP), when all Cylinders are firing.
   \[ BP = \frac{2\pi NT}{4500} \text{ HP} \]

2. Brake Power (BP1), when first Cylinder is cut-off.
   \[ BP1 = \frac{2\pi NT_1}{4500} \text{ HP} \]

3. Brake Power (BP2), when second Cylinder is cut-off.
   \[ BP2 = \frac{2\pi NT_2}{4500} \text{ HP} \]

4. Indicated Power (IP), when first Cylinder is not firing.
   \[ IP1 = (BP) - (BP1) \]
   Similarly, when second is not firing
   \[ IP2 = (BP) - (BP2) \]

Total Indicated Power (IP) = IP1 + IP2

RESULT:
The total indicated power for the engine is ______________.
The total frictional power for the engine is ______________.
HEAT BALANCE TEST ON SINGLE CYLINDER FOUR STROKE COMPRESSION IGNITION ENGINE (KIRLOSKAR)

AIM:

To perform a heat balance test on the given single cylinder four stroke C.I engine and to prepare the heat balance sheet at various loads.

APPARATUS REQUIRED:

1. C.I. Engine coupled with a dynamometer.
2. Air tank with air flow meter
3. Burette for fuel flow measurement
4. Rotameter for water flow measurement
5. Stop watch.
6. Thermometers.

BRIEF THEORY OF THE EXPERIMENT:

From the law of conservation of energy, the total energy entering the engine in various ways in a given time must be equal to the energy leaving the engine during the same time, neglecting other form energy such as the enthalpy of air and fuel. The energy input to the engine is essentially the heat released in the engine cylinder by the combustion of the fuel. The heat input is partly converted into useful work output, partly carried away by exhaust gases, partly carried away by cooling water circulated and the direct radiation to the surroundings. In a heat balance test all these values are calculated and converted to percentage with respect to the input and are presented in a chart at various loads.
EXPERIMENTAL SETUP:

The compact and simple engine test rig consisting of a four stroke single cylinder, water cooled, constant speed diesel engine coupled to a rope brake dynamometer. The engine is started by hand cranking using the handle by employing the decompression lever. Air from atmosphere enters the inlet manifold through the air box. An orifice meter connected with an inclined manometer is used for air flow measurement. A digital temperature indicator is used to measure temperature of exhaust gas. A burette is connected with the fuel tank through a control valve for fuel flow measurement. Provision is made to circulate water continuously through the engine jacket. Rotameter is provided to measure the flow rate of cooling water. Thermometers are provided to measure the temperature of cooling water passing through the jacket.

STARTING THE ENGINE:

1. Keep the decompression lever in the vertical position
2. Insert the starting handle in the shaft and rotate it
3. When the flywheel picks up speed bring the decompression lever into horizontal position and remove the handle immediately.
4. Now the engine will pick up.

STOPPING THE ENGINE:

1. Cut off the fuel supply by keeping the fuel governor lever in the other extreme position. (For Diesel Engine)
PROCEDURE:

1. Start the engine at no load and allow idling for some time till the engine warm up.

2. At no load condition, note down the readings as per the observation table.

3. Note down the time taken for 10cc of fuel consumption using stopwatch and fuel measuring burette.

4. After taking the readings open the fuel line to fill burette and supply fuel to run the engine from the fuel tank again.

5. Now load the engine gradually to the desired valve.

6. Allow the engine to run at this load for some time in order to reach steady state condition.

7. Note down the readings as per the observation table.

8. Repeat the experiment for different loads.

9. Release the load slowly and stop the engine.

SPECIMEN CALCULATIONS:

1. Total fuel consumption = \( \frac{X}{Time} \) \times \text{specific gravity of fuel} \times \frac{3600}{1000} \text{kg/hr}

   Where

   \( X \) = Quantity of fuel consumed in cc

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Time – time taken for 10cc of fuel consumption

Specific gravity of fuel = 0.85 gm/cc

2. Heat input = \( \frac{TFC \times CV}{3600} \) kW

Where,

CV = calorific value

3. B.P (Heat used for useful work output) = \( \frac{2\pi NT}{60000} \) kW

4. % of heat used for useful work output

\[
\% Q = \frac{BP}{HI} \times 100
\]

