LAB-I MED421- INTERNAL COMBUSTION ENGINES (ICE)

Examination Scheme

Practical Scheme: 2 Hrs/week

Term Work: 25 Marks
Practical Exam: 25 Marks

List of Experiments

Any seven (7/10) of the following list of practicals should be performed and recorded in a Laboratory book **on his/her 100 % attendance for each experiment conducted**.

1. Performance test on a single cylinder diesel engine
2. Performance test on a single cylinder petrol engine
3. Evaluation of the heat balance for single cylinder diesel engine
4. Performance test on a multi-cylinder petrol engine
5. Morse test on multi-cylinder engine
6. Measurement of exhaust gas emission from S.I. engine
7. Measurement of exhaust gas emission from CI engine
8. Study of Bosch type single plunger fuel pump
9. Study of various types of fuel injectors and nozzles
10. Study of different types of carburetor

The assessment of term work shall be on the following criteria:

- Continuous assessment (Regular practical & theory attendance and performance, Teachers assessment)
- Performing the experiments in the laboratory (**Compulsory: 100 % attendance for all experiments**)

Practical Examination:

The practical examination shall be consisting of Viva-voce based on the practical work done during the course and on the syllabus of subject (Internal Combustion Engines).

Mission and vision of the Department

Vision of Mechanical Department

To establish the state of the art learning center in Mechanical Engineering which will impart global competence, enterprising skills, professional attitude and human values in the student.

Mission of Mechanical Department

1. To impart quality technical education to the students.
2. To develop comprehensive competence in the students through various modes of learning.
3. To enable students for higher studies and competitive examinations.
4. To facilitate students and industry professionals for continuous improvement and innovation.

Program Educational Objectives:

[1] Use core competence acquired in various areas of Mechanical Engineering to solve techno-managerial issues for creating innovative products that lead to better livelihoods & economy of resources.

[2] To establish themselves as effective collaborators and innovators to address technical, managerial and social challenges.

[3]To equip students for their professional development through lifelong learning and career advancement along with organizational growth.

[4] Serve as a driving force for proactive change in industry, society and nation.

PROGRAM SPECIFIC OUTCOMES

Student should have

1) An ability to work professionally in mechanical systems including design, analysis, production, measurement and quality control.
2) An ability to work on diverse disciplinary tasks including manufacturing, materials, thermal, automobile, robotics, mechatronics, engineering software tools, automation and computational fluid dynamics.

1) STUDY OF BOSCH TYPE SINGLE PLUNGER FUEL PUMP

EXPERIMENT TITLE: Study of Bosch type single plunger fuel pump

AIM: To study the construction details and understand working principle of Bosch type fuel pump

PRIOR KNOWLEDGE: Diesel engine and Compression ignition system

THEORY:

A. Objectives of a fuel pump

1. To deliver accurately metered quantity of fuel.
2. High pressures in the range of 100 MPa needed to achieve required atomization of fuel.
3. Fuel must be injected and terminated at the correct timing.

B. Construction Details and Working Principle of Bosch type Fuel Injection Pump

Fig.1 shows the schematic diagram of Bosch fuel injection pump. This pump is cam operated, spring return plunger pump of constant stroke type. Its special features are effective method of regulating the quantity of fuel to be delivered to the cylinder. This is achieved by means of helical groove cut on the plunger.

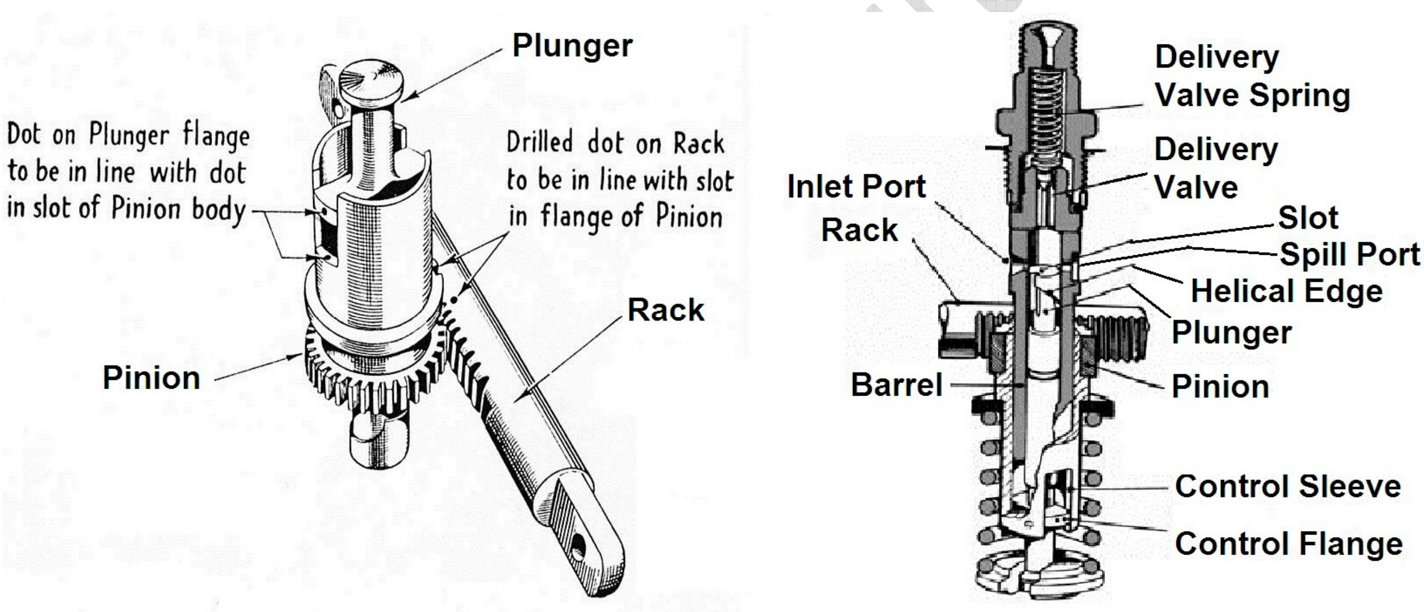


Fig. 1. Bosch Fuel Pump

Spill ports always remain full of fuel since it is connected to the fuel line. Each pump consists of a steel pump barrel in which fits accurately a steel pump plunger. A spring loaded delivery valve is fitted at the upper end of the barrel. Various positions of plunger are shown in Fig.2 which moves vertically and rotated by rack as shown in Fig.1. Fuel flows by gravity from a fuel sump in the pump unit body. During the downward motion of the plunger, a partial vacuum is created and as a result the fuel flows from the sump through the intake port into the barrel as shown in Fig.2. The plunger moves vertically in its barrel with a constant stroke. During the upwards stroke of the plunger, it uncovers the intake port and compresses the fuel which flows past the delivery valve as shown in Fig.2. The plunger is provided with vertical channel called plunge helix extending from its top edge to an annular groove at a short distance down the plunger to vary quantity of fuel delivered. This annular groove has its upper edge curved upwards to a helical shape for almost half the plunger circumference as shown in Fig.2. The rotation of the plunger controls the delivery of fuel. As the plunger is rotated slightly, the pressure is released earlier and the total effective stroke of the plunger is reduced. Fig.2 shows the position when the pump chamber is always opens to the inlet port via the plunger helix. In this position there is no delivery of fuel and the engine can be stopped.

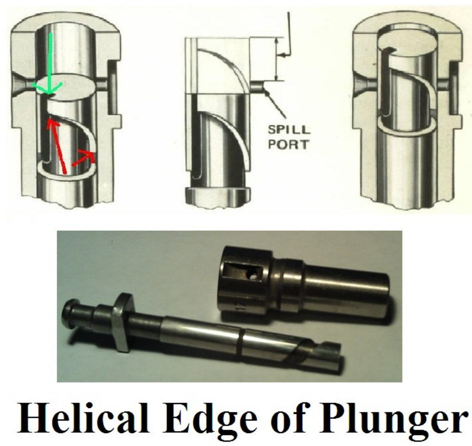


Fig. 2. Plunger of Fuel Pump

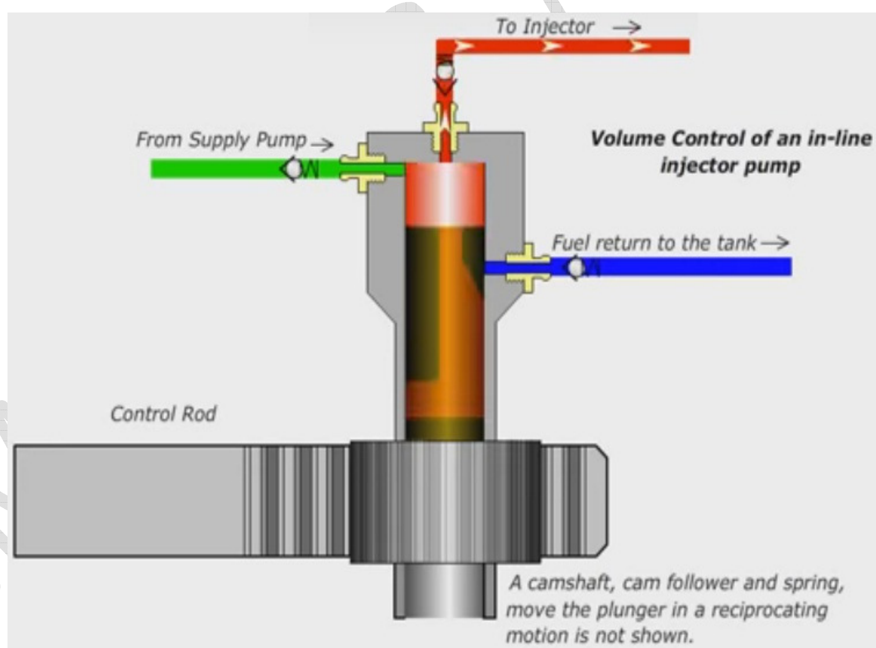


Fig. 3. Complete Fuel Pump Assembly

<u>CONCLUSION</u>: - Hence, compression ignition (C.I.) engine has Fuel Pump as a device with its control rod coupled with the Governor to control accurately metered quantity of fuel supply at high pressure at correct timing using cam follower mechanism. This high pressure fuel is then supplied to the Fuel Injector mounted on the engine cylinder.

