EXPERIMENT 1: STUDY OF IC ENGINES

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Basic Definitions

Engine: A device that converts thermal energy to mechanical energy. The thermal energy is produced from the combustion of hydrocarbons in presence of oxygen in exothermic reaction commonly called Combustion Reaction.

The Second law of thermodynamics is the basis of all types of heat engine.

The Second law states that "Heat flows from regions of higher temperature to regions of lower temperature, but it will not flow natural the other way".

Based on the location of combustion engines are of two types

- External Combustion Engine: Product of combustion is not the working fluid. Combustion occurs outside of the cylinder. Example: Steam Engine, Sterling Engine
- Internal Combustion Engine: Products of combustion works as the working fluid and the combustion takes place inside the cylinder. Example: Petrol Engine, Diesel engines, Biofuel engine and so on

Our discussion is based on the internal combustion engine which itself can be of two type

- Reciprocating: Pistons transfer power to the crankshaft via reciprocating motion. Example: Petrol, Diesel engines
- Rotary: Pistons transfers power to the crankshaft via rotary motion. Example: Rotary engine

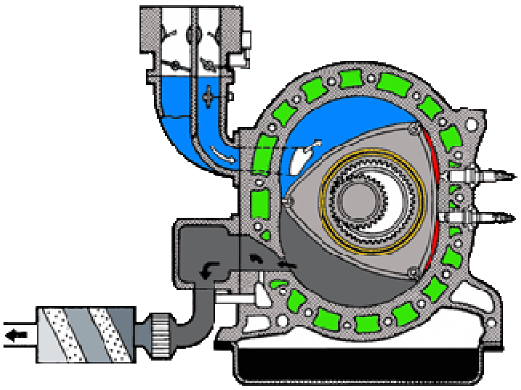


Fig: Rotray Engine (Wankel Engine)

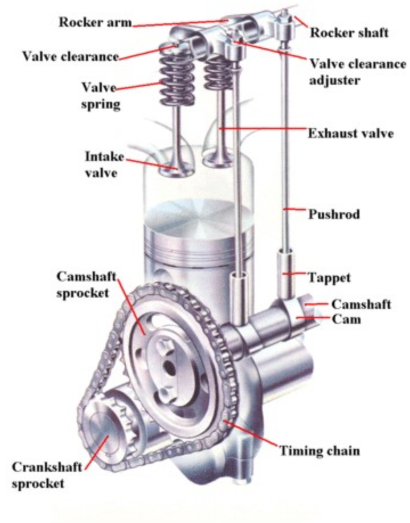


Fig: Reciprocating Piston Heat Engine

Basic Engine Terminology

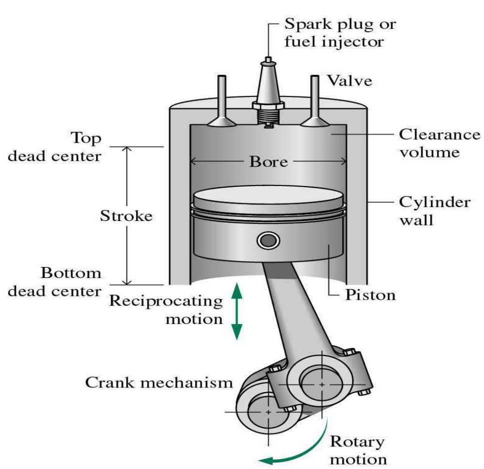


Fig: Simplified image of a cylinder showing various terms used to describe an IC engine

1. **Bore:** The nominal inside diameter of the engine cylinder is called bore.
2. **Top Dead Centre (T.D.C):** Position of the crankshaft when the piston is at the topmost position.
3. **Bottom Dead Centre (B.D.C):** Position of the crankshaft when the piston is at the bottommost position.
4. **Stroke (L):** The distance travelled by the piston from the TDC to BDC is called the stroke. It is the maximum distance that the piston can travel in the cylinder. **It is equal to twice the radius of the crank**.
5. **Clearance Volume:** Extra headroom above the piston head from the when it is at the Top Dead Centre. It is denoted as Vc
6. **Piston Displacement:** Volume covered in between TDC and BDC of piston displacement. This is the **combustion chamber** of the heat engine.
7. **Total Piston Displacement or Engine Capacity:** Capacity of engine found by multiplying the number of pistons with Piston Displacement.
8. **Swept Volume:** It is the volume which is swept by the piston. The difference between total volume and clearance volume is knows as the swept volume.
9. **Compression ratio:** The ratio of maximum volume to minimum volume of cylinder is known as the compression ratio. It is between 8-12 for SI engine and between 12-24 for CI engine. Mathematically it is defined as
   - r=(Vs + Vc) / Vc or (Total volume / Clearance Volume)
10. **Mean Effective Pressure:** The average pressure acting upon the piston is known as mean effective pressure. It is given by the ratio of the work done by the engine to the total volume of the engine.
11. **Indicated Power (IP):** The power developed within the engine cylinders.
12. **Brake Power (BP):** The actual power delivered at the crankshaft. It is measured with a dynamometer and is expressed in kilowatts. It is always less than Indicated power due to frictional and pumping losses in cylinders and the reciprocating mechanism.
13. **Engine Torque:** It is the force of rotation acting about the crankshaft axis at any given instant.
    - Engine with high brake power and low torque -> Vehicle is easy to accelerate but high speed is difficult to maintain.
    - Engine with low brake power and high torque -> Vehicle is difficult to accelerate but high speed is easy to maintain.

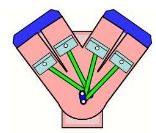
Engine Classification

Heat engine can be classified by many categories. They are

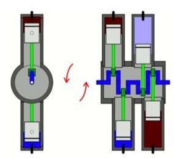
i. Number of cylinders : V4, V6 etc engines
ii. Arrangement of Cylinder: Inline, V-type, Opposed.
iii. Arrangement of Valves: Overhead camshaft, pushrod camshaft, valveless.
iv. Type of cooling: Water cooled, Air cooled
v. Number of strokes per cycle: 2-stroke, 4-stroke
vi. Type of fuel used: Gasoline, Diesel, Ethanol, CNG
vii. Method of Ignition: Spark Ignition, Self or Compression Ignition.
viii. Firing Order: For four cylinder
   - 1-2-4-3
   - 1-3-4-2

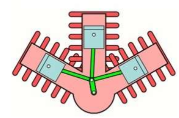
Arrangement of Cylinders

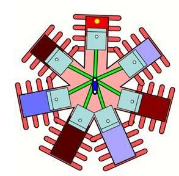

Inline Vertical Engine


V-Type Engine


Horizontal Engine


Opposed Cylinder Engine


W-Type Engine


Radial Engine

Firing Order

If in multicylinder engine various cylinders are made to fire one after other, interference between adjacent cylinders would occur, since these may have overlapping periods which prevents proper distribution o fresh charge in the inlet manifold. Likewise, overlapping periods of the exhaust periods in case of adjacent or nearby cylinders would increase exhaust back-pressure which may prevent the combustion products escaping from the cylinders. Therefore to obtain best engine performance in multi cylinder engines, the occurrence of power strokes in various cylinders is not kept directly one after the other. Proper firing order gives the following advantages

- A proper firing order reduces engine vibrations
- Maintains engine balancing
- Secures an even flow of power

Homogeneous Charge Compression Engine (HCCI)

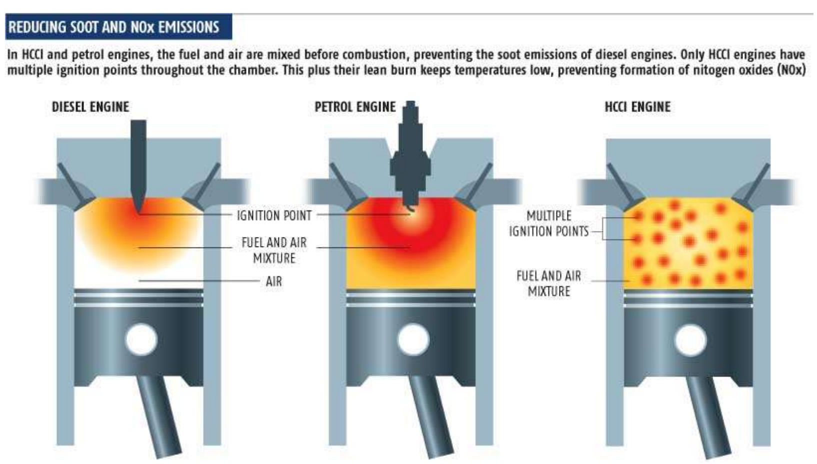
This is an internal combustion engine in which well-mixed fuel and oxidizer (air) are compressed to point of auto-ignition. Thus it has the characteristics of combustion of both the spark ignition and compression ignition engine.

HCCI engine employs a homogenous *i.e.* well-mixed and a very lean (high proportion of air to fuel mixture which is compressed until it ignites automatically i.e. without any spark. Unlike (SI or CI) engines, here the ignition occurs at several places at a time, which makes the air/fuel mixture burn almost spontaneously, without any initiator of combustion and any flame propagation, which eliminates heterogeneous air/fuel mixture regions.

Advantages of HCCI engine are as follows

- Higher efficiency compared to S.I engines due to lean combustion and no throttling of the charge.
- Lower emissions due to homogeneous mixing charge.

Comparison of combustion in various types of I.C engine



Comparison of Petrol and Diesel Engine

I. In Petrol engine (Spark Ignition Engine) mixture of air and petrol is charged into the cylinder and compressed but in the case of Diesel engine (Compression Ignition) only the air is compressed.

