Department of

Mechanical Engineering

LAB MANUAL

APPLIED THERMODYNAMICS-1

B.Tech–3rd Semester

KCT College of Engineering & Technology

Village Fatehgarh (Distt. Sangrur)

List of experiments

1 To Study 2 stroke and 4 stroke Petrol and Diesel engines

2. To draw valve timing diagram of a diesel engine and study of its impact on the performance of an IC Engine.

3. Study of various circuits of a carburetor fitted on Indian Make Vehicle.

4. Study of various types of Boilers, Boiler trial: Estimation of equivalent evaporation and efficiency of a fire tube/ water tube boiler.

5. Determination of dryness fraction of steam and estimation of brake power, Rankine efficiency, relative efficiency, generator efficiency, and overall efficiency of a steam engine/ steam turbine unit and plotting of William line.

6. Determine the brake power, indicated power, friction power and mechanical efficiency of a multi cylinder petrol engine running at constant speed (Morse Test).

7. Performance of a diesel/ semi diesel engine from no load to full load (at constant speed) for a single cylinder/ multi- cylinder engine in terms of brake power, indicated power, mechanical efficiency and SFC (Specific fuel consumption) and further obtain power consumption curves and draw the heat balance sheet.

8. Performance of single stage/ multi stage reciprocating compress

LAB IN-CHARGE **HOD ME**

OBJECTIVE: To Study Two stroke and Four stroke Petrol and Diesel engines

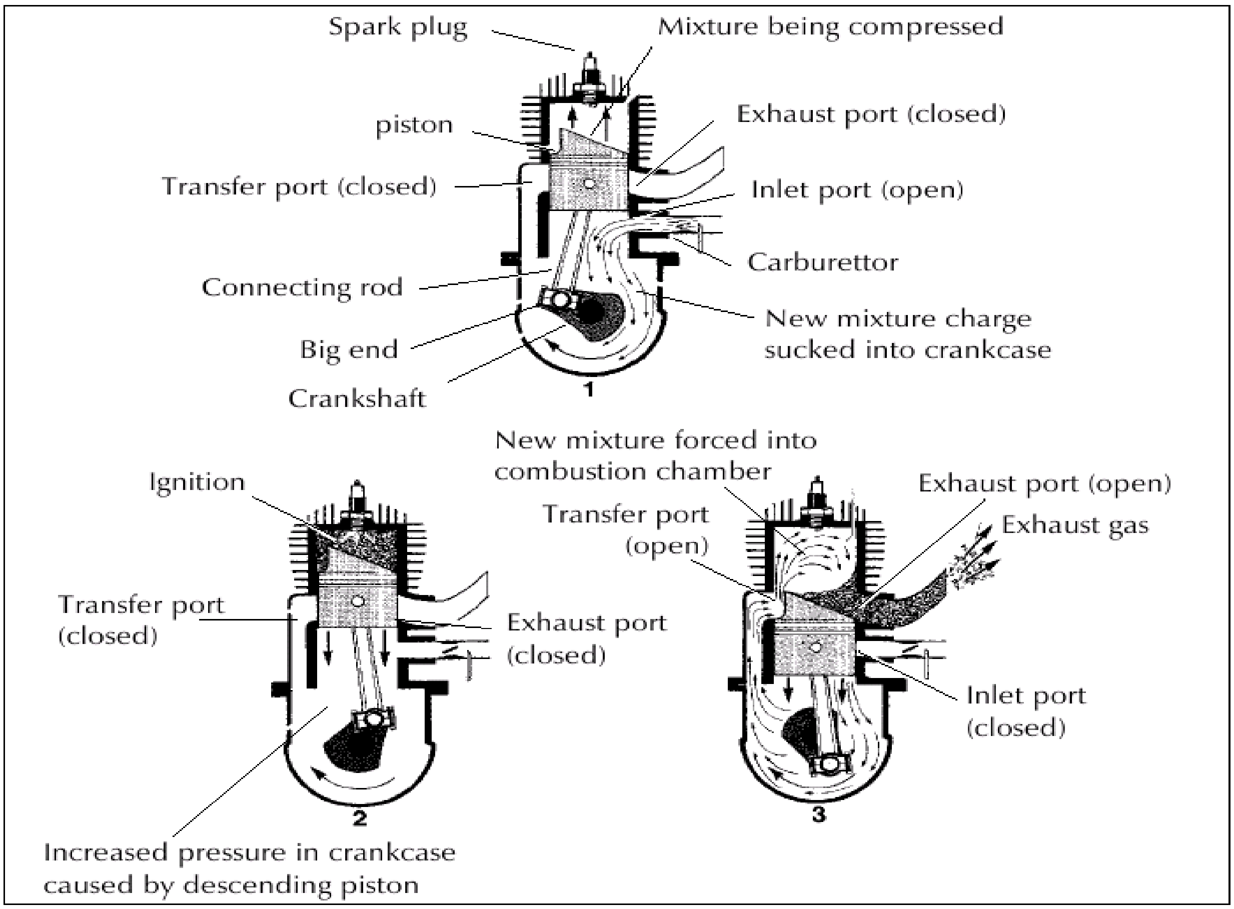
APPARATUS: Two stroke and Four stroke Petrol and Diesel Engines..

THEORY:

The purpose of internal combustion engines is the production of mechanical power from the chemical energy contained in the fuel. This energy is released by burning or oxidizing the fuel inside the cylinder.

TWO STROKE PETROL ENGINE

In 1878, Dugald – clerk, a British engineer introduced a cycle which could be completed in two strokes of piston rather than four strokes. In this suction and exhaust strokes are eliminated. Here instead of valves, port are used. The exhaust gages are driven out from the engine cylinder by the fresh charge of fuel entering the cylinder nearly at the end of the working stroke.



Intake Stroke:
The fuel/air mixture is first drawn into the crankcase by the vacuum created during the upward stroke of the piston. The illustrated engine features a poppet intake valve, however many engines use a rotary value incorporated into the crankshaft.

During the downward stroke the poppet valve is forced closed by the increased crankcase pressure. The fuel mixture is then compressed in the crankcase during the remainder of the stroke.

Transfer/Exhaust: Toward the end of the stroke, the piston exposes the intake port, allowing the compressed fuel/air mixture in the crankcase to escape around the piston into the main cylinder. This expels the exhaust gasses out the exhaust port, usually located on the opposite side of the cylinder. Unfortunately, some of the fresh fuel mixture is usually expelled as well.
Compression: The piston then rises, driven by flywheel momentum, and compresses the fuel mixture. (At the same time, another intake stroke is happening beneath the piston).

Power: At the top of the stroke the spark plug ignites the fuel mixture. The burning fuel expands, driving the piston downward, to complete the cycle.

Since the two stroke engine fires on every revolution of the crankshaft, a two stroke engine is usually more powerful than a four stroke engine of equivalent size. This, coupled with their lighter, simpler construction, makes two stroke engines popular in chainsaws, line trimmers, outboard motors, snowmobiles, jet-skis, light motorcycles, and model airplanes. Unfortunately most two stroke engines are inefficient and are terrible polluters due to the amount of unspent fuel that escapes through the exhaust port.

NOTE: The two stroke petrol engine are generally employed in very light vehicles such as scooters, sprayers etc

TWO STROKE DIESEL ENGINE

A two stroke Diesel engine also has one working stroke after every revolution of the crankshaft. All the four stages of two stroke diesel engine are described below:

1. **Suction Stage:** In this stage, the piston while going down towards BDC (Bottom dead centre) uncovers the transfer port and the exhaust port. The fresh airflows into the engine cylinder from the crankcase.

2. **Compression Stage**: In this Stage, the piston moves upwards first covers the transfer port and then exhaust port. After that the air is compressed as the piston moving upwards. Inn this stage, the inlet port opens and the fresh air enters into the crank case

3. **Expansion Stage**: Shortly before the piston reaches the TDC (Top dead center) during compression stroke, the fuel oil is injected in the form of very fine spray into the engine cylinder through the nozzle known as fuel injection valve. At this moment, temperature of the compressed air is sufficiently high to ignite the fuel. It suddenly increases the pressure and temperature of the products of combustion. The fuel oil is continuously injected for a fraction of the crank revolution. The fuel oil is assumed to be burnt at constant pressure .Due to increased pressure ,the piston is pushed with a great force. During the expansion, some of the heat energy produced is transformed into mechanical work

4. **Exhaust Stage**: In this stage , the exhaust port is opened and the piston moves downwards. The products of combustion from the engine cylinder are exhausted through the exhaust port into the atmosphere. This completes the cycle ,And the engine cylinder is ready to suck the air again

NOTE: The two stroke Diesel Engine is mainly used in marine propulsion where space and lightness are the main considerations.