2) STUDY OF BOSCH TYPE FUEL INJECTOR AND TYPES OF NOZZLES

EXPERIMENT TITLE: Study of Bosch Fuel Injector and different types of Fuel Injector Nozzles

AIM: To study the working and construction of Bosch Fuel Injector and types of Fuel Injector Nozzles

PRIOR KNOWLEDGE: Injection Systems, Necessity of Fuel Injection in Diesel Engines

THEORY:

A. Objectives of a fuel injector

(i) To atomize the fuel and distribute such that it makes a homogeneous mixture of air and fuel

(ii) To prevent the fuel to be injected directly on the piston or cylinder walls

(iii) To provide instantaneous starting and stopping of the fuel

B. Bosch Fuel Injector or Atomizer

Fuel from fuel pump is supplied to the fuel injector and delivers into engine cylinder through any one type of the nozzles. Fig.1 shows the cross-section of a Bosch fuel injector.

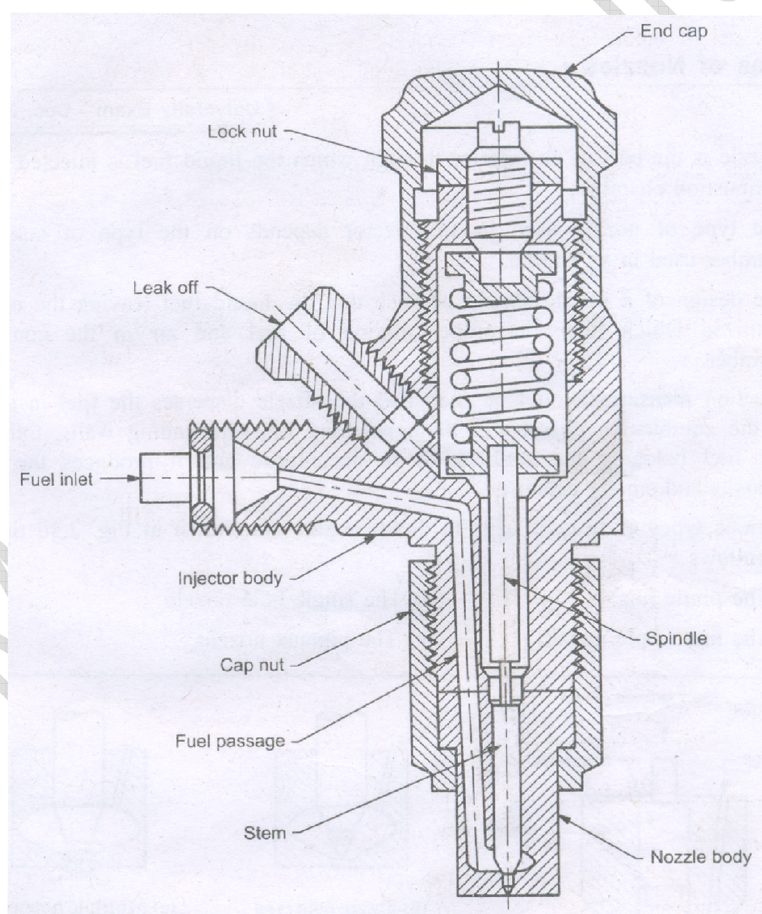


Fig. 1. Bosch Fuel Injector

C. Nozzle of the Fuel Injector or Atomizer:

Nozzle is the part of an injector through which the liquid fuel is sprayed into the combustion chamber. The nozzle holes are normally closed by the spindle and spring. Delivery pipe pressure forces up the spindle during injection and when the pressure falls, the spindle abruptly interrupts injection. The injection pressure is regulated by adjusting the nuts above the spring. The quantity of fuel injected may be regulated by the duration of opening of the valve or by varying the fuel pressure in the system.

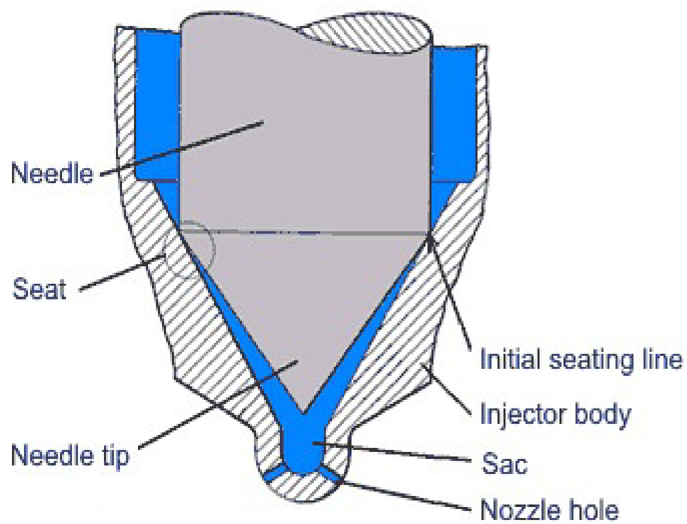


Fig. 2. Nozzle with actual Diagram Fuel Injection

Nozzles Requirement:

1. Atomization, 2 Fuel distribution, 3.Prevention of fuel impingement on walls,
4. Mixing of diesel fuel droplets and air molecules inside the combustion chamber

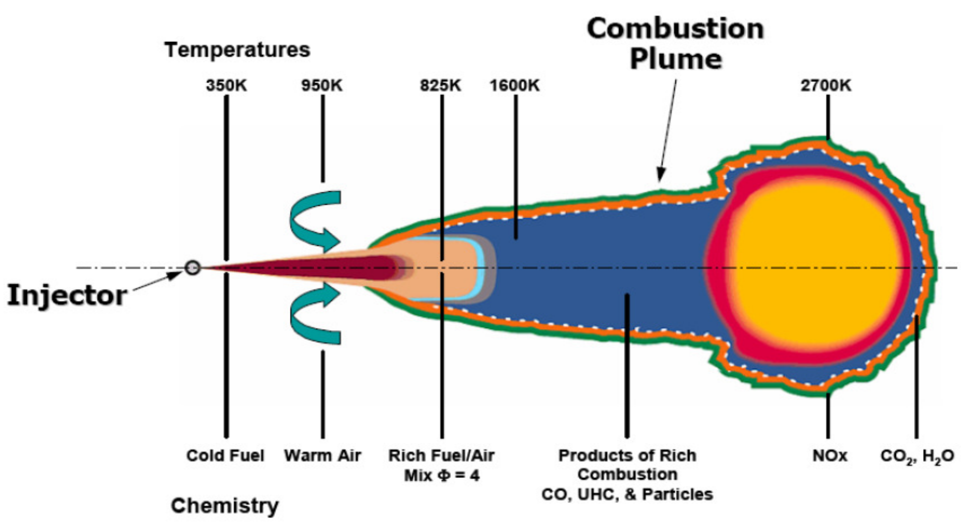
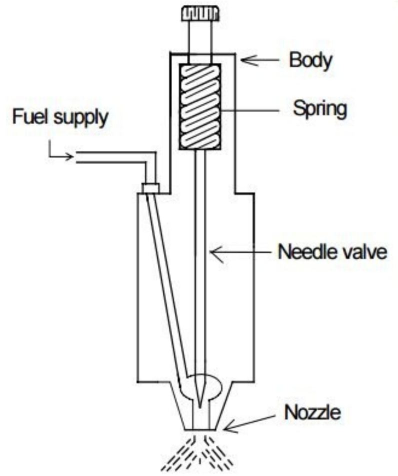
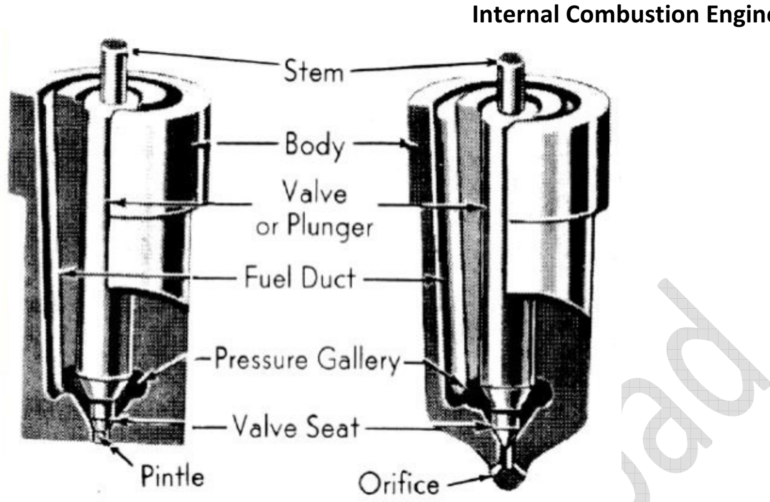


Fig. 3. Diesel flame with temperatures and chemistry

Source: Charlton S. J., "US Perspective on Engine Development"

SAE Heavy Duty Diesel Emissions Control Symposium, 2007





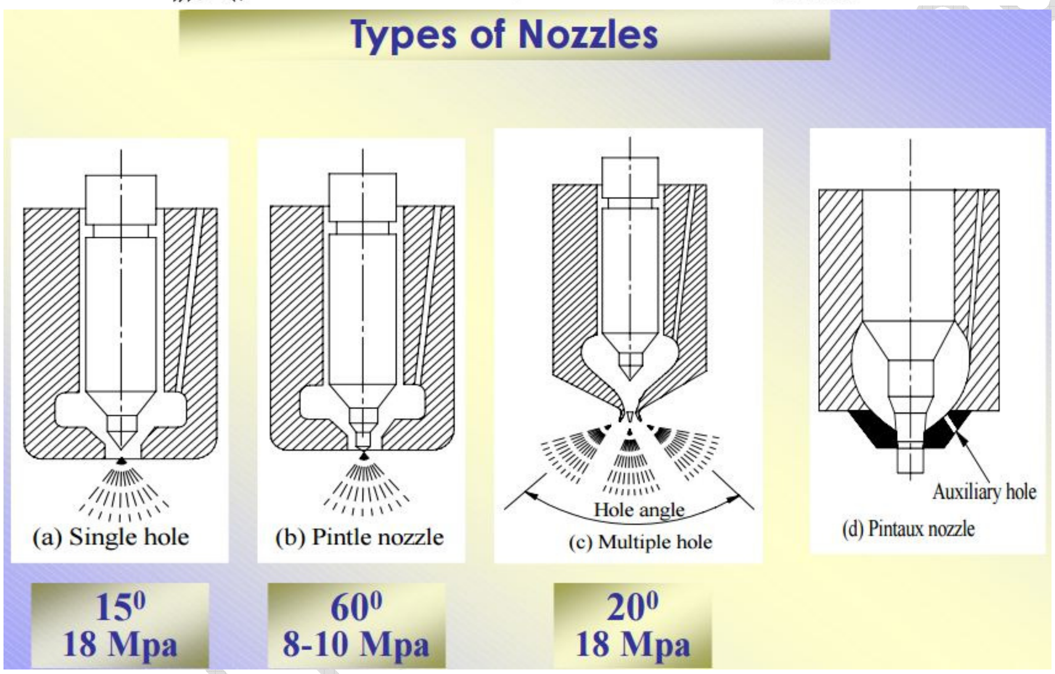


Fig. 4. Types of Nozzles

Source: Prof Ujjwal K Saha, IIT Guwahati under QIP CD Cell Project

V_f = the fuel jet velocity at the orifice exit

$$\therefore V_f = C_d \sqrt{2\left(\frac{p_{inj} - p_{cyl}}{\rho_f}\right)}$$

where p_{inj} = injection pressure

p_{cyl} = cylinder pressure

ρ_f = density of fuel

C_d = coefficient of discharge for orifice

Fig. 5. Nozzle orifice fuel jet velocity
Source: Prof Ujjwal K Saha, IIT Guwahati under QIP CD Cell Project