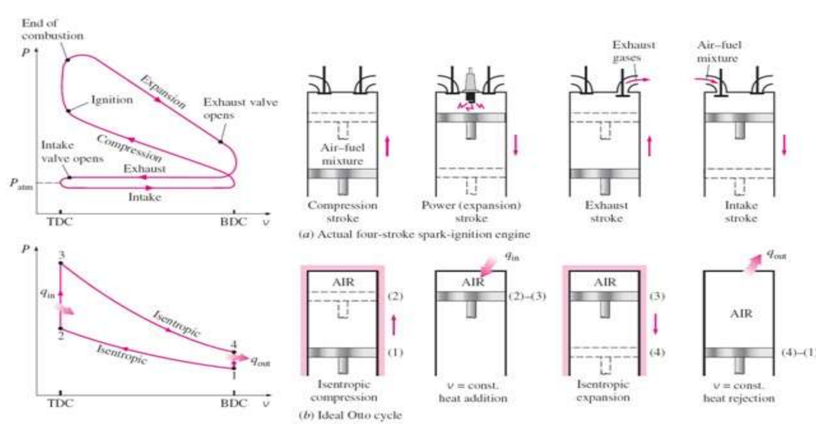
II. For SI engine compression ratio is in between 8-12 whereas the compression ratio for CI engine is between 12-24. The result is higher thermal efficiency and fuel savings in diesel engine when compared to a SI engine of similar specifications.

III. No throttle valve is present in the passage of diesel engine which results in higher volumetric efficiency. Diesel is also cheaper than petrol

IV. There is no spark plug, carburetor, etc parts in a CI engine. CI engines typically have common rail injection with modern ones having the capability to control how much fuel goes into each cylinder from the common injection rail very accurately.

V. SI engines have higher accelerating power whilst CI engines are typically used for its high torque available at different engine operating conditions.

Petrol Cycle / Otto Cycle



Diesel Cycle

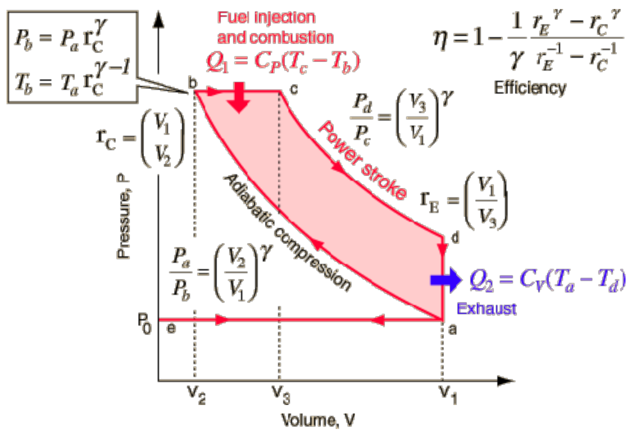


Fig: Ideal Diesel Cycle

Atkinson Cycle

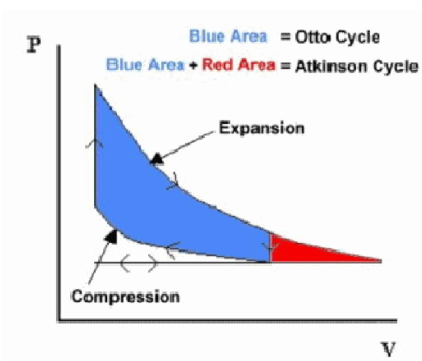


Fig: P-V diagram of Atkinson cycle

This system was developed by British Engineer James Atkinson around the same time as otto cycle.
The primary difference between the two cycle is that in Atkinson cycle the compression stroke is shorter than expansion stroke. *This means that the compression ratio is lower than the expansion ratio.*

Advantages of Atkinson Cycle Engine:

1. Decreased compression ratio made the engine less prone to detonation.
2. Increased expansion ratio meant longer power stroke and reduced heat wasted in exhaust, leading to greater engine efficiency.
3. Due to special linkage all the *four strokes are completed in single crankshaft rotation.* This allows to directly control the valve timing from the crankshaft without the need for a separate camshaft.

How Engine Operates

In a four stroke SI engine power is produced in a four stage operation. They are

1. Intake Stroke: Piston moves downwards creating a vacuum inside the combustion chamber. When the intake valve opens, atmospheric pressure forces the air-fuel mixture inside the combustion chamber.
2. Compression Stroke: Intake valve is closed, piston moves upwards compressing the air-fuel mixture to around 1/8th of its original volume.
3. Power Stroke: The ignition system provides the spark in the spark plug. As a result the compressed fuel mixture ignites with a large explosion. The resulting explosion causes sudden expansion of the air-fuel mixture which forces the piston to move downward creating the power necessary to drive the wheel of the vehicle.
4. Exhaust Stroke: The exhaust valve opens and the piston moves upwards. This upward movement forces the burnt gases out of the cylinder.

➢ We see that for two complete rotation of the crankshaft power is produced once.

Four Stroke Petrol Engine Operation

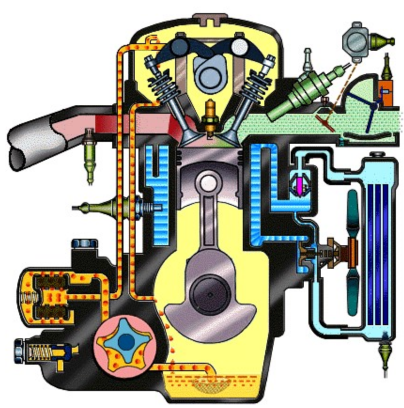
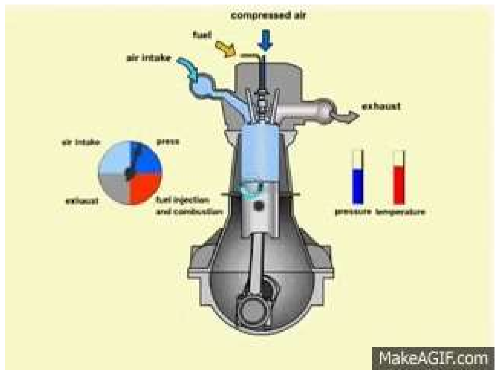


Fig: Animation showing the four strokes in a typical heat engine

Four Stroke Diesel Engine Operation



Same as that of four stroke SI engine but at the compression stroke air fuel mixture ignites by self ignition of the diesel fuel. In Diesel engines when the air is compressed to such a large extent it's temperature rises well above 600 degree Celsius. This temperature is above the self ignition temperature of diesel fuel which when injected into the compressed air explodes to create the power to drive the crankshaft.

Intake And Exhaust Valve

Engine valves are located in the cylinder head. Their main function is to let air in and out of the cylinders. That air is used to help ignite the fuel which will drive the pistons up and down.

Intake valves lets air in and exhaust valves expels burnt gas to go out of the cylinder.

Intake Valves are always ***larger*** *than Exhaust valve* for the following reasons

a) The more air it is possible to charge inside the cylinder the better the combustion and power output will be. Better the combustion greater the volumetric efficiency which translates to smoother power output and low fuel consumption. At higher speed more air is needed and a smaller intake valve would hinder the passage of needed air in these engine condition which would cause the power in the car to diminish and loose speed.

b) During intake stroke, the pressure difference between the inside of the cylinder and atmospheric pressure is very low. Hence a wider inlet valve allows for more air intake and *scavenging*. As opposed to this notion the exhaust valve needs not to be larger since during exhaust stroke, the pressure difference is very high which facilitates the quick expulsion of burnt gas from the combustion chamber.

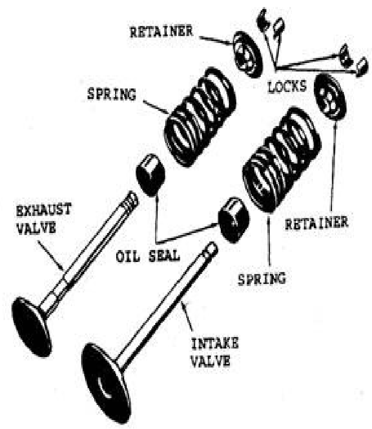


Fig: Intake and Exhaust valve with important parts

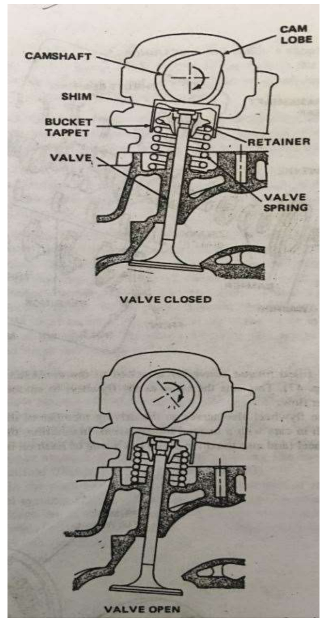
Valve Action

The action of valve operation in a heat engine is achieved by the *valve train.*

Valve train is a series of parts that open and close the valves. The action starts at the cam shaft. The crankshaft drives the camshaft through gears, sprockets and chains or sprocket and a toothed timing belt. Most camshaft have a cam for each valve in the engine. Each cam is a round collar with a high spot or lobe.

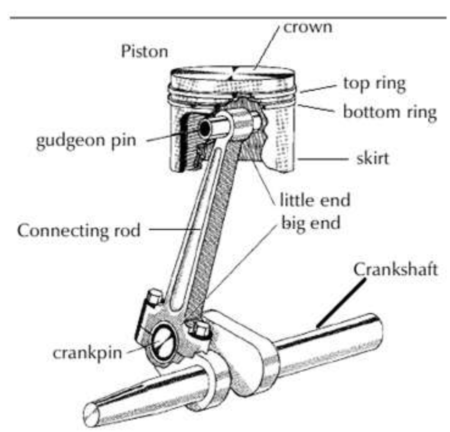
Figure 2 (next slide) shows the arrangement of a simple valve train. The cam mounts overhead, on top of the cylinder head. The *bucket tappet* sits on top of the valve stem. Underneath the tappet is a valve spring that holds the tappet up against the cam. When the rotating cam brings the cam lobe down against the top of the bucket tappet, the lobe pushes the tappet down. This compresses the spring and pushes the valve down off its seat. The valve opens. As the cam continues to rotate, the lobe moves away from the tappet. The spring pushes the tappet and valve lifts up until the valve seats.