Four Stroke Petrol Engine:

It is also known as Otto Cycle. It requires four strokes to complete one cycle of operation. The four strokes of the Petrol engine are discussed below:

1. **Suction or Charging Stroke:** During this stroke (also known as induction stroke) the piston moves from top dead centre (T.D.C) to the bottom dead centre. The inlet valve opens and proportionate fuel-air mixture is sucked in the engine cylinder. The exhaust valve remains closed through out the stroke.

2. **Compression Stroke**: In this Stroke, the piston moves towards T.D.C and compresses the enclosed fuel-air mixture drawn in the engine cylinder during suction. The pressure of the mixture rises in the cylinder to a valve of about 8 bar. Just before the end of this stroke the operating –plug initiates the mixture and combustion takes place at constant volume. Both inlet and exhaust valve remains closed in the stroke

3. **Power Stroke or Expansion Stroke:** When the mixture is ignited by the spark plug the hot gases are produced which drive or throw the piston from T.D.C to B.D.C and thus the work is obtained in this stroke. It is during this stroke we get work from the engine, the other three strokes namely suction, compression and exhaust being idle. The flywheel mounted on the engine shaft strokes energy during this stroke and supplies it during idle strokes. Both the valves remain closed during the start of the stroke but when the piston just reaches the B.D.C the exhaust valve opens.

4. **Exhaust Stroke:** Here the gases from which the work has being collected become useless after the completion of the expansion stroke and are made to escape through exhaust valve to the atmosphere. The piston moves from B.D.C to T.D.C and the exhaust gases are driven out the engine cylinder this is also called scavenging.

Four Stroke Diesel Engine

It is also known as compression ignition engine because the ignition takes place due to the heat produced in the engine cylinder at the end of compression stroke. The four strokes of the Diesel engine are discussed below:

1. **Suction Stroke:** During this stroke the piston moves from top dead centre (T.D.C) to the bottom dead centre(B.D.C). The inlet valve opens and air at constant atmospheric pressure is drawn inside engine cylinder. The exhaust valve remains closed through out the stroke.

2. **Compression Stroke**: Air drawn at atmospheric pressure during suction stroke is compressed to high temperature and pressure, the piston moves from B.D.C to T.D.C .Both inlet and exhaust valve remains closed in the stroke

3. **Expansion Stroke:** As the piston stars moving from T.D.C a matered quantity of fuel is injected into the hot compressed air in fine sprays by the fuel injector and fuel starts burning at constant pressure. The fuel is injected at the end of compression stroke but in actual practice the ignition of the fuel starts before the end of the compression stroke. The hot gases in the cylinder expands adiabatically, thus work on the piston

4. **Exhaust Stroke: :** Here the gases from which the work has being collected become useless after the completion of the expansion stroke and are made to escape through exhaust valve to the atmosphere. The piston moves from B.D.C to T.D.C and the exhaust gases are driven out the engine cylinder.

OBJECTIVE: -To draw valve Timing diagram of a diesel engine and study of its impact on the performance of an IC engine.

THEORY:-

A valve-timing diagram is a graphical representation of the exact moments, in the sequence of operations, at which the two valves (i.e. inlet and exhaust valves) open and close as well 3s firing of the fuel. It is, generally, expressed in terms of angular positions of the crankshaft.

1. Theoretical Valve Timing Diagram for Four Stroke Cycle Engine:

The theoretical valve timing diagram for a four-stroke cycle engine is
Shown in Fig. I In this diagram, the inlet valve opens at A and the suction takes place from A to B. The crankshaft revolves through 180° and the piston moves from T.D.C. to B.D.C. At B, the inlet valve closes and the compression takes place from B to C. The crankshaft revolves through 180° and the piston moves from B.D.C. to T.D.C. At C, the fuel is fired and the expansion takes place from C to D. The crankshaft revolves through 180° and the piston again moves from T.D.C. to B.D.C. At D, the exhaust valve opens and the exhaust takes place from D to E. The crankshaft again revolves through 180° and the piston moves back to T.D.C. In four-stroke cycle, the crank revolves through 180° and the piston moves back to T.D.C. In four-stroke cycle, the crank revolves through two revolutions.

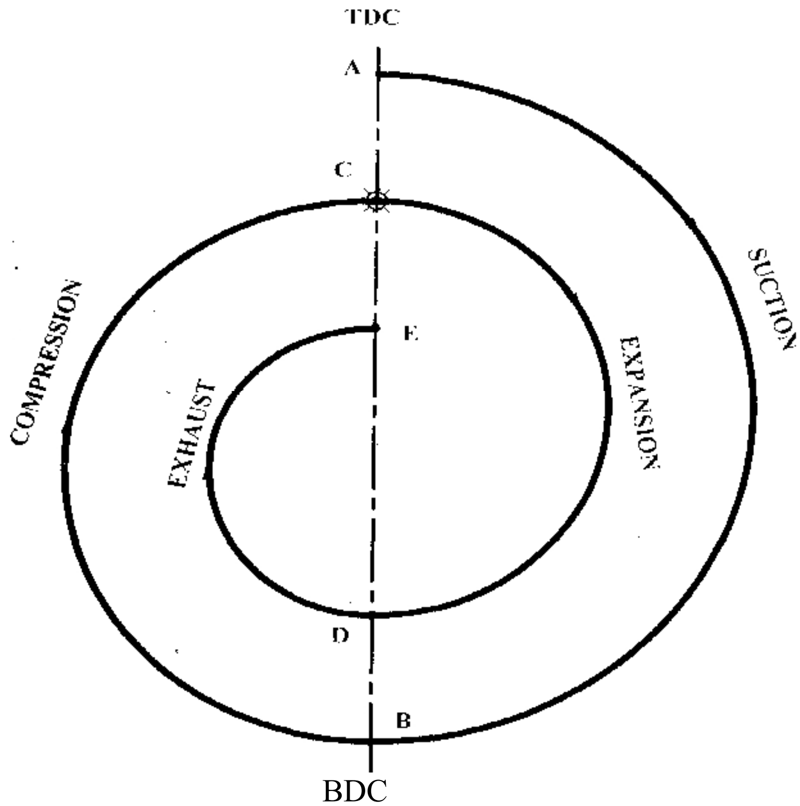


Fig. 1

2. Valve Timing Diagram for A Four-Stroke Cycle Diesel Engine:-

In the vale timing diagram as shown in Fig. 3 we see that the inlet valve open before the piston reaches TDC; or in other words while the piston is still moving .up before the beginning of the suction stroke. Now the piston reaches the TDC and suction stroke starts. The piston reaches the BDC and then starts moving up. The inlet valve closes, when the crank has moved a little beyond the BDC. This is done as the incoming air continues to flow into the cylinder although the piston is moving upwards from BDC. Now the air is compressed with both valves closed. Fuel valve opens a little before the piston reaches the TDC. Now the fuel is injected in the form of very fine spray, into the engine cylinder, which gets ignited due to high temperature of the compressed air. The fuel valve closes after the piston has come down a little from the TDC. This is done as the required quantity of fuel is injected into the engine cylinder. The burnt gases (under high pressure and temperature) push the piston downwards, and the expansion or working stroke takes place.

Now the exhaust valve opens before the piston again reaches BDC and the burnt gases start leaving the engine cylinder. Now the piston reaches BDC and then starts moving up thus performing the exhaust stroke. The inlet valve opens before the piston reaches TDC to start suction stroke. This is done as the fresh air helps in pushing out the burnt gases. Now the piston again reaches TDC. and the suction starts. The exhaust valve closes when the crank has moved a little beyond the TDC. This is done as the burnt gases continue to leave the engine cylinder although the piston is moving downwards.

TDC: Top Dead Centre

BDC: Bottom Dead Centre

IVO: Inlet Valve Opens (10° - 20° before TDC)

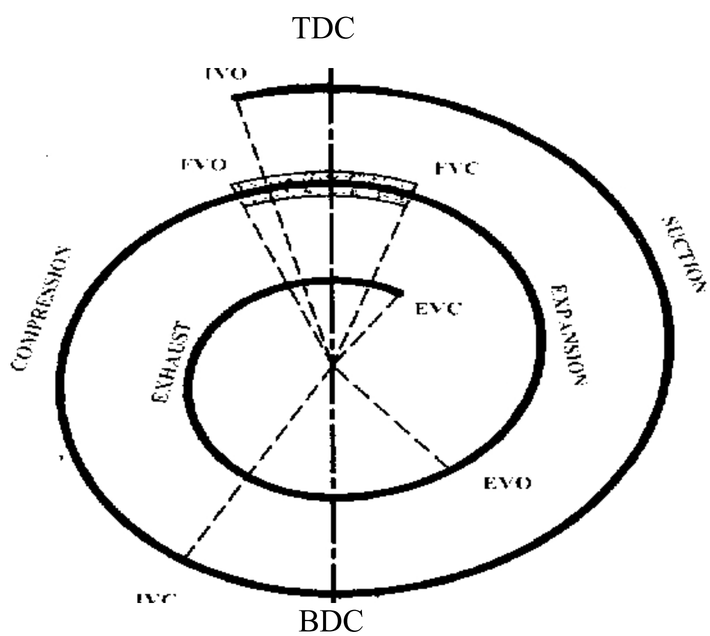
IVC: Inlet Valve Closes (25°   40° after BDC)

FVO: Fuel valve opens (10^0-15^0 before TDC)

FVC: Fuel valve closes (15^0-20^0 after TDC)

EVO: Exhaust Valve Opens (39° - 50° before BDC)

EVC: Exhaust Valve Closes (10-15° after TDC)



1. **Objective:**
   To study the various circuits of a carburettor fitted on an Indian make vehicle.