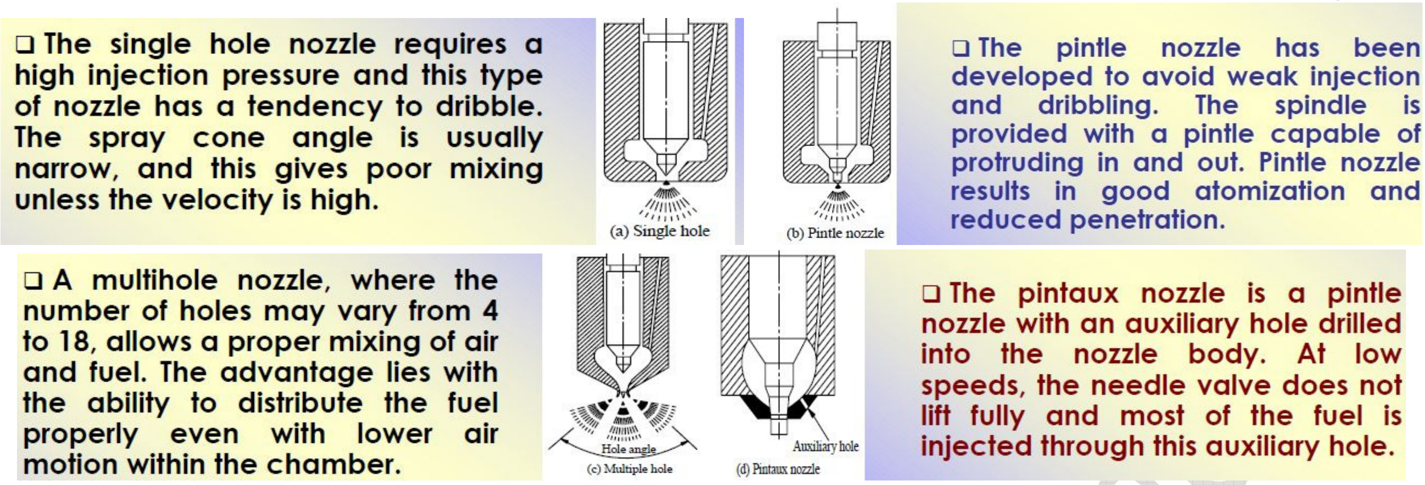


Fig. 5. Brief description on types of Nozzles

Source: Prof Ujjwal K Saha, IIT Guwahati under QIP CD Cell Project

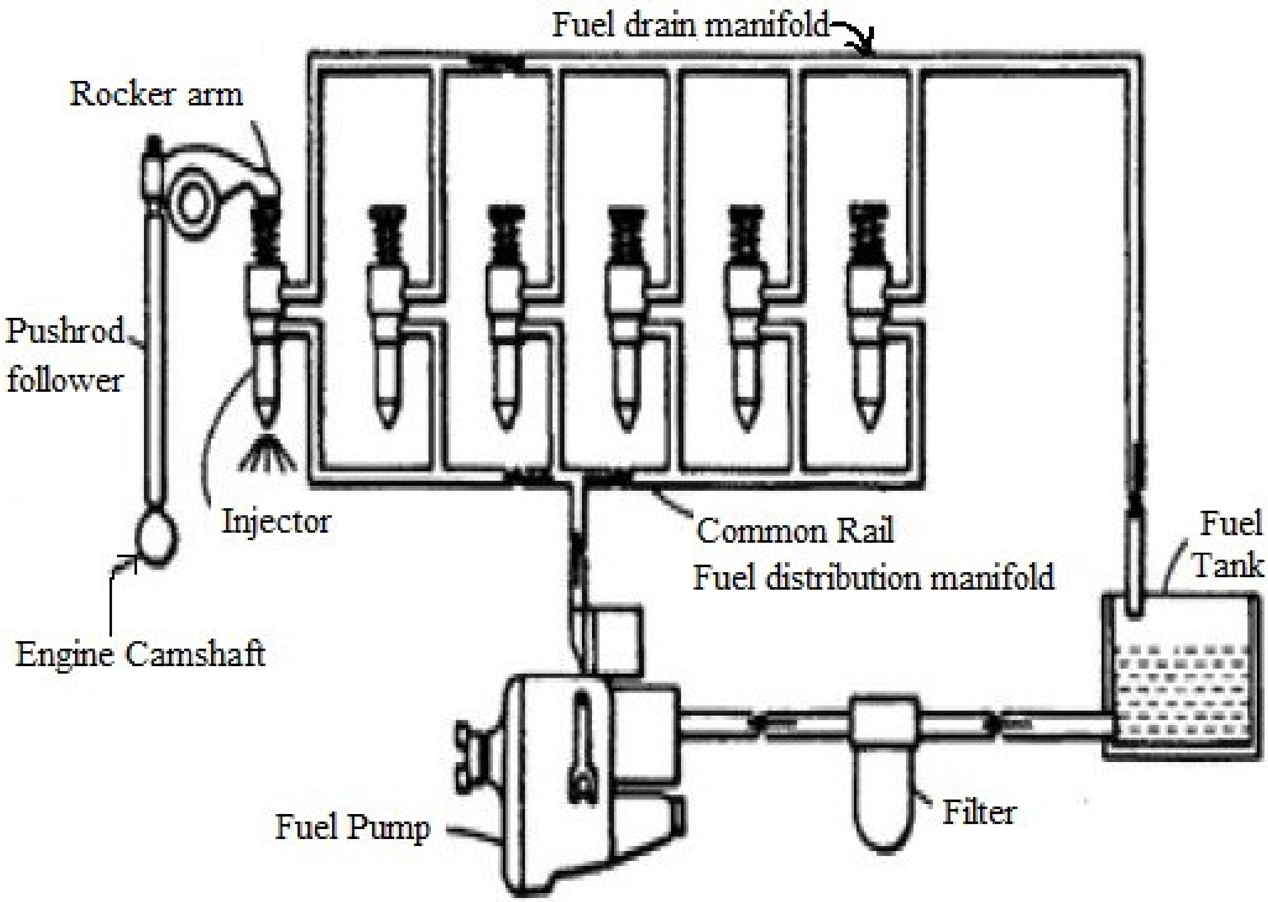


Fig. 6. Fuel pump and fuel injector interconnection

Source: Prof Ujjwal K Saha, IIT Guwahati under QIP CD Cell Project

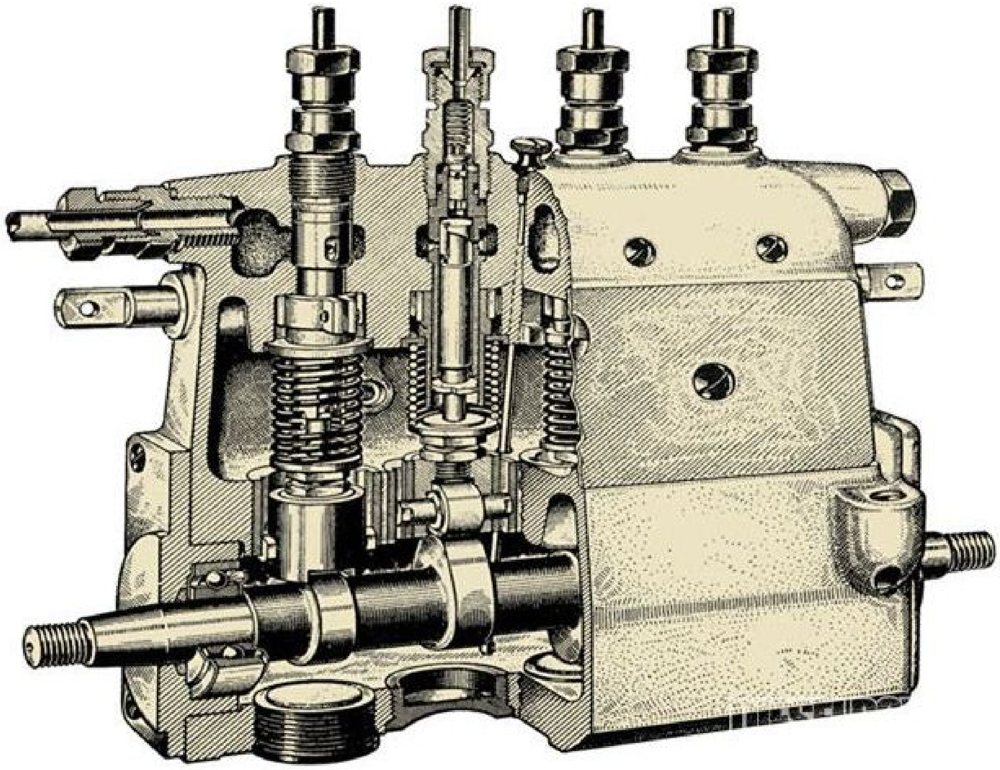


Fig. 7. Fuel pump assembly for 4 cylinder engine showing cam for activating the plunger of fuel pump