Fig: Operation of a cam on an overhead-camshaft engine as the camshaft rotates. Top, the cam lobe is away from the bucket tappet and the valve is closed. Bottom, the cam lobe is pushing the tappet and valve down, opening the valve.



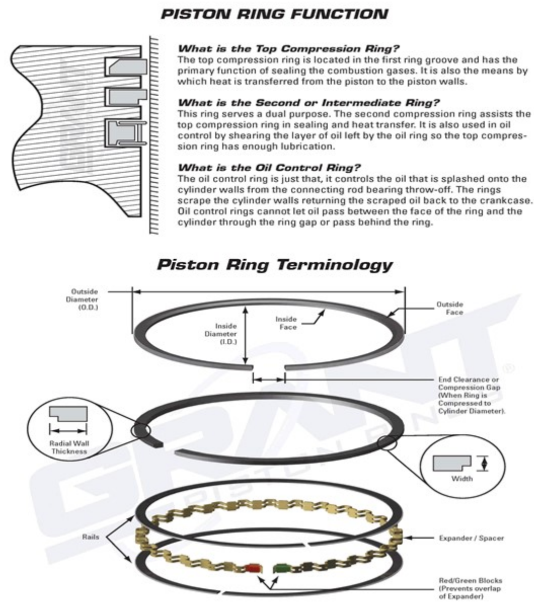
PISTON

- A piston is a component of reciprocating engines, reciprocating pumps, gas compressors and pneumatic cylinders, among other similar mechanisms. It is the moving component that is contained by a cylinder and is made gas-tight by piston rings. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod and/or connecting rod. In a pump, the function is reversed and force is transferred from the crankshaft to the piston for the purpose of compressing or ejecting the fluid in the cylinder. In some engines, the piston also acts as a valve by covering and uncovering ports in the cylinder wall. The petrol enters inside the cylinder and the piston moves upwards and the spark plug produces spark and the petrol is set on fire and it produces an energy that pushes the piston downwards.
- Piston are made up of Crown, Piston Rings, Skirt and Gudgeon Pin which connects the piston head to the Connecting Rod



PISTON RINGS

1. Three main functions of piston rings are as follows
   - ➢ Sealing the combustion chamber so that there is minimal loss of gases to the crankcase. This phenomena is called Blowby
   - ➢ Improve heat transfer from the piston to the cylinder wall.
   - ➢ Regulating engine oil consumption by scraping oil from the cylinder wall back to the sump.
2. Important Ring Properties: Wear resistance, Elasticity, High Temperature Stability.
3. Ring Materials: Cast Iron with Chromium, Alloy coated with Molybdenum.

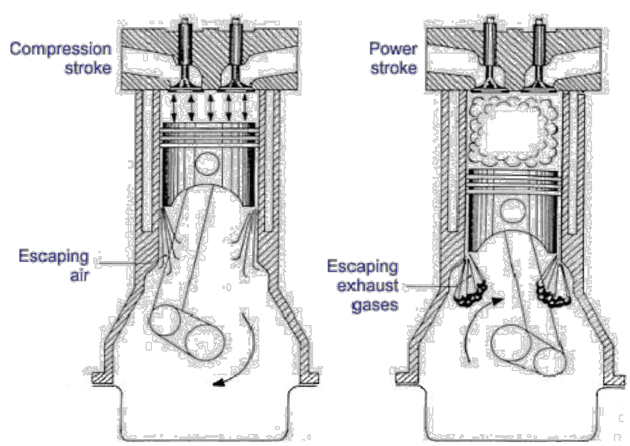


Blowby

It is the unintentional escaping of air-fuel mixture , burnt gasses and moisture past the piston-cylinder seal into the crankcase.

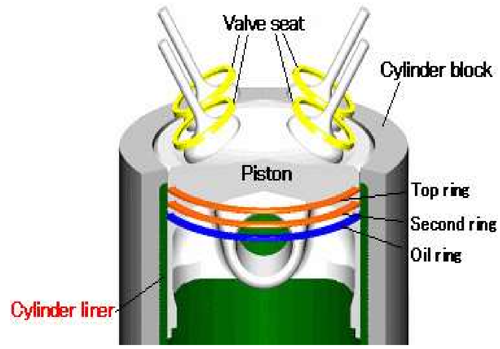
Effect of blowby:

- ➢ *Loss in compression which affects power.*
- ➢ *Dilution of Lubricant Oil.*
- ➢ *Increased wear of piston rings.*



Cylinder Liners

- A cylinder liner is a cylindrical part to be fitted into an engine block to form a cylinder. It is one of the most important functional parts to make up the interior of an engine.
- This is the wear resistant part which faces the rubbing friction of the piston and piston rings.
- It primary function is to form a sliding surface for the piston to reciprocate whilst maintaining the lubricating film.
- Other functions of the liner are as follows
    - Help in heat transfer
    - Compression Gas Sealing
- Cylinder Liner Material: Cast Iron, CI with Nickel and Chromium alloy
- Cylinder Block Material: Aluminum or Cast Iron
- Two types of liners
    - Dry Liner: The coolant water does not come in to direct contact with the cylinder liner.
    - Wet Liner: The coolant water does come in direct contact with the cylinder liner. It requires tight seals. This provides more effective cooling.



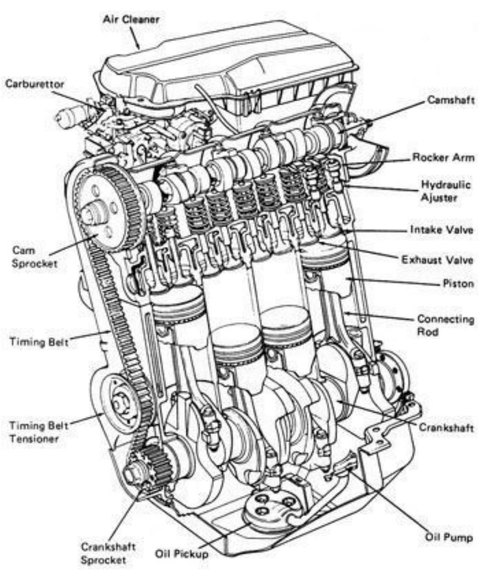


Fig: Cutaway view of a IC engine showing important parts

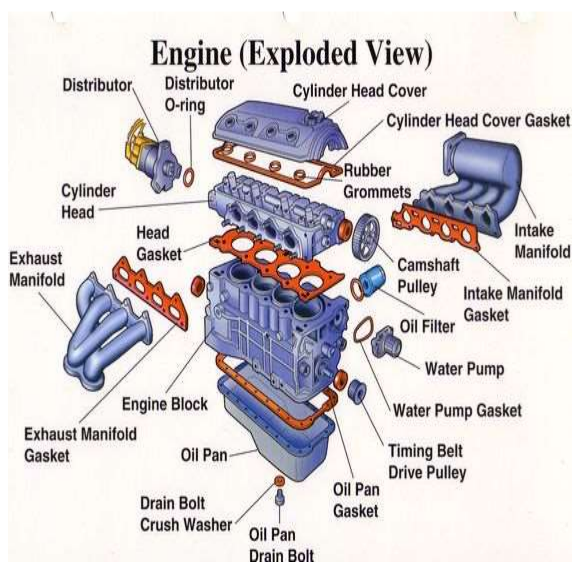


Fig: Exploded view of a IC engine

Experiment No: 01

Performance Test of a 4-Stroke Single Cylinder Diesel Engine

Objectives:

a) To conduct a load test on 4-stroke, single cylinder diesel engine to study its performance under various loads.

b) To plot the following engine performance graphs based on the experiment

Apparatus:

a) TD 202 or TD 212 Four-stroke Diesel Engine Test Bed.
(specification is given on the following page)

b) Stop watch

Theory:

Single cylinder stationary, constant speed diesel engines are generally quality governed. As such the air supplied to the engine is not throttled as in the case of S.I. engines. To meet the power requirements of the shaft, the quantity of fuel injected into the cylinder is varied by the rack in the fuel pump. The rack is usually controlled by a governor or by a hand. The air flow rate of single cylinder engine operating at constant speed does not vary appreciably with the output of the engine. Since the fuel flow rate varies more or less linearly with output, the fuel air ratio increases with output. Performance tests can be conducted either at constant speed (or) at constant throttle. The constant speed method yields the Frictional Power of the engine.

Procedure:

1. Make sure that the Test Engine Fuel Tank has enough fuel for the test.

2. Switch on the electrical and water supplies to the TD-200 Test Bed.

3. Open the fuel taps on your fuel gauge to allow fuel to flow to the Test engine. If necessary, tap the fuel line to remove ant air bubble.

4. Adjust the engine rack (speed control) to half way.

5. Slowly pull out the engine start handle until you feel resistance, then slowly let the start handle to return back to it’s original position.

6. Make sure you are in a stable position with both hands on the starter handle.

7. Firmly and quickly pull out the starting handle. The engine should start. Keep your hand on the starting handle and allow it to return back down to tha engine, then let it go.

8. If the engine does not start then repeat steos 5,6 and 7.

9. Allow the engine to run for few minutes until it reaches normal operating temperature and runs steadily.

10. Note the following readings carefully:

- **a) Engine speed (rpm)**
- **b) Torque (N/m).**
- **c) Inlet air temperature (K) and inlet cooling water temperature (K)**
- **d) Exhaust gases temperature (K) and cooling water outlet temperature (K)**
- **e) Time for 8 or 16 cc of fuel consumption (s)**
- **f) Airbox differential pressure (Pa)**

11.Repeat the above procedure at different engine speeds. Use the engine rack to reduce the speed.