5. Heat loss through cooling water = \( M_w \times C_{pw} \times (T_2 - T_1) \) kW

Where Mw = mass flow rate of water kg/sec

m = quantity of water collected

t2- time taken for m litres of water collection

Cpw – specific heat of water = 4.18 kJ/kg-K

T1 – inlet temperature of cooling water

T2 – outlet temperature of cooling water

6. % of heat loss through cooling water = \( \frac{Q_{(cooling\text{water})}}{HeatInput} \times 100 \)

7. Heat loss through exhaust gases = \( M_g \times C_{pg} \times (T_g - T_a) \) kW

Where Mg = ma + mf
Mass flow rate of air, \( m_a = \text{Manometer (H)} \times 0.8826 \times 10^{-3} \times \rho_{\text{air}} \text{ (kg/s)} \)

Density of air, \( \rho_{\text{air}} = \frac{P_{\text{atm}}}{R \times T_{\text{atm}}} \text{kg/m}^3 \)

Where

\( P_{\text{atm}} \) – atmospheric pressure (N/m\(^2\))

\( R \) – Gas constant, 287 J/kg-K

\( T_{\text{atm}} \) = atmospheric temperature

Mass flow rate of fuel = \( \frac{TFC}{3600} \text{ kg/sec} \)

8. \% of heat lost through exhaust gases = \( \frac{Q(\text{exhaustgases})}{\text{Heatinput}} \times 100 \)

9. Unaccounted heat losses = Heat input – [\( Q(BP) + Q(\text{cw}) + Q(\text{eg}) \)]

**PRECAUTIONS:**

1. The engine should be checked for no load condition.

2. The cooling water inlet for engine should be opened.

3. The level of fuel in the fuel tank should be checked.

4. The lubrication oil level is to be checked before starting the engine.

**RESULT:**
The heat balance test is conducted in the given diesel engine to draw up the heat balance sheet at various loads.
<table>
<thead>
<tr>
<th>Electrical Load connected in Watts</th>
<th>Engine Speed in RPM</th>
<th>Fuel Consumption for 10 ml in Sec.</th>
<th>Air Flow-Reading in mm or Water</th>
<th>Energy Meter Readings for No. of Revolutions.</th>
<th>Alternator Voltage in Volts</th>
<th>Alternator Current in Amps</th>
<th>TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>T2</td>
<td>T3</td>
<td>T4</td>
<td></td>
<td></td>
<td></td>
<td>Air Inlet</td>
</tr>
<tr>
<td>Water Inlet</td>
<td>Water Outlet</td>
<td>Exhaust gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Water Inlet</td>
</tr>
<tr>
<td>T1</td>
<td>T2</td>
<td>T3</td>
<td>T4</td>
<td></td>
<td></td>
<td></td>
<td>Exhaust gas</td>
</tr>
</tbody>
</table>

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PERFORMANCE TEST ON
RECIPROCATING AIR COMPRESSOR

AIM:
To conduct a performance test on the two stage reciprocating air compressor and to determine the volumetric efficiency and isothermal efficiencies at various delivery pressures.

APPARATUS REQUIRED:
1. Reciprocating air compressor test rig.
2. Manometer
3. Tachometer

SPECIFICATIONS:
Power : 5KW
Type : Two stage reciprocating
Cooling Medium: Air
Capacity: 0.6 m/min
Maximum Pressure: 10 Bar
Speed : 950 rpm

BRIEF THEORY OF THE EXPERIMENT:
The two stage reciprocating compressor consists of a cylinder, piston, inlet and exit valves which is powered by a motor. Air is sucked from atmosphere and compressed in the first cylinder (Low pressure) and passed to the second cylinder (High pressure) through an inter cooler. In the second cylinder, air is compressed to high pressure and stored in the air tank.
During the downward motion of the piston, the pressure inside the cylinder drops below the atmospheric pressure and the inlet valve is opened due to the pressure difference. Air enters into the cylinder till the piston reaches the bottom dead center and as the piston starts moving upwards, the inlet valve is closed and the pressure starts increasing continuously until the pressure inside the cylinder above the pressure of the delivery side which is connected to the receiver tank. Then the delivery valve opens and air is delivered to the air tank till the TDC is reached. At the end of the delivery stroke a small volume of high pressure air is left in the clearance volume. Air at high pressure in the clearance volume starts expanding as the piston starts moving downwards up to the atmospheric pressure and falls below as piston moves downward. Thus the cycle is repeated. The suction, compression and delivery of air take place in two strokes / one revolution of the crank