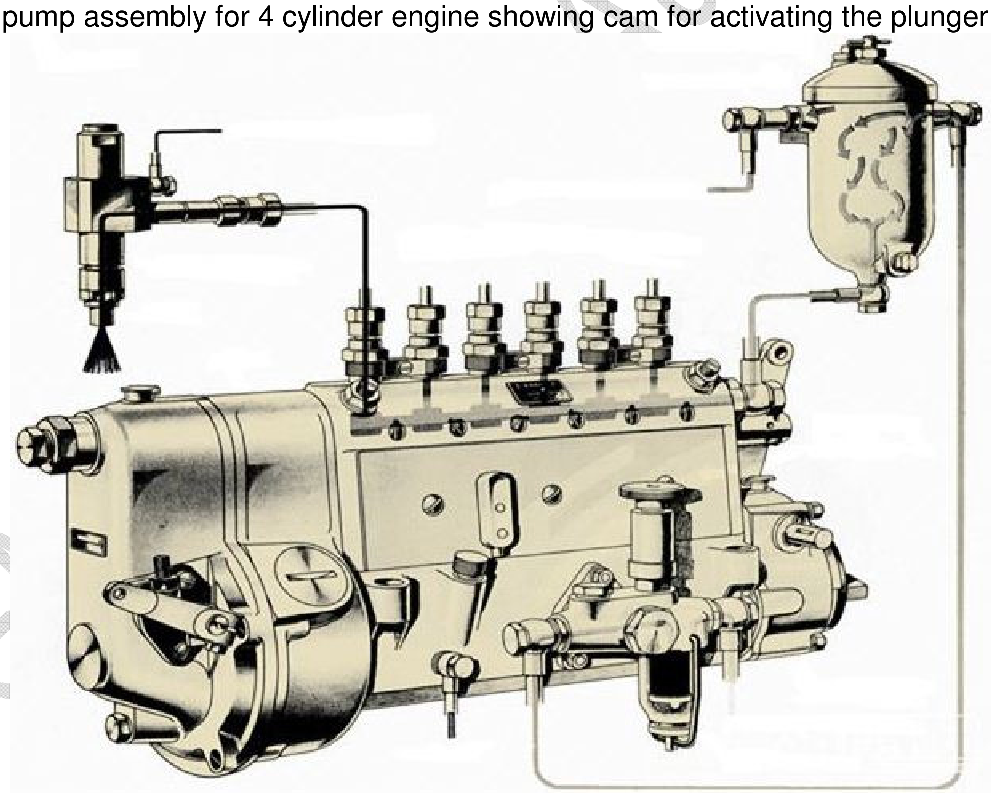


Fig. 8. Individual 6 Fuel pumps connected with individual 6 fuel injectors for 6 cylinder 4 stroke diesel engine

CONCLUSION: - Hence studied that C.I engine has Fuel Injector as a device mounted on the engine cylinder for injecting atomized form of fuel through nozzle into the Engine cylinder for proper mixing of fuel with air for complete combustion. There are four main type of nozzles for fuel injector.

3) STUDY OF DIFFERENT TYPES OF CARBURETORS

EXPERIMENT TITLE: Study of different types of Carburetors of an I. C. Engine

AIM: To study the working and construction of the various carburetors of an I.C. Engines.

To understand the fuel - air circuits provided in the carburetors.

PRIOR KNOWLEDGE: Working and Construction of the simple type of carburetor.

THEORY: Some of the important types of modern carburetors used in automobiles are

(1) Solex carburetor

(2) Carter carburetor

(3) S.U. carburetor.

1) Solex Carburetor:

The solex carburetor is one of the well known carburetor for easy starting, good performance and its reliability. It is used for various Indian Cars and Jeeps. The schematic diagram of a Solex carburetor is shown in Fig. below. It is down draught type carburetor. It consists for various fuel and air circuits. These are

(i) Normal running

(ii) Cold starting and warming

(iii) Idling and slow speed operation

(iv) Acceleration.

(I) Normal running

In normal running circuit, the fuel is provided by the main jet (b) and the air by the choke tube or venturi (c). The fuel from the main jet enters into the air bleed emulsion tube (d). The correct balance of air and fuel is automatically ensured by air entering through air correction jet (f). The metered emulsion of fuel and air is discharged through the orifice (g) drilled horizontally in the vertical pipe in the middle of venturi tube.

(ii) Cold starting and warming

The unique feature of this carburettor is to provide progressive starter. The starter valve is in the form of a flat disc (i) with holes of different sizes. These holes connect the starter petrol jet (j) and starter air jet sides to the passage which opens just below the throttle valve at (I). Depending upon the position of the starter lever (m) either bigger or small holes of flat disc come opposite the passage. For starting richer mixture is required. So in the start position bigger holes are the connecting holes. When the throttle valve is in closed position the engine suction is applied to starting passage (l). The air enters from the starting air jet (k) and fuel from starter petrol jet (j). This mixture is sufficiently rich to start the engine. After the engine has started, the starter lever is brought to the intermediate position, thus reducing the amount of petrol, till it reaches the normal running temperature. After this the starter lever is brought to the off position.

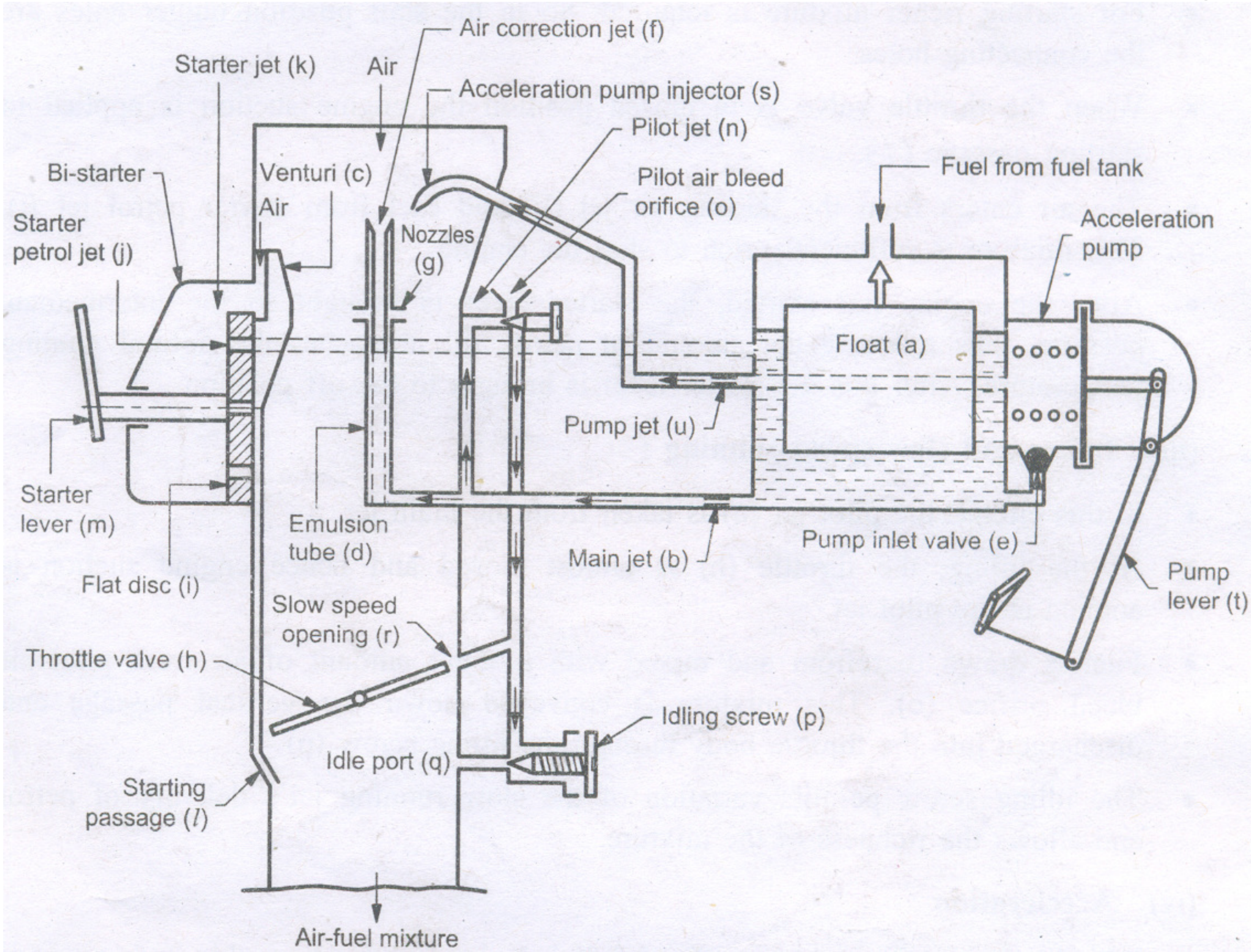


Fig.1. Solex Carburetor

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(iii) Idling and slow speed running

In this circuit, the pilot jet (n) is taken from the main jet. At the idling, the throttle (h) is almost closed and hence engine suction is applied at the pilot jet. Fuel is drawn there from and mixed with a small amount of air from pilot air bleed orifice (o). This mixture is conveyed down the vertical passage and discharged into the throttle body through the idling screw (p). The idling screw permits variation of the slow running jet's delivery of petrol and allows the richness of the mixture. .

(iv) Acceleration

In order to, provide extra quantity of fuel during acceleration, this carburettor is provided with a diaphragm pump system. When accelerator pedal is pressed for acceleration, the pump lever (t) connected to it is also pressed. Due to this movement, the fuel is compressed and it flows through pump jet (u) and accelerator pump injector (s) to mixing chamber. When the force on lever is removed; the diaphragm retains its original position due to spring. Due to this movement of diaphragm a suction is created, thus opening the pump valve (e) and admitting the fresh fuel into the pump.

2) Carter Carburetor

A sketch of an American make Carter carburetor is shown in Fig. 2. It is a down-draught type carburettor. Petrol fuel enters into the conventional type of float chamber (1). The air enters from the top through the choke valve (12) which is kept fully open during the normal running of the engine.