2. **Apparatus:**
   Model of Zenith and S.U. Carburettor.

3. **Diagram:**
   Respective diagrams of both types of carburettor are present with the descriptions of the same.

4. **Theory:**

Carburettor

The carburettor is a device used to discharge a homogeneous air fuel mixture in an engine. The mass of this mixture is controlled by the throttle valve. For the purpose, it first atomizes the fuel by discharging it into stream of air as desired. A good carburettor must produce automatically the desired air fuel ratio at various speed and load conditions of the engine. A carburettor generally serves the following functions:

a) maintain a small reserve of petrol at a constant head.
b) vaporize the petrol by engine suction and produce a homogeneous air fuel mixture.
c) supply required air and petrol vapours at correct mixture strength and according to the varying load requirement of the engine.

As expected to fulfill most desirable requirements, a carburettor should:

a) meter the liquid fuel in such quantities to produce air fuel ratio required to meet engine operating conditions.
b) atomize the fuel and mix it homogeneously with air.
c) enable engine to run smoothly without Missing, Hunting or Fuel Wastage.
d) be reliable and provide easy starting from cold.
e) be capable of providing required mixture during transient conditions like acceleration, change in altitude etc.
f) uniformly distribute the mixture to various cylinders in case of multi-cylinder engines.

A carburettor satisfying all above requirements becomes too complicated, costly and extremely difficult to be kept properly tuned. So, for particular types of engines, carburettors are developed to serve appropriately. In automotive engines, operating under variable speed and load, different air fuel ratios are required for different conditions as:

(i) Idling and low load (from 0% to about 20% of rated power)

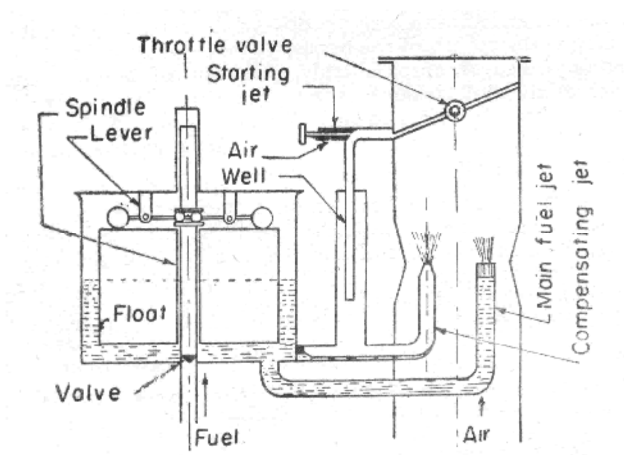
An idling engine demands a rich mixture because of dilution of charge by residual gases.

(ii) Economy range with medium loads (from about 20% to about 75% of rated power)

On medium loads, the mixture can be made leaner, the optimum fuel air ratio, hence, for this condition, is 16:1 to 17:1. This is the most economical air-fuel ratio.

(iii) Power range with full load (from 75% to 100% of rated power)

If engine is required to develop maximum power, a rich mixture becomes necessary. So, the ratio desired is 14:1 to 12:1.



- **Zenith Carburettor**

A Schematic diagram of the Zenith Carburettor

Construction : It is the simplest device, which makes use of two jets, the main fuel jet and the compensating jet. The compensation is provided by an additional compensating jet. This jet has a narrow restriction and in the passage, the supply through which leads to a well, open to atmosphere, from where it gets its air supply. The supply to the well, is not affected by engine suction, because due to open well suction is destroyed. Main jet directly communicates with the float chamber. The petrol supply through the main jet continuously increases with increase of suction due to increase of the engine speed. When the engine is standstill, there is no flow through the compensating jet. As the speed increases, petrol is sucked from the well through delivery tube of compensating jet, and falls the petrol level in the well. With increase in speed, this level becomes steady. With further increase in speed, more air is drawn, while the amount of petrol drawn through the compensating jet remains the same, so, the mixture grows leaner. Since, with increase in engine speed, supply through main jet increases progressively, by combining this compensating device with single jet, a compound nozzle is obtained, which gives a constant mixture strength.

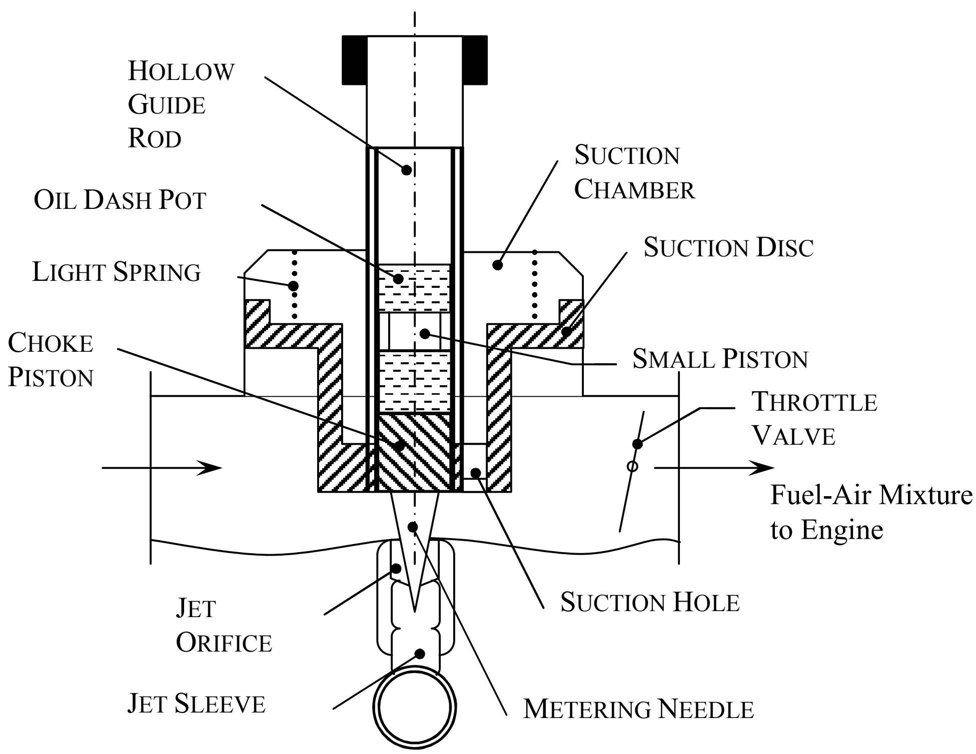
Working : For start-up and slow running or idling, a separate starting jet is provided to function automatically. For normal running, the throttle is opened about two–thirds and as the air passes through the venturi, its velocity increases due to a narrower area. Consequently, its pressure drops resulting in a suctioning effect. The fuel is sprayed in the venturi by two nozzles. As engine speed increases, the air velocity also increases providing greater suction i.e. fuel supply. But since compensating jet draws fuel from reservoir, which is subjected to atmospheric pressure through an air hole, fuel supplied by it to the venturi doesn't change appreciably. This supplies a weaker solution than if only one jet was provided, where mixture at high speed will be richer than desired. Thus the compensating jet regulates the mixture to be of desirable strength.

For a start-up or low speed running, the suction is quite insufficient to operate the nozzles because of lower velocity of air. So, throttle is closed leaving only a small contracted passage. The air velocity at this passage increases, producing a high suction. To vary the air supply, set screw is loosened and the setup for start-up is taken out. As the speed increases, throttle valve is gradually opened, till air velocity be insufficient and low suction become incapable of keeping the fuel supply through the nozzle, which is thus put out of action.

Zenith carburetor has no moving parts except throttle and choke valves. It is, thus, simple in construction and is widely used.

- S.U. Carburettor

Generally used carburettors e.g. Zenith, Solex etc. are 'constant choke' type, but S.U. carburettor is a 'constant vacuum' type carburettor. It is mostly used in British cars and was used in Hindustan Ambassador car.



A Schematic Diagram of S.U. Carburettor

Construction : It generally has a conventional system of float chamber, which feeds fuel into a vertical channel, where there is a jet sleeve. The sleeve bears a no. of holes in its side for fuel to enter it and thus stand at the same level as in the float chamber. A tapered metering needle, secured by a grub screw in choke piston or piston assembly, fits in the jet sleeve. This piston reciprocates vertically in the air passage, whose one end is connected to atmosphere through an air cleaner, and other to the engine through a conventional throttle valve. The upper portion of choke piston is formed into a suction disc, which is a sliding fit in suction chamber. The whole assembly is located by a hardened hollow steel guide rod, which has its bearing in the long boss in center of suction chamber. The upper side of suction disc is connected to air passage through an atmospheric hole.