12. After taking the readings use the engine rack to reduce the engine speed to a stop.

13. Turn off the fuel supply to the engine.

Experimental Properties Table:

Item	**Value**
Date of Test	___ /___ /______
Engine type	Diesel Engine
Engine size (litres)	0.232 (single cylinder)
Engine Cycles (stroke)	Two (4)
Fuel type	Diesel
Fuel density (kg/m³)	840
Fuel Calorific Value (Mj/kg)	39
Ambient air pressure, (Pa)	101325
Airbox orifice diameter, d (mm)	18
Co-efficient of discharge for orifice, C_d	0.6

Data Collection Table:

Engine			Fuel		Air and Exhaust		
Engine speed (rpm)	Engine torque (N-m)	Engine power (W)	Fuel volume (8/16/24 mL)	Fuel drain time (s)	Ambient Air Temperature (°C)	Exhaust Gas Temperature (°C)	Airbox differential pressure, (Pa)

Calculation Table:

Engine Speed (rpm)	Energy	Air and Fuel				Thermal efficiency (%)	BMEP (bar)
	Heat of Combustion (W)	Air mass flow rate (kg/s)	Fuel mass flow rate (kg/s)	Air/Fuel ratio	Specific fuel consumption (kg/kW-hr)		

Calculation Procedures:

a) **Engine power:** An engine produces power by providing a rotating shaft which can exert a given amount of torque on a load at a given rpm.

$$\mathbf{P = 2\pi NT}$$

where: N is revolution per second
T is in torque (N/m)
P is in watts

b) **Air Flow Rate:** Air flow rate is the measurement of the amount of air per unit time that flows through a particular device. The amount of air can be measured by volume (m^3/s) or by mass (kg/s).

$$\boldsymbol{m_a = C_d \times \tfrac{1}{4}\pi d^2 \times \sqrt{\left(\frac{2\,P_a\,\Delta P}{RT_a}\right)}}$$

where:
P_a = atmospheric pressure in N/m^2
ΔP = airbox differential pressure N/m^2
T_a = air inlet temperature (K)
R = characteristic gas constant (287 J/kg-K)

**** other symbols have their usual meanings stated earlier**

c) **Fuel Flow Rate:** Fuel flow rate is the measurement of the amount of fuel per unit time that flows through a particular device.

$$\boldsymbol{m_f = \frac{\rho_f x\, V_f}{t}}$$

where: ρ_f = density of fuel (kg/m^3)
V_f = volume of fuel consumed (m^3)
t = time of fuel consumption (s)

d) **Air-Fuel Ratio**: Air–fuel ratio (AFR) is the mass ratio of air to fuel present in a combustion process such as in an internal combustion engine or industrial furnace.

$$\mathbf{AFR} = \frac{m_a}{m_f}$$

e) **Heat of Combustion:** The heat of combustion is the energy released as heat when a compound undergoes complete combustion with oxygen under standard condition.

$$\boldsymbol{H_f = m_f\ x\ CVF}$$

where, CVF = Calorific value of fuel (J/kg)

f) **Specific Fuel Consumption:** The mass flow rate of fuel required to produce a unit of power or thrust, for example, kg per kW-hr is abbreviated as SFC. It is also known as specific propellant consumption.

mass fuel flow (in kg/s) = fuel density (kg/m^3) x fuel volume flow rate (m^3/s)

$$\textbf{specific fuel consumption} = \frac{\boldsymbol{mass\ fuel\ consumption\ x\ 3600}}{\boldsymbol{mechanical\ power/\ 1000}}$$

where,

Specific fuel consumption = kg/kW-hr

Mass fuel consumption = kg/s

Mechanical power = watts

g) **Thermal Efficiency**: This is the ratio of the heat of combustion from fuel against the useful mechanical power developed by the engine.

$$\eta_{th} = \frac{\boldsymbol{Mechanical\ power}}{\boldsymbol{H_f}} \textbf{ x 100}$$

h) **Brake Mean Effective Pressure (BMEP):** This is the average mean pressure in the cylinder thet would produce the measured brake output. This pressure is calculated as the uniform pressure in the cylinder as the piston rises from top to bottom of each power stroke.

The BMEP is a useful calculation to compare engines of any size.

$$\textbf{BMEP} = \frac{\textbf{60 x Power x (strokes/2)}}{\textbf{speed x engine capacity}}$$

where:

BMEP is in pascal (Pa)

Power is in watts

Speed is in rev/min

Engine capacity is in cubic meter (m^3)

Graphs:

a) Engine power vs Speed
b) Torque vs Speed
c) Air-Fuel ratio vs Speed
d) Exhaust temperature vs Speed
e) Thermal efficiency vs Speed
f) Specific fuel consumption vs Speed

Answer the following Questions:

a) What variables affect the efficiency of a Heat Engine?

b) Why is the efficiency of human cells is less than the efficiency of a Heat Engine?

c) Why does Heat Engines need to reject energy to environment?

d) Can a Heat Engine cool it's Heat source?

Report Writing:

i) Objectivs

ii) Experimental set-up (with specification)

iii) Schematic diagram of the set-up

iv) Properties table

v) Data collection table

vi) Calculation table

vii) Sample calculation

viii) Graphs

ix) Discussion

x) Answer to the Questions

Experiment No: 02

a) Study of Power Balance of a 4-Stroke Single Cylinder Diesel Engine

b) Study of Heat Balance of a 4-stroke Single Cylinder Diesel Engine

Objectives:

a) To conduct performance test on 4-stroke, single cylinder diesel engine to observe its power balance

b) To conduct performance test on a 4-stroke single cylinder Diesel engine to observe the heat balance and make a thermal balance sheet

Apparatus:

a) TD 202 or TD 212 Four-stroke Diesel Engine Test Bed.
(specification is given on the following page)

b) Stop watch

c) Water bucket

d) Infrared IR Temperature Gun Digital Thermometer

e) Balance

Theory:

Single cylinder stationary, constant speed diesel engines are generally quality governed. As such the air supplied to the engine is not throttled as in the case of S.I. engines. To meet the power requirements of the shaft, the quantity of fuel injected into the cylinder is varied by the rack in the fuel pump. The rack is usually controlled by a governor or by a hand. The air flow rate of single cylinder engine operating at constant speed does not vary appreciably with the output of the engine. Since the fuel flow rate varies more or less linearly with output, the fuel air ratio increases with output. Performance tests can be conducted either at constant speed (or) at constant throttle. The constant speed method yields the Frictional Power of the engine.

Procedure:

1. Make sure that the Test Engine Fuel Tank has enough fuel for the test.

2. Switch on the electrical and water supplies to the TD-200 Test Bed.

3. Open the fuel taps on your fuel gauge to allow fuel to flow to the Test engine. If necessary, tap the fuel line to remove ant air bubble.

4. Adjust the engine rack (speed control) to half way.

5. Slowly pull out the engine start handle until you feel resistance, then slowly let the start handle to return back to it's original position.
6. Make sure you are in a stable position with both hands on the starter handle.
7. Firmly and quickly pull out the starting handle. The engine should start. Keep your hand on the starting handle and allow it to return back down to tha engine, then let it go.
8. If the engine does not start then repeat steos 5,6 and 7.
9. Allow the engine to run for few minutes until it reaches normal operating temperature and runs steadily.
10. Note the following readings carefully:

   a) Engine speed (rpm)
   b) Torque (N/m).
   c) Inlet air temperature (K) and inlet cooling water temperature (K)
   d) Exhaust gases temperature (K) and cooling water outlet temperature (K)
   e) Time for 8 or 16 cc of fuel consumption (s)
   f) Airbox differential pressure (Pa)

11.Repeat the above procedure at different engine speeds. Use the engine rack to reduce the speed.
12. After taking the readings use the engine rack to reduce the engine speed to a stop.
13. Turn off the fuel supply to the engine.
14. From the water supply line collect water (in kg) for some definite time (in sec) and from this find the water flow rate (m_w)

Experimental Properties Table:

Item	Value
Date of Test	___ /___ /______
Engine type	Diesel Engine
Engine size (litres)	0.232 (single cylinder)
Engine Cycles (stroke)	Two (4)
Fuel type	Diesel
Fuel density (kg/m³)	840
Fuel Calorific Value (Mj/kg)	39
Ambient air pressure, (Pa)	101325
Airbox orifice diameter, d (mm)	18
Co-efficient of discharge for orifice, C_d	0.6

Data Collection Table:

Engine		Fuel		Air and Exhaust			Cooling water	
Engine speed (rpm)	Engine torque (N-m)	Fuel volume (8/16/24 mL)	Fuel drain time (s)	Ambient Air Temperature (°C)	Exhaust Gas Temperature (°C)	Airbox differential pressure (Pa)	Inlet temperature (°C)	Outlet Temperature (°C)

Calculation Table:

Engine Speed (rpm)	**Energy**	**Air and Fuel**				Mechanical efficiency (%)	BMEP (bar)
	Heat of Combustion (W)	Air mass flow rate (kg/s)	Fuel mass flow rate (kg/s)	Air/Fuel ratio	Specific fuel consumption (kg/kW-hr)		

Calculation Procedure:

a) ***For Power Balance***

We know that for a Heat Engine,

Inducated Power (I.P) = Brake Power (B.P) + Frictional Power (F.P)

Now, **Brake power** = Tω = 2πNT/60

where: N is in rpm, T is in N/m and B.P is in watts

Frictional power is calculated from Willians Line…

Willians Line: Willian's line method is used to find the Friction Power of the engine. In Willian's line method, we plot the graph of fuel consumption (kg/s) against the BMEP. We then extrapolate the graph (which is partially a straight line) to zero fuel consumption and note down the FMEP which gives us the approximate value of friction power.

Frictional Power = $\frac{FMEP * V_s * n * N}{Z\ x\ 60}$

where: V_s = engine capacity (m³)

n = no of engine cylinder

N = engine speed (rpm)

Z = 1 (for 2-strokes); 2 (for 4-strokes)

Now we can determine the mechanical efficiency of the engine.