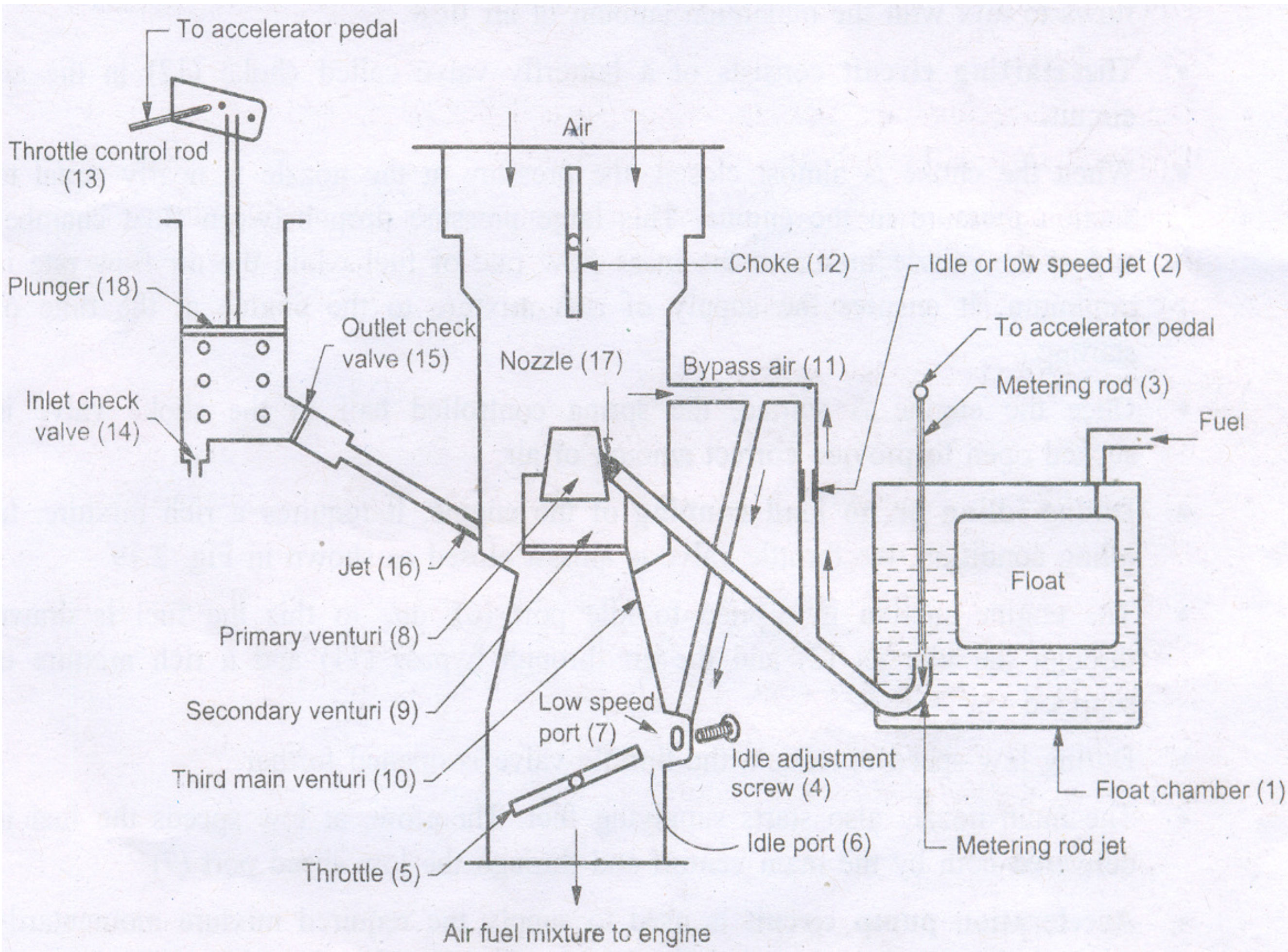


Fig. 2. Carter Carburetor

Carter carburetor has three venturies, the smallest venturi called primary venturi (8) lies above the fuel level in the float chamber and the other two called secondary (9) and third (10) main venturies lie below the fuel level as shown in Fig. 2. The suction in primary venturi is adequate to draw petrol even at low speeds. Fuel from float chamber enters the venturi through the nozzle (17) at an angle in upward direction against the air stream securing an even flow of finally divided atomized fuel. The fuel and air mixture descends through the secondary venturi which is surrounded by a blanket of air stream; finally, it passes through the main venturi to the engine cylinder. Use of multiple venturi ensures that the fuel reaching the engine is in atomized form even at very slow speeds causing the smooth running of the engine.

(i) Fuel circuit: It consists of a metering rod (3) actuated by a mechanism connected to the main throttle. The metering rod has two or more steps of diameter. The difference in area of metering rod jet and metering rod controls the amount of fuel drawn into the engine. Corresponding to maximum throttle opening at maximum speed, the smallest section of the metering rod is in the jet, therefore, the maximum quantity of fuel flows to mix with the maximum amount of air flow.

(ii) Starting circuit: It consists of a butterfly valve called choke (12) in the air circuit. When the choke is almost closed, the pressure at the nozzle is nearly equal to suction pressure in the engine. This large pressure drop between float chamber and at the nozzle increases the mass flow rate of fuel while the air flow rate is minimum. It ensures the supply of rich mixture to the engine at the time of starting. Once the engine is started, the spring controlled half of the choke valve is sucked open to provide correct amount of air.

(iii) Idling or no load running: Idling or no load running of the engine, it requires a rich mixture. In idling condition, the throttle valve is almost closed as shown in Fig. 2. The engine suction is applied to idle port (6), due to this the fuel is drawn through the idle jet (2) and the air through bypass (11) and a rich mixture is supplied. During low speed operation, the throttle valve is opened further. The main nozzle also starts supplying fuel. Therefore, at low speeds the fuel is delivered both by the main venturi and through the low speed port (7).

(iv) Acceleration pump circuit: It is used to supply the required mixture momentarily when the engine is to be accelerated by opening the throttle valve suddenly. Pump consists of a plunger (18), inlet check valve (14) and outlet check valve (15). Plunger is connected to accelerator pedal by throttle control rod (13). When the engine is suddenly accelerated, the plunger moves down and forces the required extra fuel through jet (16) into the choke tube. When the accelerator pedal is released, the plunger moves up and draws the fuel from float chamber into the pump through inlet check valve for the next operation.

3) S.U. Carburetor

Generally the carburetors are choke type e.g. Solex, Carter and Zenith carburetors. Whereas, the S.U. Carburettor completely differs from these since it is a constant vacuum or depression type of carburettor with automatically variable choke. Fig. 3. represents the sketch of a horizontal type of S.U. Carburettor. It consists of a piston (1) which is always loaded by a helical spring, a piston rod (2), the piston rod guide (3) and the float chamber (10) of a conventional carburettor.

The lower end of the piston rod carries a taper jet needle (7) which is inserted into the main jet (9). The flat portion above the piston is called suction disc (12). The piston assembly moves up and down along with taper needle by operating a lever from the dash board. The movement of the piston controls the air passages (5). The portion above the suction disc is called the suction chamber (4) which connects the air passage by means of suction air entrance (11). The lower portion of the suction disc is connected by an air rectifier hole (8) to the atmospheric air. The air passage has a butterfly type throttle valve (6). The movement of piston controls the air-fuel ratio for all the operating conditions of the engine. The pressure in the suction chamber depends upon the throttle opening while the pressure below the suction disc is atmospheric. The position of the piston depends upon its weight and the vacuum existing (according to throttle opening) in the suction chamber, therefore, a variable cross-sectional area of air passage is obtained depending upon the piston position.

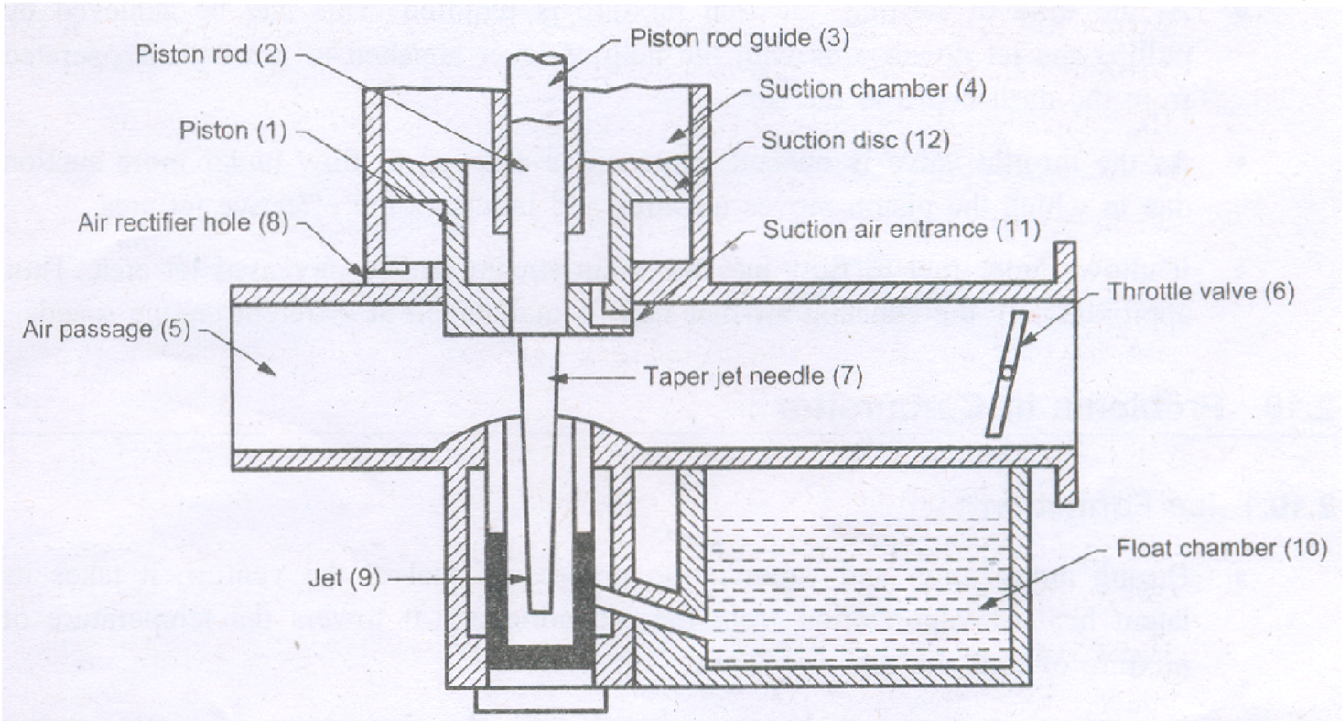


Fig. 3. S. U. Carburetor

The movement of piston controls the air-fuel ratio for all the operating conditions of the engine. The pressure in the suction chamber depends upon the throttle opening while the pressure below the suction disc is atmospheric. The position of the piston depends upon its weight and the vacuum existing (according to throttle opening) in the suction chamber, therefore, a variable cross-sectional area of air passage is obtained depending upon the piston position.

This carburetor has only one jet and no separate idling jet or accelerating pump is required. At the time of starting, the rich mixture is required. This can be achieved by pulling the jet downwards with the help of lever attached to it which is operated from the dash board in the car. As the throttle valve is opened, more air is allowed to flow under more suction due to which the piston moves upwards and increases the effective jet area. It allows more fuel to flow into the main stream due to increased jet area. Thus approximately the constant air-fuel ratio is maintained at different engine speeds.

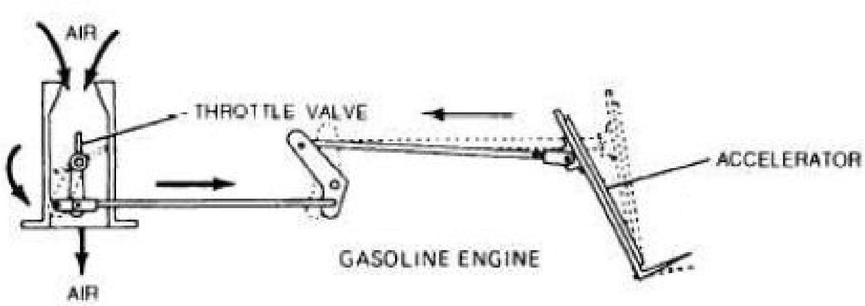


Fig.4. Petrol engine acceleration operation

CONCLUSION: S.I engine has carburetor as a device for atomizing & vaporizing fuel and homogeneously mixing with air in varying proportion as per the engine dynamic requirements.