Working : From suction hole, engine depression (adjusted by the degree of throttle opening) is transmitted to upper face of suction piston, while air pressure is admitted to lower chamber through atmospheric hole. Thus, position of choke piston at any instant depends upon the balance of its own weight and a light spring (if provided) ↓, against the vacuum force ↑. The piston weight being constant, vacuum also remains constant. [Constant Vacuum]. A constant vacuum, variable choke (due to variable cross-sectional area of air passage) is obtained. The constant vacuum leads maintaining an approximately constant air velocity. With reciprocating movement of choke piston, the metering needle also moves up and down concentrically in the petrol jet orifice, varying the effective area of jet. Upward movement of piston under increased suction, also moves the tapered needle and increases the effective jet area, allowing a greater amount of petrol to flow into the main air stream and vice versa. So, approximately constant air-fuel ratio is maintained.

For cold starting, a rich mixture is required. This is provided by an arrangement to lower the jet tube away from the needle by the jet lever enlarging the jet orifice. The lever is operated from the dashboard in the car. For a slightly rich mixture on acceleration, an oil dashpot is provided in the upper part of the hollow piston guide rod. In this, a small piston is suspended by a rod from the oil cap nut. The arrangement also prevents the flutter of choke piston.

Tuning : For tuning of the carburettor, mixture strength is varied by using selecting needles with different tapers, and a wide range of needles. The idling speed is adjusted by an adjustment nut, which moves jet sleeve up and down.

5. Result:

Working of carburettors was successfully studied.

6. Precautions:

a) Check the proper functioning of metering needle.
b) Sliding parts should be lubricated regularly.
c) Ensure proper functioning of the throttle valve.
d) The light springs' tension should be checked at regular intervals.
e) Tuning should be regularly adjusted to gain a proper fuel-air mixing.

7. Questions for Viva:

a) State functions served by a carburettor.
b) What is the most economic air-fuel ratio of a petrol engine?

c) What is the basic difference between Zenith carburettor and S.U. Carburettor?
d) What is the function of a throttle valve in a carburettor?
e) How do you vary the air-fuel mixture strength in Zenith and S.U. carburettor?
f) Why S.U. carburettor is classified under ‘constant vacuum’ type carburettors?

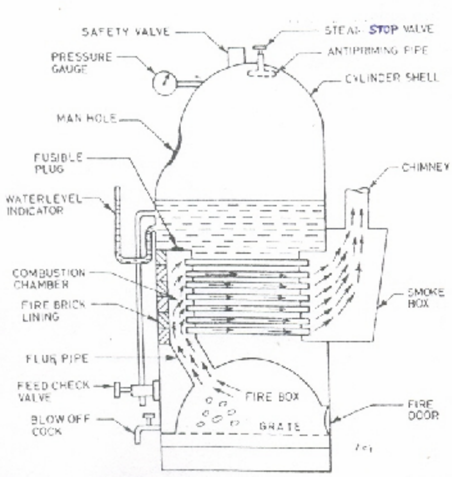
1. Objective:

To aware the students about the different kind of boilers.

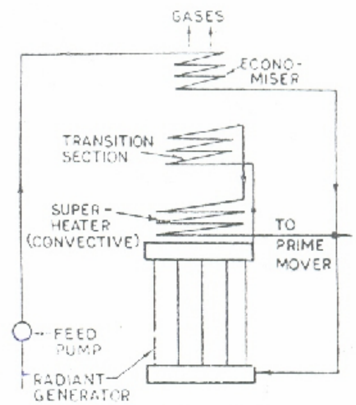
2. Apparatus:

Cochran Boiler; Babcock and Wilcox Boiler; Benson Boiler

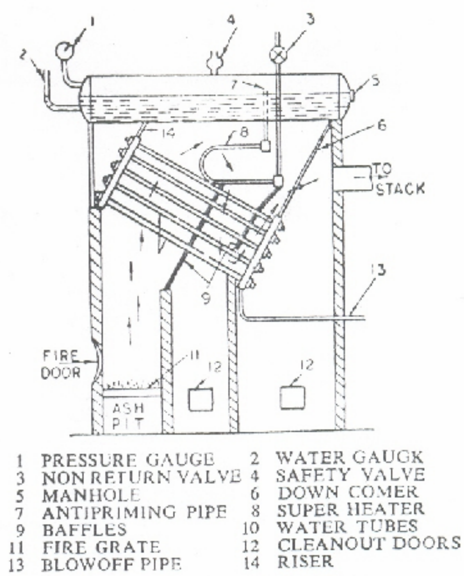
3. Diagram



Cochran boiler.



Benson boiler.



Babcock and Wilcox Boiler.

Theory

The purpose of the boiler, as pointed out earlier, is to generate steam at the predetermined pressure and temperature by using heat produced by the combustion of fuel. The evaporation (steam raising) capacity of the boiler depends upon:

(a) Grate area i.e the amount of fuel the boiler can consume
(b) Heating surface i.e. the quantity of heat which the boiler can absorb,

The evaporation capacity may be expressed as kg/hr-m^2 of heating surface or kg/kg of fuel burnt.
If these parameters are kept constant, the amount of water which a boiler can evaporate further depends upon:

(a) Condition of pressure and temperature under which the boiler is operating,
(b) Quality of steam being raised (wet, dry or superheated).
(c) Temperature of feed water being supplied to the boiler.

Thus it may be realized that number of kg of water evaporated per hour is not an exact measure of the performance of the boiler. For making a comparison of the relative evaporation capacity of the boiler, the water is supposed to evaporate under the following standard conditions.

1. Feed water is supplied to the boiler at 100 ^{o}C.
2. Evaporation of steam takes place at the same temperature of 100 ^{o}C
3. The steam raised is just dry and saturated.

When water evaporates under these conditions, it requires 538.9 kcal of heat which equals the latent heat of steam at 100 ^{o}C under atmospheric pressure of 1.0332 kgf/cm^2.

Equivalent Evaporation of water

"Evaporation which would be obtained if the feed water were supplied at 100 ^{o}C and converted into dry saturated steam at 100 ^{o}C at the standard atmospheric pressure of 1.0332kgf/cm^2."

Let Wa = weight of water actually evaporated into steam per kg of coal burnt at the working pressure.
Hs = specific enthalpy of steam at the working pressure.
hw = specific enthalpy (sensible heat) of feed water.

Then heat absorbed by the water at actual working pressure = Wa (Hs-hw) (i)

Further if Wo is equivalent evaporation, then

Heat absorbed at the water under standard conditions
= We x Lo (ii)

where L_o = enthalpy of evaporation (latent heat) of steam at 1 kgf/cm^2 and 100 ^oC = 539 kcal/kg (2256 kj/kg)

Equating (i) and (ii), we get

$$W_e = \frac{W_a(H_s - h_w)}{L_o} \text{ kg/kg of coal burnt} \qquad \text{(iii)}$$

$$= \frac{W_a(H_s - h_w)}{539}$$ when Hs and hw are expressed in Kcal

$$= \frac{W_a(H_s - h_w)}{2256}$$ when Hs and hw are expressed in KJ

In equation (iii), the factor (Hs-hw/Lo) is always greater than unity and is known as factor of evaporation or generation factor. The factor of evaporation may be defined as the ratio of heat absorbed by 1kg of feed water under working conditions to that absorbed by 1kg of water from and at 100 ^oC.

Boiler Efficiency

It is defined as the ratio of heat energy utilized by feed water in converting it into steam in the boiler to the heat energy realized by complete combustion of fuel during the same time.

$$\text{Boiler Efficiency} = \frac{\text{Energy absorbed by feed water}}{\text{Energy absorbed by fuel}}$$

$$\eta = \frac{W_a(H_s - h_w)}{W_f \times \text{Calorific value of fuel}}$$

Where
Wa = actual evaporation of steam/hr
Hs = total heat of steam produced ,
Hw = sensible heat of feed water,
Wf = weight of fuel consumed/ hr.

However, if the boiler is equipped with an economizer and a super heater, then efficiency of the unit is called overall efficiency of the boiler plant and it takes into account the efficiency of all the three elements namely: boiler, economizer and super heater.

5. Observation and Calculations

Heat absorbed by the water at actual working pressure = Wa(Hs-hw)
Heat absorbed bt the water under standard conditions = We x Lo

Equivalent evaporation, $We = \frac{Wa(Hs-hw)}{Lo}$ kg/kg of coal burnt

$= \frac{Wa(Hs-hw)}{539}$ (when Hs and hw are expressed in Kcal)

$= \frac{Wa(Hs-hw)}{2256}$ (when Hs and hw are expressed in KJ)

Wa = weight of water actually evaporated into steam per kg of coal burnt at the working pressure.