Mechanical efficiency = $\frac{\textbf{Brake Power}}{\textbf{Indicated Power}}$

b) ***<u>For Heat Balance</u>***

Total heat supplied by fuel, Q = $m_f * CVF$

where:

m_f = mass fuel flow (kg/s)

CVF = calorific value of fuel (J/kg)

i) **Brake power,** Q_1 = Tω = 2πNT/60

where: N is in rpm, T is in N/m and Q_1 is in watts

ii) **Heat taken by cooling water,** Q_2 = m_w x C_w x $(T_2 - T_1)$

where:

m_w = mass flow rate of water (kg/s)

C_W = specific heat of water (4120 J/kg-K)

T_1 = cooling water inlet temperature (K)

T_2 = cooling water outlet temperature (K)

iii) **Heat taken by exhaust gases,** Q_3 = $(m_a + m_f)$ x C_{pg} x $(T_{ext} - T_{atm})$

where:

m_a = mass air flow rate (kg/s)

m_f = mass fuel flow rate (kg/s)

C_{pg} = specific heat of gases (1005 J/kg-K)

$T_{ext} = exhaust$ gas temperature (K)

T_{atm} = inlet air temperature (K)

iv) **Heat taken by lubricant oil,** Q_4 = $m_{oil}\ x\ C_{oil}$ x ΔT

where:

m_{oil} = mass flow rate of oil (kg/s)

C_{oil} = specific heat of oil (J/kg-K)

ΔT = temperature rise in oil (K)

v) **Unaccountable heat losses,** Q_5 = $Q - (Q_1 + Q_2 + Q_3 + Q_4)$

<u>Some Important Formual Related to the Experiment</u>

a) **Air Flow Rate:** Air flow rate is the measurement of the amount of air per unit time that flows through a particular device. The amount of air can be measured by volume (m^3/s) or by mass (kg/s).

$$m_a = C_d \text{ x } ¼ \, \pi d^2 \text{ x } \sqrt{\left(\frac{2\, P_a \, \Delta P}{RT_a}\right)}$$

b) **Fuel Flow Rate:** Fuel flow rate is the measurement of the amount of fuel per unit time that flows through a particular device.

$$m_f = \frac{\rho_f \, x \, V_f}{t}$$

where: ρ_f = density of fuel (kg/m^3)

V_f = volume of fuel consumed (m^3)

t = time of fuel consumption (s)

c) **Heat of Combustion:** The heat of combustion is the energy released as heat when a compound undergoes complete combustion with oxygen under standard condition.

$$H_f = m_f \; x \; CVF$$

where, CVF = Calorific value of fuel (J/kg)

d) **Specific Fuel Consumption:** The mass flow rate of fuel required to produce a unit of power or thrust, for example, kg per kW-hr is abbreviated as SFC. It is also known as specific propellant consumption.

mass fuel flow (in kg/s) = fuel density (kg/m^3) x fuel volume flow rate (m^3/s)

$$\textbf{specific fuel consumption} = \frac{mass\ fuel\ consumption\ x\ 3600}{mechanical\ power/\ 1000}$$

where,

Specific fuel consumption = kg/kW-hr

Mass fuel consumption = kg/s

Mechanical power = watts

e) **Brake Mean Effective Pressure (BMEP):** This is the average mean pressure in the cylinder thet would produce the measured brake output. This pressure is calculated as the uniform pressure in the cylinder as the piston rises from top to bottom of each power stroke.

The BMEP is a useful calculation to compare engines of any size.

$$\text{BMEP} = \frac{60\ x\ Power\ x\ (strokes/2)}{speed\ x\ engine\ capacity}$$

where:

BMEP is in Pa, power = watts, speed = rev/min, engine capacity = cubic meter (m^3)

Graphs:

a) Willian's Line

Answer the following Questions:

a) Can Willian's line be used to find the frictional power of a SI engine? Explain.
b) How can you tell if a vehicle has a Diesel engine or a Petrol engine?
c) Why it is not possible to burn both Petrol and Diesel simultaneously in a single I.C. engine?

<u>Report Writing:</u>

a) Objectivs
b) Experimental set-up (with specification)
c) Schematic diagram of the set-up
d) Properties table
e) Data collection table
f) Calculation table
g) Sample calculation
h) Graphs
i) Discussion
j) Answer to the Questions

EXPERIMENT 4: ENGINE SUBSYSTEMS

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1

Different Engine Subsystem

1. **Air Intake and Exhaust System:** It supplies clean air to the engine and expels burned gases.
2. **Fuel System:** It supplies the engine with combustible air-fuel mixture.
3. **Starting System:** It starts the engine.
4. **Lubrication System:** It reduces wear between moving parts.
5. **Cooling System:** It keeps the temperature of the engine within operable range.
6. **Ignition System:** It delivers the spark to initiate combustion.
7. **Charging System:** Charges the onboard battery.
8. **Engine Management System:** On board computer modules connected by CAN bus system which forms the brain of a modern automobile.

Of the seven above, **Air intake and exhaust, Fuel, Lubrication and Cooling must be present for a engine to function.**

2

Air Charging Methods

- Burning more fuel efficiently means the maximum power output of the engine will be increased.
- But burning more fuel requires more air.
- So the amount of air inducted into the engine cylinder must be increased.

➢ **Natural Aspiration**: Induction depends on pressure difference.

➢ **Forced Induction**: Charge is forced into the cylinder at substantially higher pressure. Usually done by help of a compressor which can be run by the engine (supercharging), flow of exhaust gas (turbocharging) or by electric power (ECU controlled electric compressor).

3

Air Charging Methods

Natural Aspiration

➢ **Inertia Ram Charging:** Employs 'ram effect' to tune the timing of closing of intake valve. Thus more charge is trapped inside the cylinder at high engine speed since the momentum of incoming air flow keeps it flowing inside the cylinder.

➢ **Pressure Wave Tuning:** The high-pressure wave, created when the exhaust valve opens and rapidly blows down the cylinder contents, travels to the end of exhaust pipe and is reflected as a low-pressure wave or rarefaction wave. If this wave is tuned to enter the cylinder near the end of the exhaust stroke it can assist in evacuating the residual gases and draw in fresh charge as the intake valve opens.

4

Air Charging Methods

Forced Induction:

Mechanical Supercharging :

- The supercharger is powered directly by the engine.
- It is a simple unit mounted on the 'cold side' of the engine and exhaust is not involved.
- The supercharger is driven at a fixed transmission ratio.
- It responds immediately to load changes.
- Directly engine driven hence increases fuel consumption.

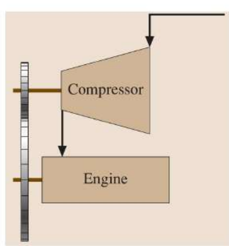
Turbocharging:

- The turbocharger is powered by the energy in exhaust gases and significantly reduces fuel consumption..
- The exhaust-driven turbine is employed to convert the energy in the exhaust gases into mechanical energy, making it possible for the turbocharger to compress the induction gas.
- A waste gate valve bypasses additional exhaust gases.
- The losses due to back pressure generated in the exhaust system is more than offset by the effect of the higher induction pressure in reducing specific fuel consumption and increasing power.
- Turbocharger Lag: Owing to the inertia of the rotating assembly it may take several seconds to respond to higher load demand.
- Installation of turbocharges requires high temperature resistant materials and space for compressor, intercooler and turbine.

5

Air Charging Methods

Fig: Supercharger



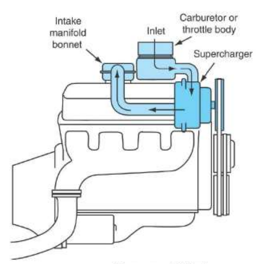
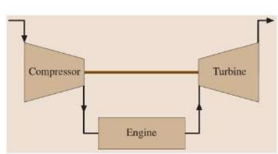
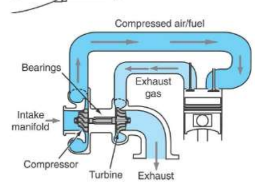


Fig: Turbocharger





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Air intake & Exhaust System

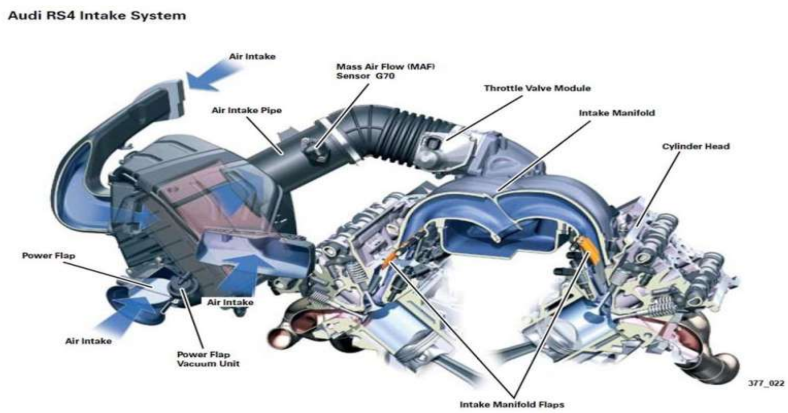


Fig: Air intake system of Audi vehicle

7

Air intake & Exhaust System

Consists of 3 important parts

- ✓ Air filter
- ✓ Mass Flow Sesnor (MAF)
- ✓ Throttle Body

Air intake system is located directly behind the front grill

8

Air intake system

- The purpose of the exhaust and intake processes is to remove the burned gases at the end of the power stroke and admit fresh charge for the next cycle.
- Indicated power of an ICE at a given speed is proportional to air induction. Inducting maximum air and retaining it within the cylinder is the primary goal of the engine gas exchange processes.
- Engine gas exchange processes are characterized by volumetric efficiency that depends on the design of engine subsystems such as manifolds, valves, and ports, as well as engine operating conditions.
- Supercharging and turbo-charging are used to increase air flow into engine cylinder, and hence output power.

9

Air intake system

Air Filter
This filter cleans air of debris, dust, sands of different size and shape so that engine gets clean air for combustion.

Dirty air if charged into the system will cause unwanted/poor quality combustion which will produce less power and cause formation of sludge, carbon residue on various internal parts of the engine viz: cylinder wall, piston head, piston rings.