**EXPERIMENTAL SETUP:**

The two-stage air compressor consists of two cylinders of “v” type. The compressor is driven by an AC motor. Air is first sucked into the low pressure (LP) cylinder and it is compressed and delivered at some intermediate pressure. The compressed air is then cooled in the intercooler and the same is then sucked by the high pressure (HP) cylinder. Compressed air is the finally discharged to the receiver tank.

An orifice plate is mounted on one side of the air tank and which is connected with a manometer for the measurement of air flow rate. One side of the air tank is attached with a flexible rubber sheet to prevent damage due to pulsating air flow. A pressure gauge is mounted on the air tank to measure the air tank pressure. The tank pressure can be regulated by adjusting the delivery valve. A pressure switch is mounted on the air tank to switch off the motor power supply automatically when the pressure inside the tank raises to the higher limit and to avoids explosion.

**PROCEDURE:**

1. The manometer is checked for water level in the limbs.
2. The delivery valve in the receiver tank is closed.

3. The compressor is started and allowed to build up pressure in the receiver tank.

4. Open and adjust the outlet valve slowly to maintain the receiver tank pressure constant. 5. The dynamometer is adjusted so that the circular balance reads zero when the points at the motor pedestal coincide. This can be done by operating the hand wheel.

6. Note down the readings as per the observation table.

7. Repeat the experiment for various delivery pressures. This can be done by closing the delivery valve and running the compressor to build up higher pressure. Ensure the tank pressure is maintained constant by adjusting the outlet valve before taking the readings.

8. Tabulate the values and calculate the volumetric efficiency and isothermal efficiency.

**OBSERVATION TABLE**

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Delivery pressure (kgf/cm²)</th>
<th>Manometer reading (mm)</th>
<th>Speed</th>
<th>Torque Kg-m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>h1</td>
<td>h2</td>
<td>h1-h2</td>
</tr>
</tbody>
</table>
SPECIMEN CALCULATION:

\[ H_{air} = \frac{h_1 - h_2}{100} \times \frac{\rho_w}{\rho_{air}} \text{ m} \]

Where,

Hair = Air head causing the flow, m

h1, h2 = Manometer reading, mm

\( \rho_w \) = Density of water = 1000kg/m³

\( \rho_{air} \) = Density of air, kg/m³

\[ \rho_{air} = \frac{Pa}{RT} \text{ kg/m³} \]

Where,

Pa = Atmospheric pressure

R = Gas constant for air = 0.287 KJ/Kg.K

T = Room temperature K

\[ V_a = C_d \times A \times \sqrt{2gH_{air}} \text{ m³/sec} \]

Where,

Va = actual volume of air compressed m³/s

Cd = Coefficient of discharge = 0.64

A = area of orifice

d = diameter of orifice = 0.02m
$V_1 = \frac{V_a}{T_{RTP}} \times T_{NTP} \text{ m}^3/\text{s}$

Where,

$V_1 =$ actual volume of air compressed at NTP m$^3$/s  
$V_a =$ actual volume of air compressed m$^3$/s

$T_{NTP} = 273 \text{ K}$  
$T_{RTP} = 273 + \text{Room temperature in K}$

$V_2 = \frac{\pi \times D^2 \times L \times N_c}{4 \times 60} \text{ m}^3/\text{s}$

Where,

$V_2 =$ theoretical volume of air compressed m$^3$/s  
$D =$ diameter of cylinder = 0.1m  
$L =$ stoke length = 0.085m  
$N_c =$ speed of the compressor

$V. \ E. = \frac{V_1}{V_2} \times 100 \%$

Where,

$VE =$ volumetric efficiency  
$V_1 =$ actual volume of air compressed at NTP m$^3$/s  
$V_2 =$ Theoretical volume of air compressed m$^3$/s
Iso. P = \frac{\ln(r) \times Pa \times Va}{1000} \text{ kW}