Hs = specific enthalpy of steam at the working pressure.

hw = specific enthalpy (sensible heat) of feed water.

Lo = enthalpy of evaporation (latent heat) of steam at 1 kgf/cm^2 and 100 ^oC = 539 kcal/kg (2256 kj/kg)

Boiler Efficiency, $\eta = \frac{Wa\ (Hs-hw)}{Wf \times \text{Calorific value of fuel}}$

Wa = actual evaporation of steam/hr
Hs = total heat of steam produced ,
Hw = sensible heat of feed water,
Wf = weight of fuel consumed/ hr.

6. Result

(i) Equivalent evaporation, $We = \frac{Wa(Hs-hw)}{Lo}$ kg/kg of coal burnt

$= \frac{Wa(Hs-hw)}{539}$ (when Hs and hw are expressed in Kcal)

$= \frac{Wa(Hs-hw)}{2256}$ (when Hs and hw are expressed in KJ)

(ii) Boiler Efficiency, $\eta = \frac{Wa\,(Hs-hw)}{Wf \times \text{Calorific value of fuel}}$

Wa = actual evaporation of steam/hr
Hs = total heat of steam produced ,
Hw = sensible heat of feed water,
Wf = weight of fuel consumed/ hr.

7. Precautions

(a) Check all valves before starting the boiler.
(b) Check uniform supply of water.
(c) The apparatus should be handled carefully.

8. Questions for Viva

(a) Distinguish b/w mountings and accessories.
(b) Distinguish b/w fire tube and water tube boilers.
(c) What is the function of economiser?
(d) What is the function of blow-off cock and fusible plug?
(e) What is the function of safety valve?

AIM: Determination of dryness fraction of steam.

APPARATUS: Combined separating and Throttling Calorimeter.

THEORY:

DRYNESS FRACTION:

The term dryness fraction refers to wet steam. It is defined as ratio of mass of dry steam actually present to the mass of the wet steam, which contains it.

Let in the sample of wet steam:-

$$X = \frac{W_d}{W_d + W}$$

Where

X	=	Dryness fraction of the sample
W_d	=	Wt. of dry steam in Kg.
W	=	Wt. of water vapours in suspension

SEPARATING AND THROTTLING (COMBINE) CALORIMETER:

The steam passing out from a separating calorimeter may still contain some water vapours in it. In other words it may not be absolutely dry. Again, in a throttling calorimeter steam after passing through the throttle valve must be superheated or at least dry saturated. This limits the extent of dryness fraction that can be reliably measured, depends upon the pressure of steam in the main steam pipe. If a sample of steam, which may be still wet after passing through the throttle valve i.e. it will not be superheated. Thus under this condition the throttling calorimeter fails to enable us in determining the value of dryness fraction of steam.

To overcome these difficulties we make use of combined separating and throttling calorimeter. First the steam is passed through separating calorimeter where it loses most of its moisture and becomes comparatively drier, It is then passed through the throttling calorimeter where superheating takes place without change of total heat. The temperature and pressure of steam after throttling are measured by using a thermometer and manometer respectively.

Let

W = Weight of suspended moisture collected in the separating calorimeter.

W_d = Weight of the steam leaving the separating calorimeter and entering the Throttling calorimeter.

X_1 = Dryness fraction of steam shown by Separating Calorimeter.

$$X_1 = \frac{W_d}{W_d + W}$$

It is not the accurate dryness fraction of steam as the separating calorimeter may not have been to remove the whole of the moisture of the sample of steam.

$W_d + W$ = Total weight of wet steam entering the separating calorimeter.

Now the improved quality steam leaving the separating calorimeter enters the throttling calorimeter, which ultimately leaves superheated. Throttling process occurs when steam is expanded through a small aperture as in case of throat of nozzle. During this process, no work is done, there is no heat supplied, and there is no change in total heat i.e. total heat remains constant.

Let

X_2 = Dryness fraction of the steam leaving the separating calorimeter and entering throttling calorimeter

P_1 = Absolute Pressure of wet Steam entering the throttling calorimeter

L_1 = Latent heat of wet steam entering the throttling calorimeter

P_2 = Absolute Pressure of steam after throttling

L_2 = Latent heat of steam at pressure P_2

t_{sup} = Temperature of superheated steam after throttling

t_2 = Saturation temperature at pressure P_2

H_{w1} = Sensible heat of water at pressure P_1

pressure P_1

H_2 = Total heat of dry steam at pressure P_2

C_p = Specific heat of superheated steam and

Total Heat before throttling = $Hw1 + X_2L_1$

Total Heat after throttling = $Hw2 + L_2 + C_p (t_s - t_2)$

If the steam is in a superheated state after throttling

Since the total heat during throttling remains constant.

Total heat of steam entering the throttling calorimeter = Total heat of steam leaving the throttling calorimeter

$H_{w1} + X_2 L_1 = H_{w2} + L_2 + C_p (t_s - t_2)$

$H_{w1} + X_2L_1 = H_2 + C_p(t_{sup}-t_2)$ $(H_2 = H_{w2} + L_2)$

$$X_2 = \frac{[H_2 + C_p(t_{sup} - t_2)] - H_{w1}}{L_1}$$

Total Dryness Fraction $X = X_1 * X_2$

DESCRIPTION:

The set up consists of a separating and throttling calorimeter. A steam generator is provided at the base of the apparatus. A thermostat knob is provided at the front of apparatus to control the temperature inside the steam generator. Steam from steam generator is passed from separating calorimeter where most of the water particles get separated from steam and then passed to throttling calorimeter where steam get superheated. After that superheated steam is passed through heat exchanger to condense the steam. A manometer and a thermometer are connected with throttling calorimeter to measure the pressure and temperature after throttling process.

Separating Calorimeter

It consists of two concentric chambers, the inner chamber, and the outer chamber, which communicates with each other through an operating at the top. As the steam discharges through the metal basket, which has a large number of holes, the water particles due to their heavier momentum get separated from the steam and collect in the chamber. The comparatively dry steam in the inner chamber moves up and than down aging through the annular space between the two chambers and enters the Throttling Calorimeter.

Throttling Calorimeter

It consists a narrow throat (Orifice). Pressure and temperature are measured by manometer and thermometer. The steam after throttling process passes through the heat exchanger and condensate is collected.

PROCEDURE:

1. Close the ball/drain valve provided before the separating calorimeter.
2. Switch on the main supply to the heaters of steam generator and set the thermostat knob at 120°.
3. Fully open the ball valve when the pressure of the steam generator rises up to 2kg / cm^2.
4. Now supply of the continuous water to the heat exchanger.
5. Now slowly open the needle valve provided after the separating calorimeter and maintain the constant pressure in the pressure gauge provided before the throttling calorimeter.
6. A light buzzing sound comes from throttling calorimeter confirms throttling.
7. Allow some time for the steady state if pressure of the pressure gauge fluctuates stables it manually by operating needle valve.
8. Note the pressure difference and temperature after the throttling from the manometer and thermometer.
9. Collect the suspended moisture from the separating calorimeter and weight it.
10. Also collect the dry steam condensing after throttling calorimeter and weight it.
11. Now calculate the dryness fraction of steam.

FORMULAE:

1. Dryness fraction of steam measured by separating calorimeter.

$$X_1 = \frac{W_d}{W_d + W}$$

2. Dryness fraction of steam measured by throttling calorimeter.

$$X_2 = \frac{\lfloor H_2 + C_p (t_{sup} - t_2) \rfloor - H_{w1}}{L_1}$$

3. Actual dryness fraction

$$X = X_1 * X_2$$

4. Pressure after throttling

$$P_2 = 1.033 + \frac{M_d}{10000} \text{ kg f / cm}^2$$

5. Absolute pressure = Gauge pressure + Atmospheric pressure.

Where

W	=	Weight of suspended moisture collected in the Separating calorimeter
W_d	=	Weight of the steam leaving the separating calorimeter and entering the Throttling calorimeter
X_1	=	Dryness fraction of steam shown by Separating Calorimeter
X_2	=	Dryness fraction of the steam leaving the separating calorimeter and entering throttling calorimeter
P_1	=	Absolute Pressure of wet Steam entering throttling calorimeter
L_1	=	Latent heat of wet steam entering the throttling calorimeter at P_1.(from steam table)
P_2	=	Absolute Pressure of steam after throttling
L_2	=	Latent heat of steam at pressure P_2
t_{sup}	=	Temperature of superheated steam after throttling
t_2	=	Saturation temperature at pressure P_2 (from steam table)
H_{w1}	=	Sensible heat of water at pressure P_1 (from steam table)
H_2	=	Total heat of dry steam at pressure P_2 (from steamtable)
C_p	=	Specific heat of superheated steam and = 0.5
M_d	=	Manometeric pressure difference in mm of water
1.033 kg f / cm^2	=	Atmospheric pressure

OBSERVATION TABLE:

S.NO	Gauge Pressure before throttling Kg f / cm^2	Temp. after throttling, T_{sup} °C	Manometer difference, M_d (mm)	Weight of moisture collected, W	Weight of dry steam, Wd

CALCULATION TABLE:

S.NO.	Absolute pressure before throttling, P_1	Absolute pressure after	Dryness fraction from	Dryness fraction from	Actual dryness

	Kg f / cm^2	throttling, P_2 Kg f / cm^2	separating calorimeter, X_1	throttling calorimeter, X_2	fraction of steam, X

SAMPLE CALCULATION:

OBSERVATION TABLE:

S.NO	Gauge Pressure before throttling Kg f / cm^2	Temp. after throttling, T_{sup} ° C	Manometer difference, M_d (mm)	Weight of moisture collected, W	Weight of dry steam, Wd
1.	0.52	95°	4	47	710
2.	0.9	95°	2	17	310

CALCULATION TABLE:

S.NO.	Absolute pressure before throttling, P_1 Kg f / cm^2	Absolute pressure after throttling, P_2 Kg f / cm^2	Dryness fraction from separating calorimeter, X_1	Dryness fraction from throttling calorimeter, X_2	Actual dryness fraction of steam, X
1.	1.553	1.0334	0.93	0.98	0.91
2.	1.933	1.0332	0.94	0.98	0.92

SAMPLE CALCULATIONS (Reading no. 1):

Initial absolute pressure of steam,	P_1	=	1.553 kgf/cm^2
Absolute pressure after throttling,	P_2	=	1.0334 kgf/cm^2
Temperature after Throttling,	t_{sup}	=	95° C
Weight of dry steam.	W_d	=	710 grams
Weight of water vapours in Suspension	W	=	47 grams
Specific heat of steam	C_p	=	0.5

By steam table for 1.553 kgf/cm^2

H_{w1}	=	111.96 Kcal / kg m
L_1	=	531.9875 Kcal / kg m

By steam table for 1.0334 kgf/cm^2

H_2	=	639.70 Kcal / kg m
t_2	=	100.8° C

Dryness fraction of steam by separating Calorimeter

$$X_1 = \frac{710}{710 + 47} = 0.93$$

Dryness fraction of steam by throttling calorimeter

$$X_2 = \frac{\lfloor H_2 + C_p (t_{sup} - t_2) \rfloor - H_1}{L_1} = 0.98$$

Total Dryness fraction $X = X_1 * X_2$

$= 0.91$

PRECAUTIONS:

1. Manometer should be filled with water up to half.
2. Thermometer pocked should be half filled with oil before inserting the thermometer.
3. Cold Water to inlet of Heat Exchanger must be supplied before opening the valve.
4. Do not set the value of thermostat knob above 120°.

AIM: To Determine Brake Horse power, Specific fuel consumption, Brake thermal efficiency, Heat lost by cooling water, Air consumption, Swept volume, and volumetric efficiency.

Apparatus: The petrol engine test Rig arrangement

Description: The petrol engine test Rig consists of following arrangement to conduct the experiment

1. Fuel input measuring arrangement

This arrangement consists of tank of suitable capacity mounted on the stand. The fuel goes to the engine through a 50 ml burette. The burette facilitates the measurement of fuel consumption for a definite period of time with the help of stopwatch.

2. Arrangement for measuring the heat carried by cooling water.

Suitable pipe fitting is provided for circulating the cooling water into the engine for measuring the rate of flow of water, meter is provided. With this entire arrangement one can find out the heat carried away by cooling water. The temperature of inlet and outlet water can be directly read from the thermometer.

3.Air intake measuring arrangement

This consists of an orifice, a diaphragm base manifold and a U-tube manometer. With the help of orifice and manometer the volume of air sucked can be calculated.

4. Loading Arrangement

The engine is coupled with AC alternator with loading arrangement. A panel board consisting of ammeter, voltmeter and switches are provided

Experimental Procedure

1. Fill oil in an oil sump of engine. It should be in between the marks provided on an oil dipstick. If oil level is reduced, add clean oil(SAE-40) to the crankcase by opening the cover of valve provided at the top of the engine
2. Fill the Petrol in the fuel tank.
3. Fill the manometer up to half of the height of manometer with water.
4. Fill the burette with petrol by opening the valve provided at the lower side of burette. Close the valve after filling the burette.
5. Supply the petrol to the engine by opening the valves provided in the fuel supply line. Supply the main power.
6. Open continuous cold water supply to the engine jacket.
7. Start the engine with starting handle and let it run for 15 minutes under no load condition.
8. When the current supply starts then give the load through the loading arrangement(200 watt bulbs)

9. Start the four cylinder petrol engine with throttle fully open .Run the engine for 15 minutes so that it can stabilize.
10. Keeping the throttle opening fixed, with all the cylinders working, take the dynamometer readings and note the engine speed.
11. Cut out the first cylinder by shorting its spark plug. This will cause the engine speed to decrease. Bring the speed back to original value by adjusting the dynamometer load and note down the new dynamometer reading.
12. Record the dynamometer load
13. Render the first cylinder operative but cut out the second, third and fourth cylinder in turn. Repeat the procedure taking care that speed remains constant and the throttle opening is undisturbed while the test is being conducted
14. Close the petrol supply valve and open the burette. Note down the time to consume 50 ml of petrol with the help of stop watch. It will give us the fuel consumption.
15. Repeat the experiment at different loads and different speeds

Morse Test: This test is basically used to determine the IP (indicated power of Multi cylinder four stroke petrol engine test rig.)

Procedure to calculate the Morse test through hydraulic dynamometer

1. Initially calculate the BP of whole engine by considering aal the cylinder open.
2. Then close down the first cylinder and calculate the BP1 at same load
3. Similarly calculate BP2, BP3 and BP4.
4. After Calculating the BP1,BP2,BP3 and BP4 calculate the IP of each cylinder
5. IP of each cylinder is calculated as:

$$IP1 = BP - BP1$$
$$IP2 = BP - BP2$$
$$IP3 = BP - BP3$$
$$IP4 = BP - BP4$$

6. Then calculating the total IP(Indicated power) as follows;

$$IP = IP1 + IP2 + IP3 + IP4$$

7.Calculate the Friction power of the engine, which is calculated as follows

$$IP = BP + FP$$

Then

$$FP = IP - BP \quad \text{(FP=Friction Power).}$$

Observation Table:

S. No.	Engine Speed (N)	Cylinder Cut-out No.	Dynamometer loadW	Brake Power	Indicated Power of Cut-out cylinder	Friction Power	Mechanical Efficiency

	rev./ min.		Kg	kW	kW	kW	%

Formulae:

Friction Power:

The difference between indicated power and the brake power is called the *friction power.*

$$\text{Friction Power} = \text{I.P.}_n - \text{B.P.}_n$$

Specific Fuel Consumption:

It is defined as the rate of fuel consumption per unit power produced

$$\text{s.f.c.} = \frac{\text{Fuel consumption per unit time}}{\text{Power output}}$$

Thermal Efficiency:

It is defined as the ratio of brake power to the energy supplied to the engine.

$$\eta_{bth} = \frac{\text{Power output}}{\text{mass of fuel(s)} \times \text{calorific value of fuel}}$$

Volumetric Efficiency:

It is an indication of the breathing capacity of the engine and is defined as the ratio of volume of air actually indicated at ambient conditions to the swept volume of the engine.

$$\eta_v = \frac{\text{Mass of charge actually inducted}}{\text{Mass of charge that fills swept volume at ambient temp, and pressure}}$$

$$= \frac{\text{Volume of charge aspirated per stroke at ambient conditions}}{\text{Swept volume}}$$

Mechanical Efficiency:

The ratio of brake power to the indicated power is called the *mechanical efficiency* of the engine

Mechanical Efficiency = Brake Power / Indicated Power

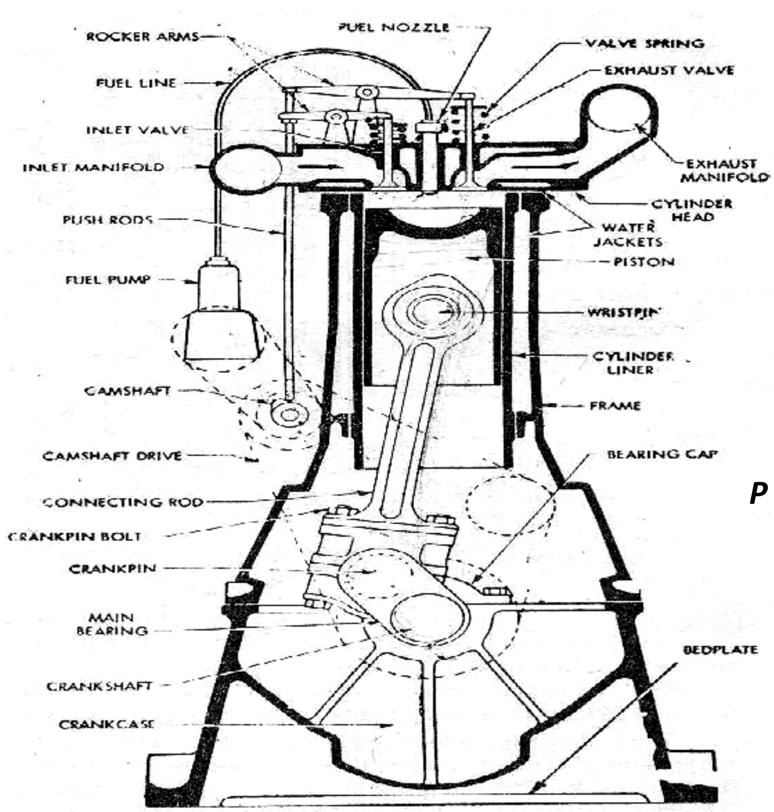
Objective:

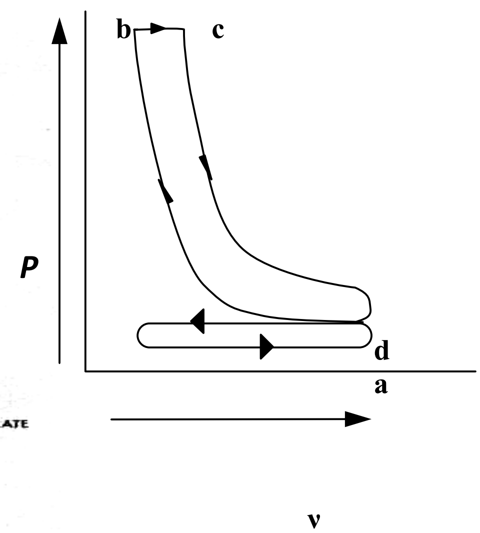
Performance of a diesel engine from no load to full load (at constant speed) for a single cylinder engine in terms of brake power, indicated power, mechanical efficiency and SFC (specific fuel consumption) and further obtain power consumption curves and draw the heat balance sheet..

Apparatus:

A single cylinder, four stroke water cooled, vertical Diesel Engine.

Diagram:





Ideal P-v Diagram

Outline Illustration of Diesel Engine

Theory:

BRAKE POWER

Brake Power is the power delivered by the engine at the drive shaft. The brake power is usually measured by attaching a power absorption device to the drive shaft of the engine. Such a device sets up measurable forces counteracting the forces delivered by the engine and the determined value of these measured forces is indicative of the forces being delivered.

In the present case, rope brake type dynamometer is used.

Let S_1	=	spring balance reading (kg)	
S_2	=	spring balance reading (kg)	
D	=	brake drum diameter (m)	
D	=	rope brake diameter (m)	
R_{eff}	=	effective radius of brake drum	
R_{eff}	=	$\frac{D + d}{2}$	
N	=	Revolutions per minute	
Brake Torque	=	$9.81 (S_1 – S_2) R_{eff}$ Nm	
Brake Power	=	$\frac{2\pi (N/60) \{9.81 \times (S_1 – S_2)\} R_{eff}}{1000}$	kW
	=	$1.027 \times 10^{-3} N (S_1 – S_2) L$	kW

BRAKE SPECIFIC FUEL CONSUMPTION

It is defined as the rate of fuel consumption per unit brake power produced

$$b_{sfd} = \frac{\text{Fuel consumption per unit time}}{\text{Brake Power}}$$

BRAKE THERMAL EFFICIENCY

It is defined as the ratio of brake power to the energy supplied to the engine.

$$\eta_{bth} = \frac{\text{Brake Power}}{\text{mass of fuel(s)} \times \text{calorific value of fuel}}$$

VOLUMETRIC EFFICIENCY

It is an indication of the breathing capacity of the engine and is defined as the ratio of volume of air actually indicated at ambient conditions to the swept volume of the engine.

$$\eta_v = \frac{\text{Mass of charge actually inducted}}{\text{mass of charge represented by swept volume at ambient temp. and pressure}}$$

$$= \frac{\text{Volume of charge aspirated per stroke at ambient conditions}}{\text{swept volume}}$$

RELATIVE EFFICIENCY

It is also known as efficiency ratio and is the ratio of thermal efficiency of an actual cycle to that of the ideal cycle. It is a very useful criterion as it indicates the degree of development of the engine.

$$\eta_{rel} = \frac{\text{Actual Thermal Efficiency}}{\text{Air – Standard Effieiency}}$$

Procedure:

a. Open the tap to allow cooling water to circulate through the engine. Engine should not be started without starting the flow of cooling water, otherwise the engine would be damaged.
b. Start the engine and allow it to run for at least 15 minutes to attain steady state. Increase load by tightening the rope.
c. Note down:
    (i) Speed of engine
    (ii) Spring balance readings
    (iii) Time taken for the consumption of 50ml of fuel
    (iv) Pressure difference, indicated by the manometer, across the orifice
    (v) Temperature of the incoming air
    (vi) Inlet and outlet temperature of the cooling water
    (vii) Exhaust gas temperature
d. Make a record of readings in a tabular form and calculate various parameters.

Observations and Calculations:

S. No.	Load Kg	Engine Speed (N) rev./ min.	Spring Balance Readings Kgf		Net Load (S_1– S_2) Kgf	Brake Power kW	Time (50ml fuel) [t] secs	Brake specific fuel consum-ption kWh	η BRAKE %	Pre-ssure drop ΔH cm	Air mass flow rate Kg/s	Ideal mass flow rate Kg/s	Vol. Effi-ciency %
			S_1	S_2									

(i) **BRAKE POWER (BP)** = 1.027×10^{-3} N ($S_1 - S_2$) R_{eff}

$$B_{mep} = \frac{BP \times 60000 \times 2}{624 \times 10^{-6} \times N} = \frac{BP}{N} \times 1923 \times 10^5 \text{ N/m}^2$$

(ii) **FUEL CONSUMPTION**

Note time required for the consumption of 50ml of the fuel. (Let it be t secs.)

$$\text{Rate of fuel comsumption} = \frac{50}{T} \times 10^{-6} \text{ m}^3\text{/s}$$

$$= \rho_f \times \frac{50 \times 10^{-6}}{t} \quad \text{kg/s}$$

where ρ_f = density of the fuel in kg/m^3

(iii) **BRAKE SPECIFIC FUEL CONSUMPTION** =

$$\frac{50 \times 10^{-6}}{t} \times \frac{\rho_f \times 3600 \times 1000}{BP} \text{ g/kWh}$$

$$= \frac{180 \times \rho_f}{t \times BP} \quad \text{t/kWh}$$

(iv) **BRAKE THERMAL EFFICIENCY** =

$$\frac{BP}{\left(\frac{50 \times 10^{-6}}{t} \times \rho_f\right) \times LHV}$$

where LHV = lower heating value

(v) **AIR FLOW MEASUREMENT:** The mass flow rate of air is measured by measuring the pressure drop across the sharp edged orifice. The mass flow rate is given by

$$M_{air} = C_d A_o \sqrt{2g\, \Delta H\, \rho_w\, \rho_{air}}$$

Where

M_{air} = Mass flow rate of air (Kg/s)

C_d = Coefficient of discharge of the orifice

A_o = Orifice area (m^2) = $\pi d_o^2/4$ (d_o being the diameter of orifice)

g = Gravity 9.81 m/sec^2

ΔH = m of water (Pressure)
ρ_w = density of manometric fluid 995 – 1000 kg/m^3
ρ_a = density of air entering the measuring orifice

(vi) VOLUMETRIC EFFICIENCY = $\dfrac{\text{Mass Flow Rate}}{\text{Ideal Mass Flow Rate}}$

Now ideal mass flow rate = Swept volume x $\dfrac{N}{60}$ x $\dfrac{1}{2}$ x ρ_{air}

where swept volume is in m^3; ρ_{air} is the ambient air density in kg/m^3

$$m_i = 624 \times 10^{-6} \times \frac{1500}{2 \times 60} \times \rho_{air}$$

$$= 7.8 \times 10^{-3}\ \rho_{air}$$

(Take ρ_{air} = 1.17 to 1.20 kg/m^3)

$$\eta_v = \frac{C_d\ A_o \sqrt{2g\ \Delta H\ \rho_w\ \rho_{air}}}{7.8 \times 10^{-3}\ \rho_{air}}$$

Result:

(i)	Brake Power (BP)	= _____________	kW
(ii)	Fuel Consumption	= _____________	Kg/s
(iii)	Brake Specific Fuel Consumption	= _____________	KWh
(iv)	Brake Thermal Efficiency	= _____________	%
(v)	Air Flow Measurement	= _____________	Kg/s
(vi)	Volumetric Efficiency	= _____________	%

Precautions:

a) Oil of tank should be checked.
b) Water supply should be regulated regularly.
c) There should be no leakage.
d) Open the screw for draining air, don't touch the fuel pump.
e) Clean the engine regularly.
f) Clean the air cleaner and the silencer after every 50 hrs.
g) Avoid loose clothing in the lab.
h) There should not be any oil etc. spilled on the floor, it should be kept clean.