4) MORSE TEST

AIM:- To find the indicated power (IP) on Multi-Cylinder Petrol Engine by Morse test.

APPARATUS: - Multi-Cylinder Petrol Engine Test Rig, Stop Watch, Hand Gloves and Digital Tachometer

THEORY:-

The purpose of Morse Test is to obtain the approximate Indicated Power of a Multi-cylinder Engine. It consists of running the engine against a dynamometer at a particular speed, cutting out the firing of each cylinder in turn and noting the fall in BP each time while **maintaining the speed constant**. When one cylinder is cut off, power developed is reduced and speed of engine falls.

Accordingly the load on the dynamometer is adjusted so as to restore the engine speed. This is done to maintain FP constant, which is considered to be independent of the load and proportional to the engine speed. The observed difference in BP between all cylinders firing and with one cylinder cut off is the IP of the cut off cylinder. Summation of IP of all the cylinders would then give the total IP of the engine under test. The schematic Morse test set up is as shown in Fig.1.

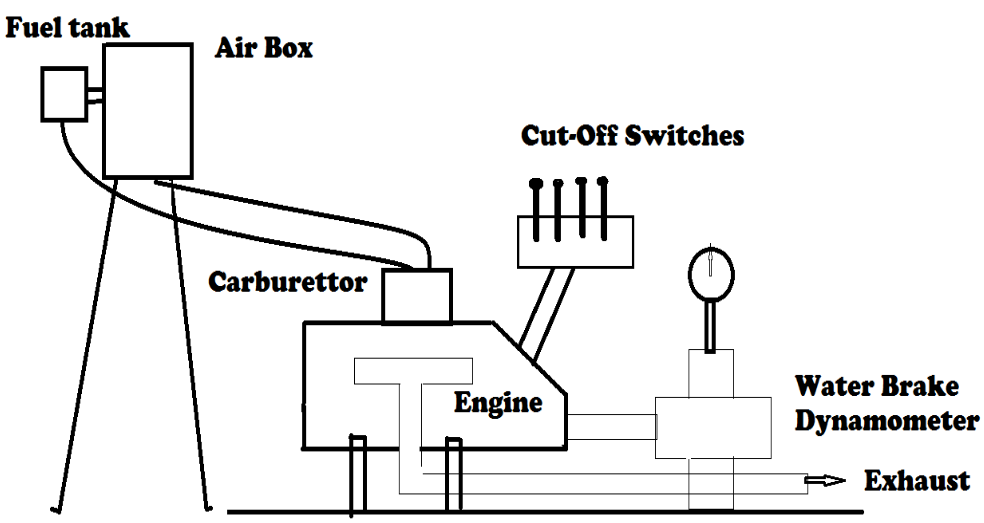


Fig. 1 Schematic of Morse Test setup of 4 stroke, 4 cylinder petrol engine

FORMULAE:-

(i) Brake Power, $BP = \frac{WN}{C}$ ....(kW)

Where, W = Load on the Dynamometer= mg (N),
N = Number of revolutions of the Engine, (rpm) and
C = Dynamometer Constant

(ii) Indicated Power (IP) of each Cylinders:

$IP_1 = (BP_T - BP_{2,3,4})$ KW
$IP_2 = (BP_T - BP_{1,3,4})$ KW
$IP_3 = (BP_T - BP_{1,2,4})$ KW
$IP_4 = (BP_T - BP_{1,2,3})$ KW

(iii) Total IP of the Engine, $IP_T = (IP_1 + IP_2 + IP_3 + IP_4)$ KW

(iv) Mechanical Efficiency, $\eta_{mechanical} = BP_T / IP_T$

PROCEDURE:-

1. Before starting the engine check the fuel supply, lubrication oil, and availability of cooling water.
2. Set the dynamometer to zero load.
3. Run the engine till it attains the working temperature and steady state condition. Adjust the dynamometer load to obtain the desired engine speed. Record this engine speed and dynamometer reading for the BP calculation.
4. Now cut off one cylinder. Short-circuiting its spark plug can do this.
5. Reduce the dynamometer load so as to restore the engine speed as at step 3 . Record the dynamometer reading for BP calculation.
6. Connect the cut off cylinder and run the engine on all cylinders for a short time. This is necessary for the steady state conditions.
7. Repeat steps 4, 5, and 6 for other remaining cylinders turn by turn and record the dynamometer readings for each cylinder.
8. Bring the dynamometer load to zero, disengage the dynamometer and stop the engine.
9. Do the necessary calculations.

OBSERVATIONS:-

Engine Speed, N = rpm

No. of Cylinders, n = 4

Calorific Value of Fuel, C.V. = 42,000 KJ/Kg

OBSERVATION TABLE :-

Sl. No.	Cylinders Working	Dynamometer Reading = Reading in kg x 9.81 (N)	Brake Power, BP (KW)	I.P. of the cut off cylinder, (KW)
1.	1-2-3-4		BP_T =	
2.	2-3-4		$BP_{2,3,4}$ =	IP_1 =
3.	1-3-4		$BP_{1,3,4}$ =	IP_2 =
4.	1-2-4		$BP_{1,2,4}$ =	IP_3 =
5.	1-2-3		$BP_{1,2,3}$ =	IP_4 =
				IP_T =

RESULT:- Total IP of the Multi-Cylinder Petrol Engine by Morse Test, IP_T = KW

CONCLUSION: - Morse-Test at constant speed is applicable for multicylinder engine to determine Indicated Power of each cylinder on the assumption that same Friction Power of firing and non-firing engine cylinder.

5) EXHAUST GAS ANALYSIS (SI Engine)

EXPERIMENT TITLE:

Study of emission norms for SI Engine (using exhaust gas analyzer).

AIM:

To study the emission norms for SI engine pollutants (using exhaust gas analyzer).

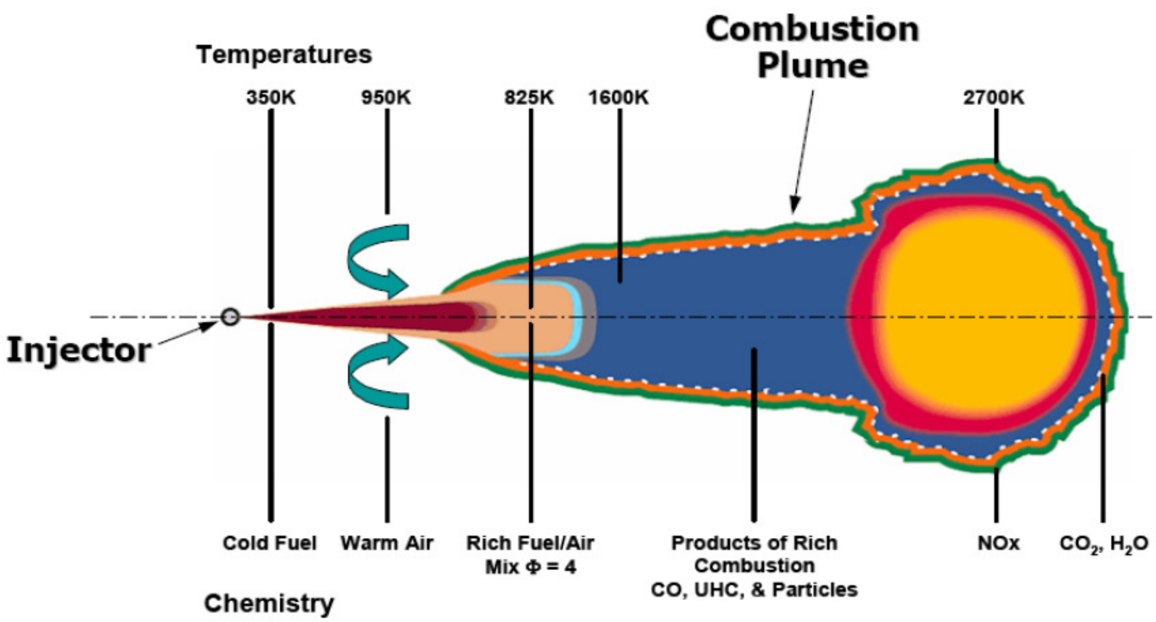
PRIOR KNOWLEDGE:

Emissions from SI, their effect on human being and environment, methods to reduce emission.

THEORY:

PUC Test

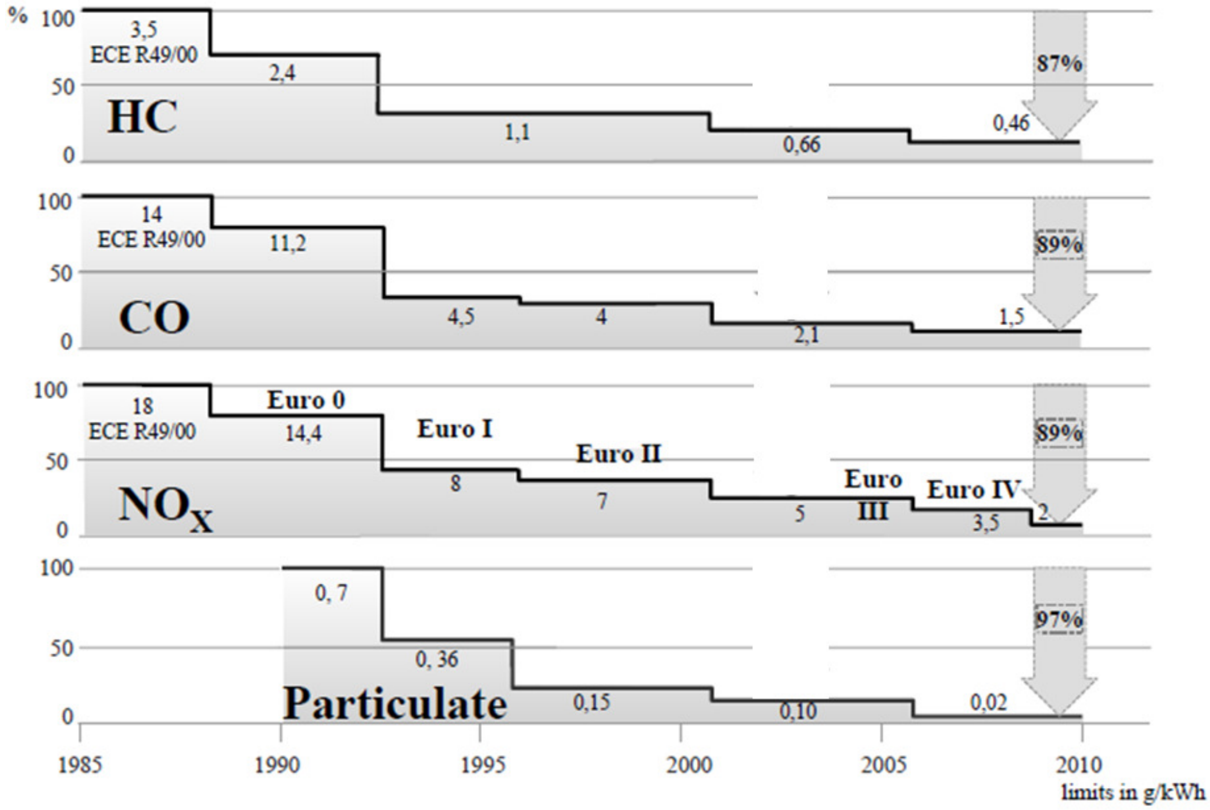
PUC test is carried out on SI engines to measure following exhaust gas pollutants. Due to increase in automobile pollution all over the country, the Government has made it mandatory for all vehicles to measure exhaust gas emission and obtain PUC certificate. This test is carried out to measure CO, CO_2, HC, NOx & PM (Particulate Matter).