Where,

Iso. P = isothermal power

\[ r = \frac{Pa + Pg}{Pa} \]

r= compression ratio

Pa = atmospheric pressure N/m2

Pg = pressure in the tank N/m2

\[ I.P = \frac{35 \times 2 \times \pi \times N_m \times (T \times 9.81)}{60000} \times \eta_{motor} \text{ kW} \]

Where,

IP = input power

Nm = motor speed rpm

T = torque on the motor kg-m

\[ \eta_{motor} = 0.9 \]

Iso. E = \frac{\text{Iso. P} \times 100}{I.P.} \times 100

Where,

Iso. E = isothermal efficiency

Iso. P = isothermal power

IP = input power.

GRAPH:

THERMAL ENGINEERING LAB
DEPARTMENT OF MECHANICAL ENGINEERING
1. Gauge pressure Vs Volumetric efficiency
2. Gauge pressure Vs Isothermal efficiency

**PRECAUTIONS:**
1. The orifice should never be closed so as to prevent the manometer fluid being sucked in to the tank.
2. At the end of the experiment the outlet valve of the reservoir should be opened as the Compressor is to be started against at low pressures so as to prevent excess strain on the piston.

**RESULT:**
The performance test on the given air compressor test rig is conducted and the volumetric and isothermal efficiencies are determined at various delivery pressures and the characteristic curves are drawn.

**REVIEW QUESTIONS:**
1. What is a plenum chamber? Why it is used?
2. What is the purpose of an inter cooler in an air compressor?
3. What will happen if the compressor is allowed to run for a very long time by closing its delivery valve?
4. How do you define volumetric efficiency and isothermal efficiency of a compressor? Plot it n Vs gauge pressure.
5. What is the reason for increase in isothermal efficiency with gauge pressure?
6. What is the reason for decrease in volumetric efficiency with gauge pressure?
7. What is the actual thermodynamic process during compression?
8. Why there is a difference discharge equation for pin fin apparatus and air compressor?

9. Convert 150 mm of Hg in to Pascal.

10. Plot PV=Constant and PV=Constant process on a PV diagram and show how will you calculate the isothermal efficiency?

11. Why are fins provided around the LP cylinders and the connecting pipe?

12. What is the type of dynamometer used for measuring the motor output? Explain its working principle.

13. What is the pressure control device incorporated in the setup and explain its use.
STUDY OF BOILER

AIM:

To study the boiler, its classifications and its accessories

THEORY:

A boiler is an enclosed vessel that provides a means for combustion heat to be transferred into water until it becomes heated water or steam. The hot water or steam under pressure is then usable for transferring the heat to a process. Water is a useful and cheap medium for transferring heat to a process. When water is boiled into steam its volume increases about 1,600 times, producing a force that is almost as explosive as gunpowder.

The process of heating a liquid until it reaches its gaseous state is called evaporation.

Boiler Systems

The boiler system comprises of feed water system, steam system and fuel system.

The **feed water system** provides water to the boiler and regulates it automatically to meet the steam demand. Various valves provide access for maintenance and repair.

The **steam system** collects and controls the steam produced in the boiler. Steam is directed through a piping system to the point of use. Throughout the system, steam pressure is regulated using valves and checked with steam pressure gauges.

The **fuel system** includes all equipment used to provide fuel to generate the necessary heat. The equipment required in the fuel system depends on the type of fuel used in the system.

A typical boiler room schematic is shown in Figure 2.1.

The water supplied to the boiler that is converted into steam is called **feed water**. The two sources
of feed water are: (1) **Condensate** or condensed steam returned from the processes and (2) **Makeup water** (treated raw water) which must come from outside the boiler room and plant processes. For higher boiler efficiencies, the feed water is preheated by economizer, using the waste heat in the flue gas.