Questions for Viva

a) Differentiate between Diesel Engine and Petrol Engine.
b) How is S.F.C. calculated in case of a Diesel Engine?
c) How many types of *Cooling* are used in a Diesel Engine?
d) What does the title "Single Cylinder Four Stroke Diesel Engine" signify?
e) What are the major Do's and Don'ts to be taken care of while the engine is running?

OBJECTIVE: Performance of single/multi stage reciprocating compressor.

APPARATUS: Multi-stage Air Compressor.

INTRODUCTION:

Air Compressor is a device, which sucks the air from atmosphere and Compresses it and delivers in reservoir tank. It compresses the air by means of a reciprocating piston, which reciprocates in a stationary cylinder. It can be single stage or multi stage.

In single stage compression, air from the atmospheric pressure is compressed to the desired discharge in a single operation.

In two-stage compression, air is partially compressed in low-pressure cylinder. This air is passed through cooler between first stage and second stage so that air at inlet of second stage is at lower temperature than the first stage outlet. This is done to reduce the work of compression in second stage. Final compression is completed in second stage i.e. in high-pressure cylinder. Also, the compressors are provided with clearance volume, two stage compressors can achieve higher volumetric efficiency than single stage compressors, because of lower compression per stage.

As the compressed air is used in a wide range in industrial, domestic, aeronautics fields etc. so compressors are applied in wide range. Compressors are used where the air is required at high pressure.

DESCRIPTION:

Single and Double stage Air Compressor Test Rig consists of a reservoir tank, two cylinders and pistons driven by A. C. motor. Thermometers are provided at inlet of low-pressure cylinder and outlet of high-pressure cylinder. Two more thermometers are provided before and after the intercooler. To find out the inlet volume of air, an orifice meter is provided. To stream line the intake, a diaphragm base manifold is provided. Pressure Gauge is provided at reservoir tank. Safety valve and auto power cut-off switch is provided for the safety factor:

EXPERIMENTAL PROCEDURE (SINGLE STAGE):

1. Close the outlet valve of tank and also close the valves 1,2,3 and 6.
2. Now open the valves 7,4 and 5 and start the compressor. The air will be compressed in single cylinder i.e. low-pressure cylinder.
3. Let the receiver pressure rise up to around 2 kg/cm^2. Now open the delivery valve so that constant delivery pressure is achieved.

4. Wait for some time and see that delivery pressure remain constant. Now note down the pressure.
5. Record the energy meter Pulses/time to find out the input H.P.
6. Record the manometer reading to find out the volume of air input.
7. Record the temperature of air at inlet of cylinder.
8. Find out the RPM of compressor with the help of RPM indicator.
9. Find out the volumetric efficiency and isothermal efficiency by given formulae.
10. Repeat the same procedure for different delivery pressure.
11. After completing the experiment stop the compressor by pressing the red button provided at the control panel.

EXPERIMENTAL PROCEDURE (DOUBLE STAGE):

1. Close the outlet and also close the valves 2,4,5 and 7.
2. Now open the valves 1,3 and 6 and connect the continuous water supply to the intercooler for cooling the compressed air and then start the compressor.
3. Let the receiver pressure rise up to around 2 kg/cm^2. Now open the delivery valve so that constant delivery pressure is achieved.
4. Wait for some time and see that delivery pressure remain constant. Now note down the pressure.
5. Record the energy meter Pulses/time to find out the input H.P.
6. Record the manometer reading to find out the volume of air input.
7. Record the temperature of air at inlet, outlet, before and after intercooler intercooler.
8. Find out the RPM of compressor with the help of RPM indicator.
9. Repeat the same procedure for different delivery pressure.
10. Repeat the same procedure for different delivery pressure.
11. After completing the experiment stop the compressor by pressing the red button provided at the control panel.

SPECIFICATIONS:

Motor	:	2 H.P. AC Single Phase, 1440 RPM
Compressor	:	Single and Double stage, Single acting
Cylinder I	:	Dia 70mm, Stroke = 70mm
Cylinder II	:	Dia 52mm, Stroke = 70mm
Energy meter Constant (EMC)	:	3200 Pulses/k Wh

STANDARD DATA:

Low pressure cylinder I:

d = Bore dia., = 70mm = 0.07 m

L = Length of stroke = 70mm = 0.07 m

d_o = Diameter of orifice = 8mm = 0.008m

a^o = Cross-sectional area of orifice = $5.026 \times 10^{-5} m^2$

d_p = Diameter of pipe = 16mm = 0.016m

a_p = Cross-sectional area of pipe = $2.011 \times 10^{-4}\ m^2$

ρ_m = Density of water = $1000\ kg/m^3$

ρ_a = Density of air at 0° C i.e.273°K= $1.293\ kg/m^3$

C_d = Co efficient of discharge = 0.64

E.M.C = Energy meter constant = 3200 pulses/kw h

P_a = Atmospheric pressure = $1.033\ kgf/cm^2$ = $1.013 \times 10^5 N/m^2$

R = Radius of swinging Field Dynamometer, = 265 m = 0.265m

T_1 = Inlet air temp.

T_2 = Temp. of air before the intercooler and outlet of first stage.

T_3 = Temp. of air after the intercooler and inlet of second stage.

T_4 = Temp. of air at oulet of second stage.

P = Nos. of pulses of energy meter.

C_p = 1×10^3 J/ kg k

FORMULAE:

1. $$\Delta P = \left(\frac{\rho_m - \rho_a}{\rho_a}\right) R' \text{ m of air}$$

where ρm = density of manometer fluid(water)

ρa = density of air

R = Manometer pressure difference

2. Actual Volume of air

$$Q_{NTP} = \frac{C_d a_o \sqrt{2 \Delta p g}}{\sqrt{1 - \left(\frac{a_o}{a_p}\right)^2}}$$

Where

C_d = 0.64

a_o = cross-sectional area of orifice

a_p = cross-sectional area of pipe
ρ_a = density of air
g = 9.81 m/s^2

3. Actual Volume of air at Room temperature

Q_{RTP} = Q_{NTP} x $\frac{273}{273+T_1}$ (T_1 = inlet air temp.)

4. Swept volume of compressor

Qt = π /4 x d^2x L x N/60

Where
d = 0.07m
L = 0.07 m
N = No. of rpm

5. Volumetric ŋ% = $\frac{Q_{RTP}}{Qt}$ X 100

6. H.P. Elec = $\frac{p}{time} X \frac{3600}{E.M.C}$ X 1.36

7 Shaft Horsepower as indicated by Swinging Field Dynamometer:

H.P. Shaft = 2 π N T / 4500

Torque, T = F x R

Where,
N = No. of rpm of motor, N' = (3.1)x N

F = Force in spring balance in kg

R = Radius of swinging field arm

8 Compression Ratio (r) = $\frac{Gauge\,\Pr. + Atm\,\Pr essure}{Atmospheric\,\Pr essure}$

9 Isothermal H.P. = $\frac{Q_{NTP}}{75} x(\log_e r) x p_a$ (p_a=Atm. Pressure)

10 Isothermal ŋ% = $\frac{Isothermal.H.P.}{H.P.shaft}$ x 100

11 heat rejected to intercooler, h = m_a x C_p x $(T_3 - T_2)$ watts

Mass flow rate of air, m_a = Q_{NTP} x ρ_a kg / sec

SINGLE STAGE AIR COMPRESSOR:
OBSERVATION TABLE:

Delivery Pressure Kg/cm^2	Differential Manometer Reading (cm)	RPM	Inlet Temp. T_1	Energy meter 20 Pulses/time (Sec)	Force, F (kg)

CALULATION TABLE:

Δp m of air	Q_{RTP} M^3 / s	Swept volume, Q_t (m^3 / s)	Volumeteric η (%)

H.P Elec.	Torque, T	H.P shaft	Compression ratio, r	Isothermal H.P.	Isothermal η (%)

DOUBLE STAGE AIR COMPRESSOR:

OBSERVATION TABLE:

Delivery Pressure Kg/cm^2	Differential Manometer Reading (cm)	RPM	Inlet Temp. T_1	Energy meter 20 Pulses/time (Sec)	Force, F (kg)

CALULATION TABLE:

Δp m of air	Q_{RTP} M^3 / s	Swept volume, Q_t (m^3 / s)	Volumeteric η (%)

H.P Elec.	Torque, T	H.P shaft	Compression ratio, r	Isothermal H.P.	Isothermal η (%)

PRECAUTIONS:

1. Check the oil before starting the Air Compressor.
2. Check the proper voltage while conducting experiments.
3. Be careful while measuring the RPM.
4. Close the delivery valve of Tank before starting the experiment.