Diesel flame with temperatures and chemistry

Source: Charlton S. J., "US Perspective on Engine Development"

SAE Heavy Duty Diesel Emissions Control Symposium, 2007



Evolution of Euro Norms 1985 to 2010 continuing limits g/kWh

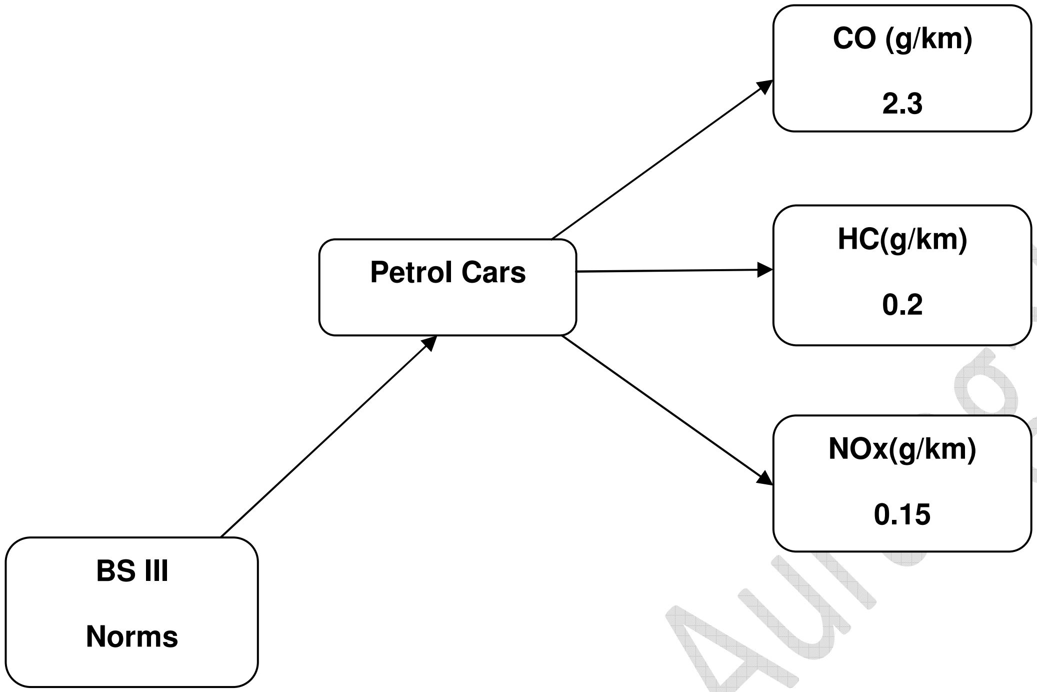
Bharat Stage III Emission norms for two wheeler (Petrol)

The norms for Bharat Stage III are

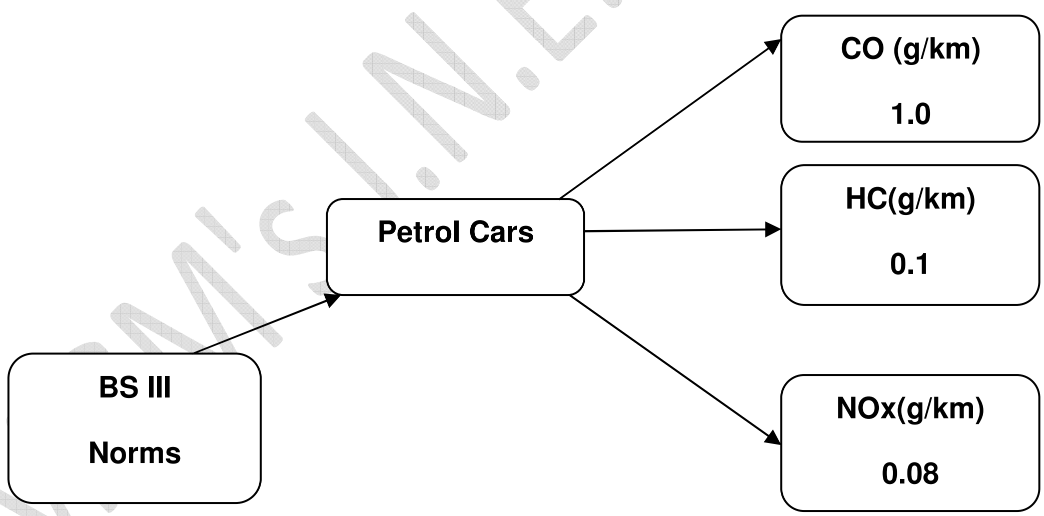
BS III Norms

- **CO (gm/km): 1.0**
- **HC + NOx (gm/km): 1.0**

Bharat Stage III Emission norms for Passenger Cars



Bharat Stage IV Emission norms for Passenger Cars



CONCLUSION: - The engine emissions norms for BS-III and BS-IV in India are studied for SI engine.

Specifications of Exhaust Gas Analyzer

1. Name of the instrument ………….
2. Make and Model No……………
3. Carbon Monoxide (CO%) measurement
   Range ………………… to …………………..
4. Carbon Dioxide (CO_2%) measurement
   Range ………………… to …………………..
5. Hydro Carbon (HC) measurement
   Range ………………… to …………………..
6. Nitrous Oxide (NO_x) measurement
   Range ………………… to …………………..

Procedure:

1. Connect the power supply cable and exhaust gas probe to the analyzer.
2. Clamp the power supply cable to the vehicle battery. Switch on the analyzer and allow it to warm up for 15 minutes.
3. After warming up, calibration is automatically carried out and analyzer is ready for measurement.
4. Start the engine and let it warm up at its idling speed.
5. Exhaust gas nose pipe is connected to the pump of analyzer through which exhaust enters into the machine for analyze.
6. Insert exhaust gas probe (nozzle) into the exhaust muffler tail pipe. Wait for few minutes.
7. Set CO and HC value to zero by using the knob.
8. Switch on the pump. Operate the gas selector switch and put it to CO and HC mode.
9. Note the readings of CO and HC. Take print out.
10. Switch off the machine and remove the pipe from the exhaust muffler of the vehicle.
11. Take additional readings by accelerating.

6) EXHAUST GAS ANALYSIS (CI Engine)

EXPERIMENT TITLE:

Study of emission norms for CI Engine (using exhaust gas analyzer).

AIM:

To study the emission norms for CI engine pollutants (using exhaust gas analyzer).

PRIOR KNOWLEDGE:

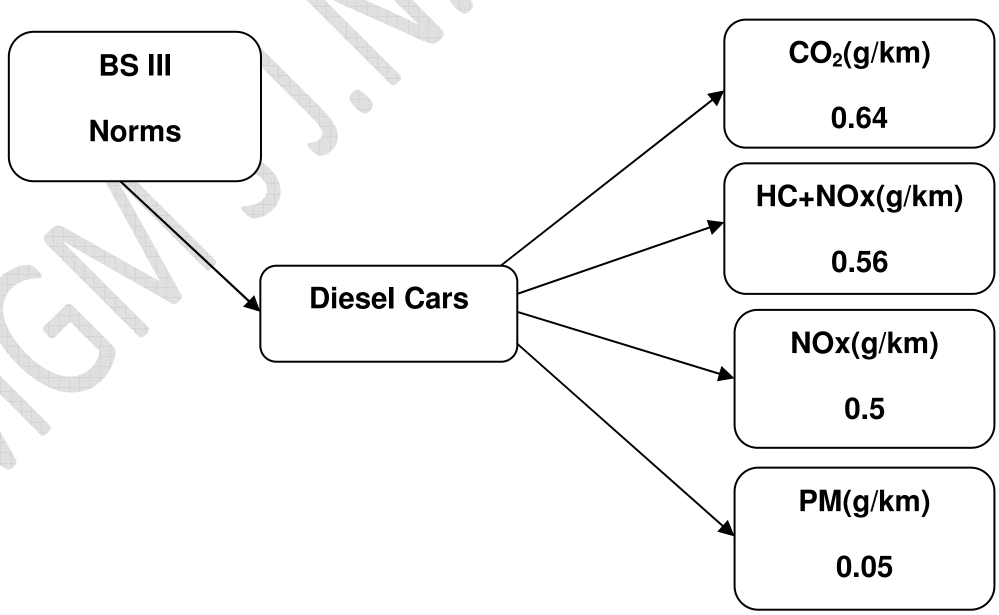
Emissions from SI, their effect on human being and environment, methods to reduce emission.