Air filters are sometimes **mounted directly** on the fuel injection system or mounts on a remote location. **Remote air filters** are connected to the throttle body via hose, metal pipes and so on.

Air cleaners also muffles induction noise or noise generated when air is charged into the air intake system.

Short note on: Resonator, Tuned induction system and Flame Arrestor

10

Air intake system

Fig: Cold air intake system

11

Air intake system

Mass Air Flow Sensor:
Sensor used to find out the mass flow rate of air entering in the engine.

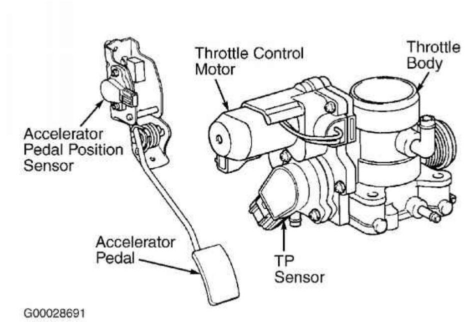
- A vital part in the electronic control system of modern automotive vehicles.
- Air density varies with the ambient temperature, altitude and the use of forced induction. This is the reason auto makers now exclusively use MAF sensor instead of volumetric sensor which is prone to error for the above mentioned reason.
- Two common type: **Vane and Hot Wire.**
- None of the MAF sensor will directly **measure the air flow rate**.
- Coupled with the Oxygen senor, MAF sensor can very accurately measure the amount of air going into the cylinders.
- MAF and Oxygen sensors are mandatory in the formation of the closed loop control system of modern automobiles.
- If the MAF sensor is failing than the following type of problems can occur
  - Runs rich at idle or lean at load
  - Constantly runs rich or lean
  - Rough idle or stalling of engine.

12

Air intake system

Throttle Body: Air control device found in all spark-ignited engines. It controls the amount of air charging in the intake manifold by controlling a throttle valve.

- ✓ In old cars it was controlled mechanically. The valve opened by depressing the accelerator pedal which was connected to the throttle valve via link cable.
- ✓ Throttle valve only controls air in the case of throttle-body injection system.
- ✓ Modern cars now employ electronical throttle control or commonly termed as drive-by-wire technology.
- ✓ In simplest form the accelerator pedal acts like a switch which is connected with a position sensor. This sensor sends the position of the accelerator pedal to ECU which in turn actuates the throttle valve with a throttle control motor. The position of the throttle valve is monitored using a Throttle Position Sensor (TP).



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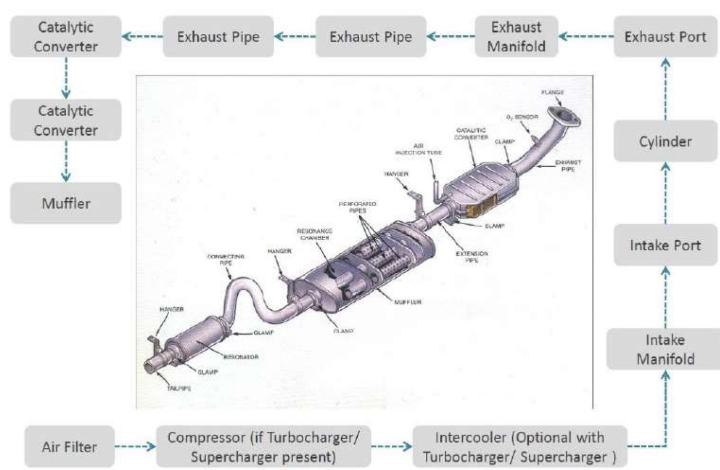
Exhaust System



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Exhaust System

Exhaust Manifold:
The exhaust manifold attaches to the cylinder head and takes each cylinders exhaust and combines it into one pipe. The manifold can be made of steel, aluminum, stainless steel, or more commonly cast iron.
Oxygen Sensor:
All modern fuel injected cars utilize an oxygen sensor to measure how much oxygen is present in the exhaust. From this the computer can add or subtract fuel to obtain the correct mixture for maximum fuel economy. The oxygen sensor is mounted in the exhaust manifold or close to it in the exhaust pipe.
Catalytic Converter:
This muffler like part converts harmful carbon monoxide and hydrocarbons to water vapor and carbon dioxide. Some converters also reduce harmful nitrogen oxides. The converter is mounted between the exhaust manifold and the muffler.
Muffler:
It is positioned between the catalytic converter and the resonator or tail pipe. It's main purpose is to quite or muffle the noise of the exhaust. It has a series of holes, passages and resonance chambers through which the exhaust gas passes. This damps out the noisy high-pressure surges resulting from the opening of the exhaust valves.
Exhaust Pipe/Tail Pipe:
Between all of the above mention parts is the exhaust pipe which carries the gas through it's journey out your tail pipe. Exhaust tubing is usually made of steel but can be stainless steel (which lasts longer due to it's corrosion resistance) or aluminized steel tubing. Aluminized steel has better corrosion resistance than plain steel but not better than stainless steel. It is however cheaper than stainless steel.

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What does color of smoke mean?

- **Thin white vapor**: This is due to the condensation of water vapors inside the exhaust system and may be accompanied by a show drip of water. This is perfectly harmless and is often seen during the starting of the vehicle from cold, in the morning.
- **Thick blue or greyish smoke**: This may be due to the lubricating oil reaching the crank case and burning in the combustion chamber. Apart from loss of lub oil, it can result in fouled spark plugs, rough idle, hard starting and sluggish acceleration. On turbocharged engines, bluish-grey smoke mean failure of turbocharger.
- **Black sooty smoke**: Such a smoke is usually due to the air-fuel mixture being excessively rich. This may be due to many factors e.g a clogged air cleaner, choke valve being stuck closed, a faulty Oxygen sensor, faulty MAF sensor etc.
- **Thick white smoke**: This type of smoke is usually the failure of radiator fan which causes the coolant to overheat and vaporize. At this point it is better to have the vechile towed since running engine at overheated state will cause catastrophic failure. Such failure will require change or complete overhaul of the engine.

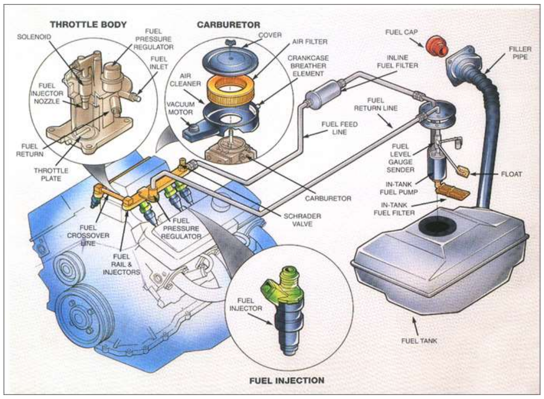
16

Fuel System

The basic fuel supply system in an automobile with petrol engine consists of a fuel tank, fuel lines, fuel pumps, fuel filters, air cleaners, carburetor, inlet manifold, supply and return lines.
Types of fuel system that have been employed by automakers are as follows

I. Gravity System
II. Vacuum System
III. Pressure System
IV. Pump System
V. Fuel Injection System

(Learn short notes on the above five systems)



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Fuel System

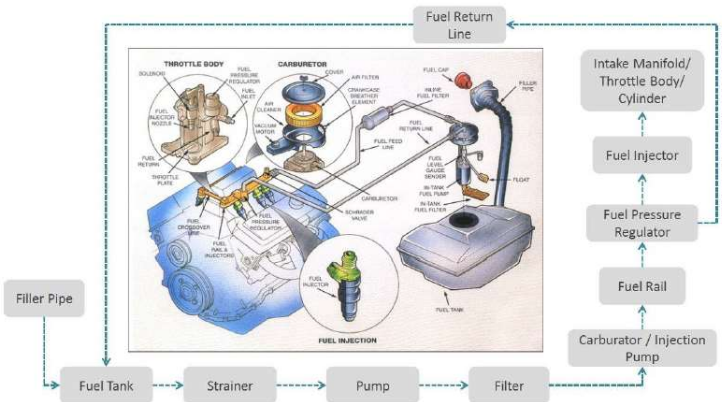

Fig: Fuel System with flow diagram

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Fuel System

- Air fuel ratio: The ratio of air to fuel by weight. A vehicle must vary this ratio as the engine operates at different condition.
- Stoichiometric ratio: It is the ideal air-fuel ratio. This produces maximum energy from the combustion reaction with minimum by products.
- Air and Fuel Metering: It is vital to monitor the air and fuel entering the engine cylinders. Proper metering provides the engine with optimal air-fuel mixture to maximize power and minimize fuel consumption.
- Too lean mixture doesn't burn properly to produce the needed power which often stalls the engine.
- Too rich mixture produces unwanted combustion which produces black smoke, damages the catalytic converter and wastes fuel.
- Air-Fuel metering is done by the Electronic Control Unit/ Electronic Control Module (ECU/ECM) which determines for how long the injectors must supply fuel charge by taking inputs from various sensors.
- Sensors reports the following variables to ECU to complete the closed loop control system
  - ❖ Engine Speed
  - ❖ Throttle Position
  - ❖ Intake-Manifold vacuum or Manifold-absolute pressure (MAP)
  - ❖ Engine Coolant Temperature.
  - ❖ Amount and temperature of air entering engine.
  - ❖ Amount of oxygen in exhaust gas.
  - ❖ Atmospheric Pressure.