**BOILER TYPES AND CLASSIFICATIONS**

There are virtually infinite numbers of boiler designs but generally they fit into one of two categories:

**Fire tube** or “fire in tube” boilers; contain long steel tubes through which the hot gasses from a furnace pass and around which the water to be converted to steam circulates. Fire tube boilers, typically have a lower initial cost, are more fuel efficient and easier to operate, but they are limited generally to capacities of 25 tons/hr and pressures of 17.5 kg/cm².

**Water tube** or “water in tube” boilers in which the conditions are reversed with the water passing through the tubes and the hot gasses passing outside the tubes (see figure 2.3). These

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**Figure 2.2 Fire Tube Boiler**

**Water tube** or “water in tube” boilers in which the conditions are reversed with the water passing through the tubes and the hot gasses passing outside the tubes (see figure 2.3). These
boilers can be of single- or multiple-drum type. These boilers can be built to any steam capacities and pressures, and have higher efficiencies than fire tube boilers.

![Water Tube Boiler Diagram](image)

**Figure 2.3 Water Tube Boiler**

**Packaged Boiler:** The packaged boiler is so called because it comes as a complete package. Once delivered to site, it requires only the steam, water pipe work, fuel supply and electrical connections to be made for it to become operational. Package boilers are generally of shell type with fire tube design so as to achieve high heat transfer rates by both radiation and convection.
Stoker Fired Boiler:
Stokers are classified according to the method of feeding fuel to the furnace and by the type of grate. The main classifications are:
1. Chain-grate or traveling-grate stoker
2. Spreader stoker

Chain-Grate or Traveling-Grate Stoker Boiler
Coal is fed onto one end of a moving steel chain grate. As grate moves along the length of the furnace, the coal burns before dropping off at the end as ash. Some degree of skill is required, particularly when setting up the grate, air dampers and baffles, to ensure clean combustion leaving minimum of unburnt carbon in the ash.

The coal-feed hopper runs along the entire coal-feed end of the furnace. A coal grate is used to control the rate at which coal is fed into the furnace, and to control the thickness of the coal bed.
and speed of the grate. Coal must be uniform in size, as large lumps will not burn out completely by the time they reach the end of the grate. As the bed thickness decreases from coal feed end to rear end, different amounts of air are required—more quantity at coal-feed end and less at rear end (see Figure 2.5).

![Chain Grate Stoker](image)

**Figure 2.5 Chain Grate Stoker**

**Spreader Stoker Boiler**

Spreader stokers (see figure 2.6) utilize a combination of suspension burning and grate burning. The coal is continually fed into the furnace above a burning bed of coal. The coal fines are burned in suspension; the larger particles fall to the grate, where they are burned in a thin, fast burning coal bed. This method of firing provides good flexibility to meet load fluctuations, since ignition is almost instantaneous when firing rate is increased. Hence, the spreader stoker is favored over other types of stokers in many industrial applications.
Pulverized Fuel Boiler

Most coal-fired power station boilers use pulverized coal, and many of the larger industrial water-tube boilers also use this pulverized fuel. This technology is well developed, and there are thousands of units around the world, accounting for well over 90% of coal-fired capacity. The coal is ground (pulverised) to a fine powder, so that less than 2% is +300 micro metre (µm) and 70-75% is below 75 microns, for a bituminous coal. It should be noted that too fine a powder is wasteful of grinding mill power. On the other hand, too coarse a powder does not burn completely in the combustion chamber and results in higher unburnt losses. The pulverised coal
is blown with part of the combustion air into the boiler plant through a series of burner nozzles. Secondary and tertiary air may also be added. Combustion takes place at temperatures from 1300-1700°C, depending largely on coal grade. Particle residence time in the boiler is typically 2 to 5 seconds, and the particles must be small enough for complete combustion to have taken place during this time. This system has many advantages such as ability to fire varying quality of coal, quick responses to changes in load, use of high pre-heat air temperatures etc.

One of the most popular systems for firing pulverized coal is the tangential firing using four burners corner to corner to create a fireball at the center of the furnace (see Figure 2.7).

![Figure 2.7 Tangential Firing](image)

**FBC Boiler**

When an evenly distributed air or gas is passed upward through a finely divided bed of solid particles such as sand supported on a fine mesh, the particles are undisturbed at low velocity. As
air velocity is gradually increased, a stage is reached when the individual particles are suspended in the air stream. Further, increase in velocity gives rise to bubble formation, vigorous turbulence and rapid mixing and the bed is said to be fluidized.