THEORY:

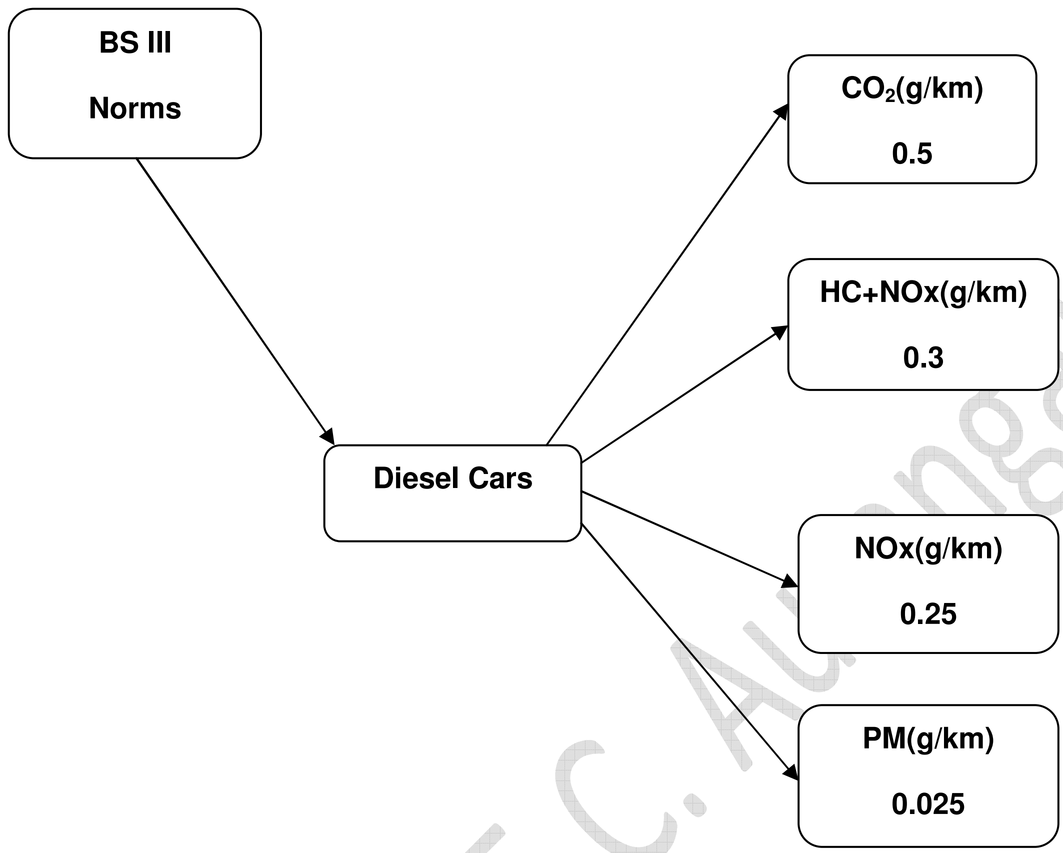
PUC Test

PUC test is carried out on SI engines to measure following exhaust gas pollutants. Due to increase in automobile pollution all over the country, the Government has made it mandatory for all vehicles to measure exhaust gas emission and obtain PUC certificate. This test is carried out to measure CO, CO_2, HC, NOx & PM (Particulate Matter).

Bharat Stage III Emission norms for Passenger Cars



Bharat Stage IV Emission norms for Passenger Cars



CONCLUSION: - The engine emissions norms for BS-III and BS-IV in India are studied for CI engine.

Specifications of Exhaust Gas Analyzer

1. Name of the instrument ………….
2. Make and Model No……………
3. Carbon Monoxide (CO%) measurement

   Range ………………… to …………………..
4. Carbon Dioxide (CO_2%) measurement

   Range ………………… to …………………..
5. Hydro Carbon (HC) measurement

   Range ………………… to …………………..
6. Nitrous Oxide (NO_x) measurement

   Range ………………… to …………………..

Procedure:

12. Connect the power supply cable and exhaust gas probe to the analyzer.
13. Clamp the power supply cable to the vehicle battery. Switch on the analyzer and allow it to warm up for 15 minutes.
14. After warming up, calibration is automatically carried out and analyzer is ready for measurement.
15. Start the engine and let it warm up at its idling speed.
16. Exhaust gas nose pipe is connected to the pump of analyzer through which exhaust enters into the machine for analyze.
17. Insert exhaust gas probe (nozzle) into the exhaust muffler tail pipe. Wait for few minutes.
18. Set CO and HC value to zero by using the knob.
19. Switch on the pump. Operate the gas selector switch and put it to CO and HC mode.
20. Note the readings of CO and HC. Take print out.
21. Switch off the machine and remove the pipe from the exhaust muffler of the vehicle.
22. Take additional readings by accelerating..

7) HEAT BALANCE SHEET ON SINGLE CYLINDER ENGINE

AIM:- To prepare heat balance sheet on Single-Cylinder Diesel Engine.

APPARATUS USED :- Single-Cylinder Diesel Engine (Constant Speed) Test Rig, Stop Watch and Digital Tachometer, Measuring Flask, Diesel Fuel etc

THEORY:-

The thermal energy produced by the combustion of fuel in an engine is not completely utilized for the production of the mechanical power. The thermal efficiency of I.C engines is about 33 %. Of the available heat energy in the fuel, about 1/3 is lost through the exhaust system, and 1/3 is absorbed and dissipated by the cooling system.

It is the purpose of heat balance sheet to know the heat energy distribution, that is, how and where the input energy from the fuel is is distributed.

The heat balance sheet of an Internal Combustion Engine includes the following heat distributions:

a. Heat energy available from the fuel brunt.
b. Heat energy equivalent to output brake power.
c. Heat energy lost to engine cooling water.
d. Heat energy carried away by the exhaust gases.
e. Unaccounted heat energy loss.

FORMULAE USED :-

(i) Torque, $\mathbf{T = 9.81 \times W \times R_{Effective}}$ N-m.

Where $R_{Effective} = (D + d)/2$ *or* $(D + t_{Belt})/2$ *m, and* $W\ (Load) = (S_1 - S_2)$ *Kg,*

(ii) Brake Power, $\mathbf{BP = (2\pi N T) / (60{,}000)}$ kW;

Where *N = Engine Revolutions, rpm,* *T = Brake Torque, N-m,*

(iii) Fuel Consumption, $\mathbf{m_f = (50\ ml \times 10^{-6} \times \rho_{Fuel}) / (t)}$ Kg/Sec

⇨ 1 ml = 10^{-3} liters, and 1000 liters = 1 m^3

⇨ 1 ml = 10^{-6} m^3

(iv) Heat energy available from the fuel brunt, $\mathbf{Q_S = m_f \times C.V. \times 3600}$ kJ/hr

(v) Heat energy equivalent to output brake power, $\mathbf{Q_{BP} = BP \times 3600}$ kJ/hr

(vi) Heat energy lost to engine cooling water, $\mathbf{Q_{CW} = m_W \times C_W (t_{WO} - t_{Wi}) \times 3600}$ kJ/hr

(vii) Heat energy carried away by the exhaust gases, $\mathbf{Q_{EG} = m_{fg} \times C_{Pfg} (t_{fg} - t_{room\_air}) \times 3600}$ kJ/hr

Where $m_{fg} = (m_f + m_{air})$ *kg/s, and* $m_{air} = C_d\, A_o\, \sqrt{2\, \rho_{air} (g\, \Delta h\, \rho_{hg})}$ kg/s

Where C_d *(Co-efficient of Discharge) = 0.6,*

$\rho_{air} = (P_a \times 10^2) / (R \times T_a)$ *kg/* m^3

Where, A_O *(Area of Orifice)* $= (\pi\, d_o^2)/4$ m^2 , $P_1 = 1.01325$ *b ar,* $R = 0.287$ *kJ/(kg K),*

$T_a = (t_a + 273)$ *K,* t_a *= Ambient Temperature* ^oC

(viii) Unaccounted heat energy loss, $\mathbf{Q_{Unaccounted} = Q_S - \{Q_{BP} + Q_{CW} + Q_{EG}\}}$ kJ/hr

<u>PROCEDURE</u> :-

1. Before starting the engine check the fuel supply, lubrication oil, and availability of cooling water.
2. Set the dynamometer to zero load and run the engine till it attain the working temperature and steady state condition.
3. Note down the fuel consumption rate, Engine cooling water flow rate, inlet and outlet temperature of the engine cooling water, Exhaust gases cooling water flow rate, Air flow rate, and Air inlet temperature.
4. Set the dynamometer to 20 % of the full load, till it attains the steady state condition. Note down the fuel consumption rate, Engine cooling water flow rate, inlet and outlet temperature of the engine cooling water, Exhaust gases cooling water flow rate, Air flow rate, and Air inlet temperature.
5. Repeat the experiment at 40 %, 60 %, and 80 % of the full load at constant speed.
6. Disengage the dynamometer and stop the engine.
7. Do the necessary calculation and prepare the heat balance sheet.

OBSERVATIONS:-

Engine Speed, N	= 1500	rpm
No. of Cylinders, n	= Single	
Calorific Value of Fuel, C.V.	= 38,000	kJ/kg
Specific Heat of Water, C_w	= 4.187	kJ/kg . K
Specific Heat of Exhaust Flue Gases, C_{fg}	= 2.1	kJ/kg . K
Gas Constant, R	= 0.287	kJ/kg . K
Ambient Temperature, t_a	=	^oC
Atmospheric Pressure, P_a	= 1.01325	bar
Orifice Diameter, d_o	= 25×10^{-3}	m
Co-efficient of Discharge, C_d	= 0.6	
Density of fuel (Diesel), ρ_{Fuel}	= 810 to 910	kg/m^3
Density of Water, ρ_{water}	= 1,000	kg/m^3
Brake Drum Diameter, D	= 181.5×10^{-3}	m
Rope Diameter, d	=	m
Or Belt thickness, t_{Belt}	= 5.5×10^{-3}	m

OBSERVATION TABLE :-

Sr. No.	Engine Speed, N (rpm)	Dynamometer Spring Balance		Time taken for 50 ml fuel, t (sec.)	Engine Cooling Water Flow Rate,	Engine Cooling Water		Exhaust Gas Temperature , tfg (^{o} C)	Manometer Reading, Δh (m)
		S_1 (kg)	S_2 (kg)			t_{wi} (^{o}C)	t_{wo} (^{o}C)		
1.	1500								
2.	1500								
3.	1500								
4.	1500								

CALCULATIONS:-

RESULT TABLE :-

Sr. No.	Engine Speed, N (rpm)	Brake Power, BP (KW)	Fuel Consumption, m_f (Kg/hr)	Air Flow Rate, m_{air} (Kg/hr)	Exhaust Gas Flow Rate, m_{fg} (Kg/hr)
1.	1500				
2.	1500				
3.	1500				
4.	1500				

HEAT BALANCE SHEET :-

Heat Energy	kJ/hr	%	Heat Energy Consumed	kJ/hr	%
Heat energy available from the fuel burnt			(a) Heat energy equivalent to output		
			(b) Heat energy lost to engine cooling		
			(c) Heat energy carried away by the exhaust		
			(d) Unaccounted heat Energy Loss.		
Total	____	**100 %**	**Total**	_________	**100 %**

RESULT:- Heat utilized for brake power is .... % and rest is lost into the ambient by the engine

CONCLUSION: - The engine heat lost has impact on the ambient air temperature rise and 20-30 % is actually utilized for the Brake Power and there is need to appropriate methods for the emissions control and reduced direct heat loss into the ambient.