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Fuel System

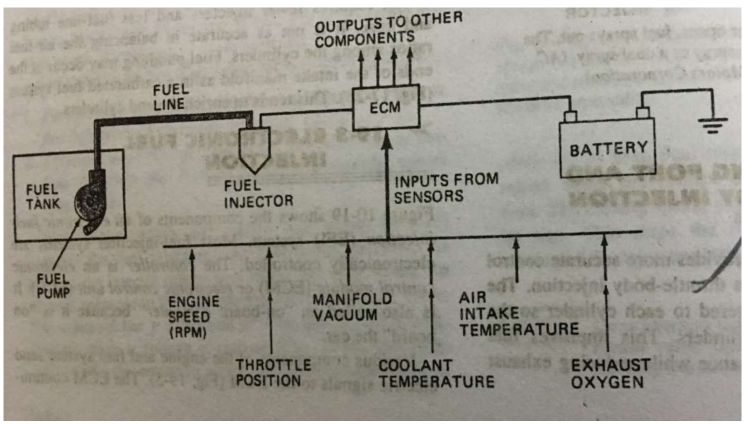


Fig: Simplified electronic fuel-injection system.
Sensors provide information or input to the Electronic Control Unit. The ECU (or ECM) then determines the amount of fuel needed and opens the injectors to produce the desired air-fuel ratio.
THIS IS A CLOSED LOOP SYSTEM.

20

Fuel System

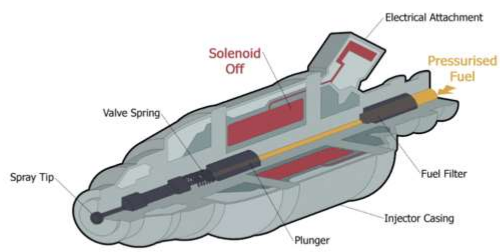
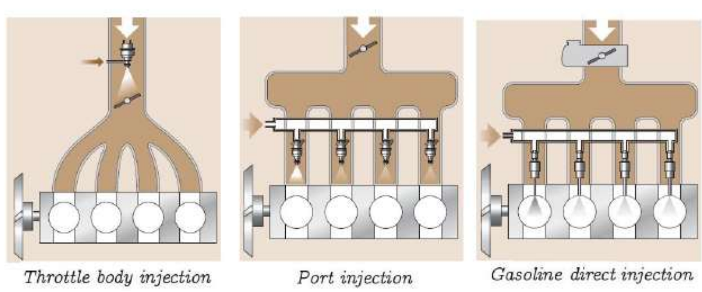


Fig: EFI cutaway model

21

Fuel System

Fuel injection system can be divided into two basis types:
- Manifold: a) Throttle body b) Port Injection
- Gasoline Direct Injection



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Fuel System

Throttle Body Injection (TBI) has one or two fuel injectors located above throttle valves.

- ✓ Requires fewer injectors and less fuel-line tubing and hose.
- ✓ However, it is not as accurate as PFI system in balancing A/F ratios among cylinders.
- ✓ Fuel puddling may occur at ends of intake manifold that tends to enrich the end cylinders.

(Learn Short note on Fuel Puddling).

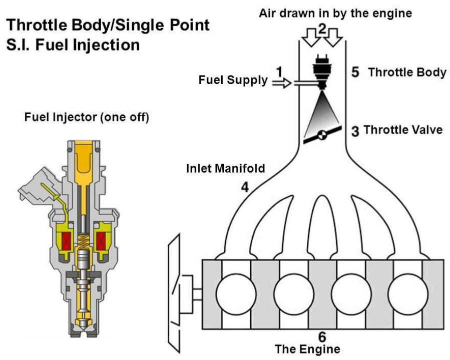
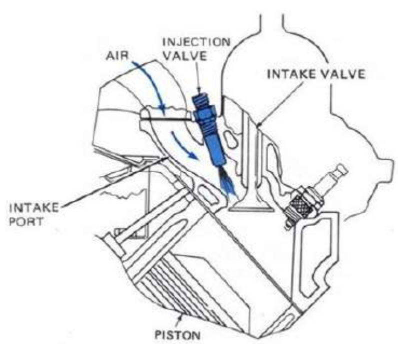


Fig: Single point Throttle body injection.

Fuel System



Port Fuel Injection (PFI) / Multipoint Fuel Injection has an injection valve or fuel injector in each intake port.

- ➢ Provides more accurate control.
- ➢ Same amount of Fuel is delivered to each cylinder.
- ➢ Improves fuel economy and reduced exhaust emissions.

𝔉𝔲𝔢𝔩 𝔖𝔶𝔰𝔱𝔢𝔪

Gasoline Direct Injection System

- In non-Diesel internal combustion engines**, Gasoline Direct Injection (GDI),** also known as Petrol Direct Injection, Direct Petrol Injection, Spark Ignited Direct Injection (SIDI) and Fuel Stratified Injection (FSI), is a variant of fuel injection employed in modern two-stroke and four-stroke gasoline engines. The gasoline is highly pressurized, and injected via a common rail fuel line directly into the combustion chamber of each cylinder, as opposed to conventional multi-point fuel injection that injects fuel into the intake tract, or cylinder port. Directly injecting fuel into the combustion chamber requires high pressure injection whereas low pressure is used injecting into the intake tract or cylinder port.

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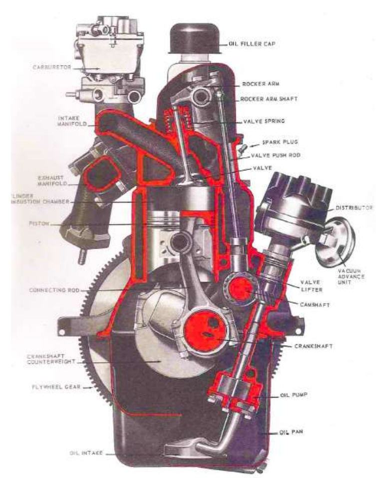
𝔉𝔲𝔢𝔩 𝔖𝔶𝔰𝔱𝔢𝔪

Carburettor

The carburettor is a mixing device that delivers the engine a combustible air-fuel mixture continously. The three main parts of carburettor are :

1. Air horn
2. Float Bowl
3. Throttle Body

Carburettor typically sits at the top of the engine cylinder. This is an antiquated fuel mixing device which has since been largely replaced by Electronic Fuel Injection System.



Front section view, Ford Falcon, 144 cu. in., 6-cylinder engine, with principal parts identified.

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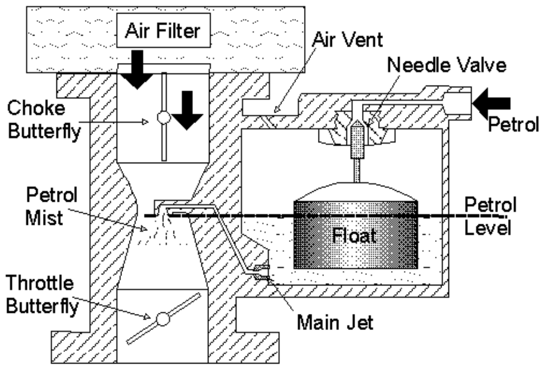
Carburation System

- The carburettor employs venturi principle. The venturi is a restricted space through which the air entering the engine must pass. The inlet air flows through a necked-down area (venturi). where the flow increases in speed and decreases in pressure.
- The pressure drop at the venturi increases with engine speed and with throttle position, thus causing fuel flow from the reservoir to the venturi to increase as engine speed and throttle position increase.
- Carburettors may have fixed venturi or variable venturi.
- Carburettors may have single barrel or multi-barrel (two or four) for better engine performance.



The actions in a carburettor are as follows :

- The float bowl in the carburettor is supplied with fuel from the fuel tank by a fuel pump. Air passing through the venture produces a vacuum. Because of the pressure differential, atmospheric pressure pushes fuel from the float bowl up through the fuel nozzle. The fuel then spills out into the passing air.
- The throttle valve is the basic control device. As the throttle valve opens, more air passes through which produces a greater vacuum. With a greater vacuum, more fuel discharges from the fuel nozzle. This relationship allows the carburetor to supply the amount of fuel to match the amount of air flowing through.

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Carburation Subsystem

- **Float system** to maintain a constant level of fuel in the reservoir.
- **Idle & low speed system** to deliver rich air-fuel mixture during starting and low speed operation.
- **Main metering system** to deliver air-fuel mixture of desired A/F ratio.
- **Power system** to deliver rich A/F mixture for high speed, full-power, wide-open throttle(WOT) operation.
- **Accelerator pump system** to deliver extra fuel during acceleration.
- **Choke system** to provide rich air-fuel mixture for starting a cold engine.

Learn short note above these subsystems from Automotive Mechanics Chap 21

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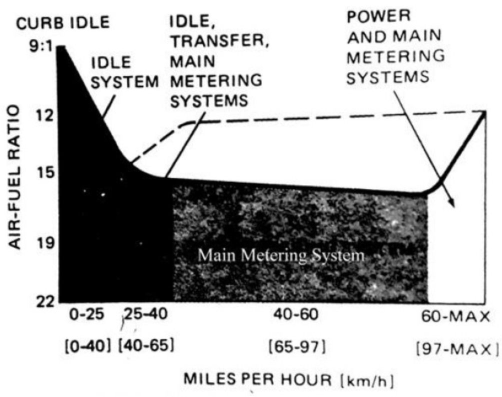
Fuel System



A/F ratio vs. Speed Curve

A rich mixture is needed for starting, especially in cold conditions when a high proportion of the fuel condenses out on to the cold walls of the induction manifold.

Enrichment of the mixture is needed for idling because of the fuel being consumed are so small.

A slightly weak mixture for cruising, at part throttle, ensures that there is enough air to burn all the fuel completely.

An extra supply of fuel for acceleration is essential because, when the throttle is suddenly opened, the flow or air increases more rapidly than that of the fuel.

To obtain the maximum possible power output, the maximum possible quantity of fuel must be supplied to it, so the mixture must be enriched. However, it is achieved at the expense of higher brake specific fuel consumption.