If the sand in a fluidized state is heated to the ignition temperature of the coal and the coal is injected continuously into the bed, the coal will burn rapidly, and the bed attains a uniform temperature due to effective mixing. Proper air distribution is vital for maintaining uniform fluidisation across the bed. Ash is disposed by dry and wet ash disposal systems.

![Figure 2.8 Fluidised Bed Combustion](image-url)
Fluidised bed combustion has significant advantages over conventional firing systems and offers multiple benefits namely fuel flexibility, reduced emission of noxious pollutants such as SOx and NOx, compact boiler design and higher combustion efficiency.

**BOILER FITTINGS AND ACCESSORIES**

- **Safety valve**: It is used to relieve pressure and prevent possible explosion of a boiler.

- **Water level indicators**: They show the operator the level of fluid in the boiler, also known as a sight glass, water gauge or water column is provided.

- **Bottom blowdown valves**: They provide a means for removing solid particulates that condense and lie on the bottom of a boiler. As the name implies, this valve is usually located directly on the bottom of the boiler, and is occasionally opened to use the pressure in the boiler to push these particulates out.

- **Continuous blowdown valve**: This allows a small quantity of water to escape continuously. Its purpose is to prevent the water in the boiler becoming saturated with dissolved salts. Saturation would lead to foaming and cause water droplets to be carried over with the steam - a condition known as priming. Blowdown is also often used to monitor the chemistry of the boiler water.

- **Flash Tank**: High pressure blowdown enters this vessel where the steam can 'flash' safely and be used in a low-pressure system or be vented to atmosphere while the ambient pressure blowdown flows to drain.

- **Automatic Blowdown/Continuous Heat Recovery System**: This system allows the boiler to blowdown only when makeup water is flowing to the boiler, thereby transferring the maximum amount of heat possible from the blowdown to the makeup water. No flash
tank is generally needed as the blowdown discharged is close to the temperature of the makeup water.

- **Hand holes:** They are steel plates installed in openings in "header" to allow for inspections & installation of tubes and inspection of internal surfaces.

- **Steam drum internals:** A series of screen, scrubber & cans (cyclone separators).

- **Low-water cutoff:** It is a mechanical means (usually a float switch) that is used to turn off the burner or shut off fuel to the boiler to prevent it from running once the water goes below a certain point. If a boiler is "dry-fired" (burned without water in it) it can cause rupture or catastrophic failure.

- **Surface blowdown line:** It provides a means for removing foam or other lightweight non-condensable substances that tend to float on top of the water inside the boiler.

- **Circulating pump:** It is designed to circulate water back to the boiler after it has expelled some of its heat.

- **Feedwater check valve or clack valve:** A non-return stop valve in the feedwater line. This may be fitted to the side of the boiler, just below the water level, or to the top of the boiler.

- **Top feed:** A check valve (clack valve) in the feedwater line, mounted on top of the boiler. It is intended to reduce the nuisance of limescale. It does not prevent limescale formation but causes the limescale to be precipitated in a powdery form which is easily washed out of the boiler.

- **Desuperheater tubes or bundles:** A series of tubes or bundles of tubes in the water drum or the steam drum designed to cool superheated steam. Thus is to supply auxiliary equipment that doesn't need, or may be damaged by, dry steam.
• **Chemical injection line**: A connection to add chemicals for controlling feedwater pH.

**CONTROLLING DRAFT**

Most boilers now depend on mechanical draft equipment rather than natural draft. This is because natural draft is subject to outside air conditions and temperature of flue gases leaving the furnace, as well as the chimney height. All these factors make proper draft hard to attain and therefore make mechanical draft equipment much more economical.

There are three types of mechanical draft:

**Induced draft**: This is obtained one of three ways, the first being the "stack effect" of a heated chimney, in which the flue gas is less dense than the ambient air surrounding the boiler. The denser column of ambient air forces combustion air into and through the boiler. The second method is through use of a steam jet. The steam jet oriented in the direction of flue gas flow induces flue gasses into the stack and allows for a greater flue gas velocity increasing the overall draft in the furnace. This method was common on steam driven locomotives which could not have tall chimneys. The third method is by simply using an induced draft fan (ID fan) which removes flue gases from the furnace and forces the exhaust gas up the stack. Almost all induced draft furnaces operate with a slightly negative pressure.