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Cooling System

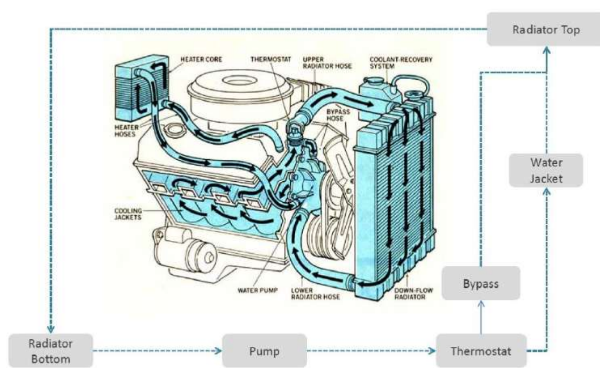

Fig in the above shows the cooling system of an automobile. During operation the engine cylinders can reach temperature of about 2200 degree Celsius. However the cylinder wall must not exceed 260 degrees. Higher temperatures cause lubrication oil to break down and lose its lubricating property. Other engine parts also gets damaged at higher temperature. Cooling system extracts this extra heat to protect the engine components. The amount extracted is about one-third the heat produced in the combustion chamber. This is a major loss but unavoidable. Cooling system performs its operation with five basic parts.

- Water Jacket
- Water Pump
- Thermostat
- Radiator
- Fan

(Learn short note about each of the five component of cooling system)

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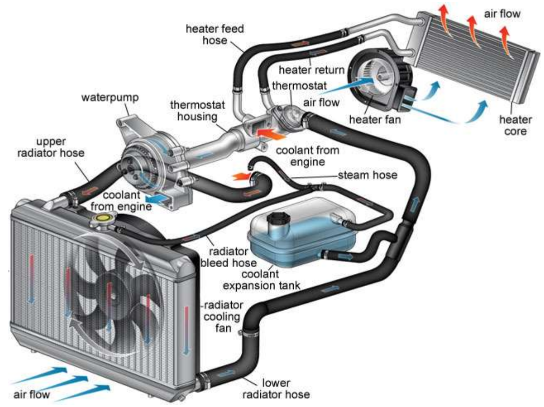
Cooling System



Coolant Bypass Passage:
Most engine have small coolant bypass passages. They permit some of the coolant to circulate within the cylinder block and head when the engine is cold and the thermostat is closed. This provides equal warming of the cylinders and prevents hot spots.

Radiator Pressure Cap:
Cooling systems are sealed and pressurized by a radiator pressure cap. Sealing reduces coolant loss from evaporation and allows the use of an expansion tank. Pressurizing raises the boiling temperature of the coolant and thereby increasing cooling efficiency.

Increasing coolant pressure increases the boiling point of the coolant. This ensures less bubble formation in the coolant and thus ensures less space between coolant molecules. This in turn increases cooling effect by increasing heat retention capacity.

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Cooling System

Math Question:
A water cooled, four cylinder engine with cast iron cylinder walls, bore 80mm, stroke 110mm and wall thickness 7mm is running at 3500 rpm. At this speed, 10 percent of the energy input is being transferred to the cylinder walls. The consumption of fuel, whose calorific value is 42,000 kJ/kg is 300 gm/min. Assume thermal conductivity of of cast iron is 168 kJ/m.hr. per degree Celsius.
Calculate

- ✓ Temperature drop through cylinder walls
- ✓ Temperature drop from the cylinder walls to cooling water which is being circulated at a speed of 5cm/s. Assume film co-efficient of heat transfer at this speed as 37800 kJ/m2.hr.per degree Celsius

Solution: Automobile Engineering Vol:2 Page 162; Example 5.1

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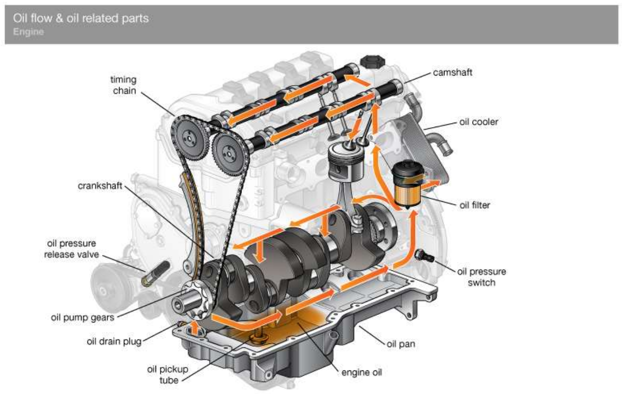
Lubrication System



Lubrication System supplies lubricating oil to different parts of the engine. As shown in the above image, the oil pump picks up oil from the oil and sends it through the oil filter. After filtration, lub oils passes through various passages (galleries) to the main bearings that support the crankshaft. Some oil flows from the main bearings through oils holes drilled in the crankshaft to the rod bearings. The oil flows through the bearing oil clearance and then is thrown off the moving parts. At the same time, oil flows through an oil passage to the cylinder head. There the oil flows through another passage to lubricate the camshaft bearing and valve train parts. After the oil circulates to all engine parts, it drops back down to the oil pan.

Learn: Functions of lubrication oil, Dry and Wet Sump, Properties of Lubrication Oil (Automotive Mecahnics)

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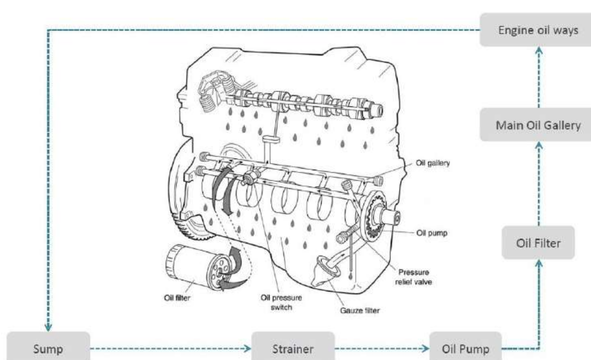
Lubrication System



Wet Vs Dry Oil System:

Wet sump systems store the oil in the pan but a dry sump system stores it in a separate tank and pumps the pan clean leaving it essentially "dry". The usual set up for a dry sup system uses all but one of the stages to scavenge oil from the pan and the last stage is used to pump oil from the motor. The primary advantage of a dry sump system is that it makes more power by creating extra crankcase vacuum with the dry sump pump, which improves ring seal, and by keeping the rotating assembly free of windage allowing it to spin freely. It also has increased capacity, remote coolers, and adjustable and consistent oil pressure. The lack of oil in the pan also allows for it to be shallower which improves weight distribution and handling

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Starting and Charging System

Fig: Starting and Charging system

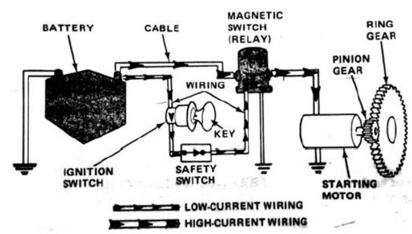

Fig: Schematic diagram of starting system

Ignition System

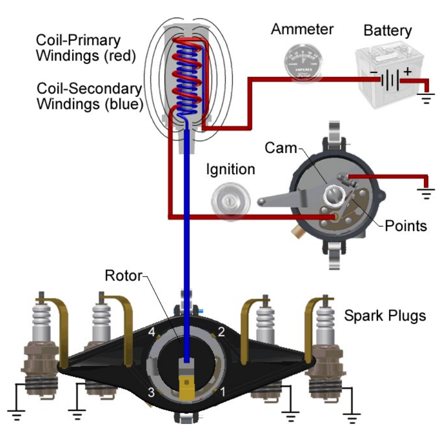

Fig: Contact point ignition system

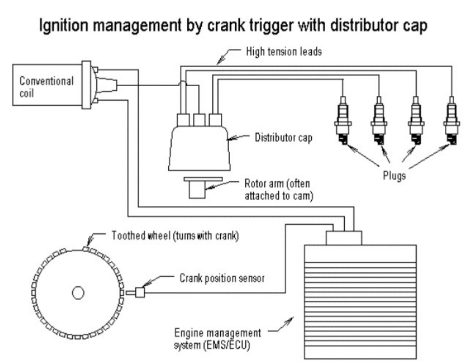

Fig: Electronic ignition system

Ignition System: This system includes the battery, ignition switch, ignition coil, distributor (with contact points and condenser), secondary winding/wiring and spark plugs. For the case of Diesel engines iginition system doesn't have spark plugs but glow plugs to facilitate quick reaching of self ignition temperature of diesel mixture.

The primary difference **between contact point ignition system** and **electronic ignition system** is that in electronic ignition, the contact points in distributor is replaced with electronically controlled contact switch which is done via a control module.

The relation between piston position and spark-plug firing is termed as **ignition timing.**

Learn: How contact point ignition / Mechanical ignition system works?

Engine Management System / Engine Control Unit (ECU)

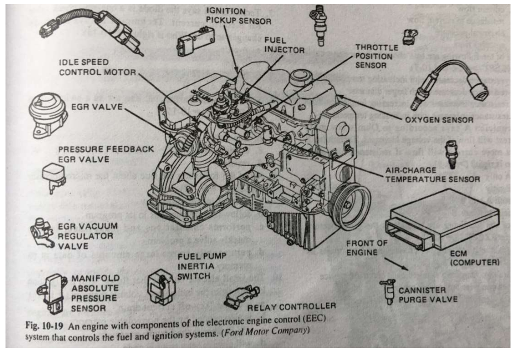

Fig. 10-19 An engine with components of the electronic engine control (EEC) system that controls the fuel and ignition systems. (*Ford Motor Company*)

Engine Management System: This subsystem is the heart of modern automotive engineering. EMS is a combination of various control modules placed throughout the whole vehicle. These systems "talks" with each other over **Controller Area Network (CAN)** bus system, a special communication protocol build specifically for automobiles. It is the modern iteration of **Engine Control Unit (ECU)**. EMS controls the following

- **Transmission Control Unit**
- **Climate Control**
- **Air and Fuel Control Unit**
- **Ignition Timing Control Module**

Engineers and Technicians can extract information from the EMS via the On-Board Diagnostics protocol built into the Engine Management System. The current iteration is OBDII.

- A fun fact: Some vehicle may not come equipped with a tachometer/speedometer but the engine still monitors the rpm of the wheel. You can see the rpm using a OBDII meter like BluDriver which plugs in a small computer in your OBDII port and shows all the data using a mobile app.

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