**Forced draft**: Draft is obtained by forcing air into the furnace by means of a fan (FD fan) and ductwork. Air is often passed through an air heater; which, as the name suggests, heats the air going into the furnace in order to increase the overall efficiency of the boiler. Dampers are used to control the quantity of air admitted to the furnace. Forced draft furnaces usually have a positive pressure.

**Balanced draft**: Balanced draft is obtained through use of both induced and forced draft. This is more common with larger boilers where the flue gases have to travel a long distance through many boiler passes. The induced draft fan works in conjunction with the forced draft fan allowing the furnace pressure to be maintained slightly below atmospheric.
Boiler Efficiency

Thermal efficiency of boiler is defined as the percentage of heat input that is effectively utilized to generate steam. There are two methods of assessing boiler efficiency.

1) The Direct Method: Where the energy gain of the working fluid (water and steam) is compared with the energy content of the boiler fuel.

2) The Indirect Method: Where the efficiency is the difference between the losses and the energy input.

RESULT:
The types of boilers and its accessories are studied.

REVIEW QUESTIONS:

1. What is the importance of draft in boilers?
2. Explain the principle of fire tube and water tube boilers?
3. Explain the principles of fluidized bed combustion and pulverized fuel combustion?
4. What is the difference between an economizer and an air pre heater?
5. Discuss the various types of heat losses in a boiler?
6. How do you measure boiler efficiency using direct method?
7. What do you understand by term evaporation ratio?
8. What is atomisation of fuel oil in combustion?
9. Discuss automatic blow down control system?
10. What is the function of de-aerator in boiler?
TO DISASSEMBLE AND ASSEMBLE PETROL ENGINE

AIM: To disassemble and assemble a given petrol engine.

Introduction: Due to use of engine continuously over period of time they may develop certain troubles. Such as loss of efficiency noise irrational, fluctuations manufacturing of fuel pump injector. As such there will be necessity of strip of all parts of the engine inspect then for visual detects provide packing and scaling when ever required for this purpose Disassembling and assembling of a petrol engine is done in a certain manner or correct sequence.

PROCEDURE: The following procedure is to be followed while disassembling and assembling of a four-stroke cylinder petrol engine.

a) Study of the engine.
b) Plan the method for disassembling and keep the tools ready.
c) Remove the rocker armies boxes
d) Remove the rocker armies and screw's to displace the covering plate on cylinder head.
e) Remove injector pipe end disconnect the injector.
f) Remove both the exhaust and inlet
g) Remove the push rod cover.
h) Remove the petrol tank
i) Remove fly wheel and fly wheel housing
j) Remove fuel pump and curb wetter
k) Remove the cylinder block
l) Remove connecting rod big ends and bearing
m) Remove side cover's
n) Remove the can shaft from the bearing.
o) Draw out all the lubricating oil from crank case
p) Remove the oil filter.

The following procedure is to be followed broadly in the given sequence for assembling the disassembled petrol engine

1) After proper cleaning and checking of all parts assembling is carried out
2) Position the piston along with rings to the small end of connecting rod, insert grudger pin for fixing the piston to small end of the connecting rod.
3) Position the crankshaft into the bearing in the proper way
4) Fix the side covers and tighten properly.
5) Position the cylinder block clad fix it in a proper way
6) Fix the fuel pump and contributor
7) Position the fly wheel housing and fix the fly wheel correctly.
8) Fix both the inlet and the exhaust manifold.
9) Place the cylinder head block properly and fix the nut's properly.
10) Position the rocker worn and fix then correctly.
11) Tighten all the blocks with the help of nuts to make the engine fit.

PRECAUTIONS: All the nuts and bolts removed during the disassembling should placed carefully. While dealing with rocker arms and crank shaft care must be taken. Use only the tools while disassembling and assembling.

RESULT:
Assembling and disassembling of four-stroke four-cylinder of petrol engine is done.