NILASAILA INSTITUTE OF SCIENCE & TECHNOLOGY
SERGARH-756060, BALASORE (ODISHA)
(Approved by AICTE& affiliated to SCTE&VT, Odisha)

AUTOMOTIVE ENGINE

(Th- 4)

FOURTH SEMESTER

AUTOMOBILE ENGINEERING

Prepared By: ***Er Pradyumna Kumar Khilar***

CHAPTER-1

1.PETROL ENGINE AND ITS CONSTRUCTIONAL DETAILS

Heat engine is a machine for converting heat, developed by burning fuel into useful work. It can be said that heat engine is equipment which generates thermal energy and transforms it into mechanical energy.

CLASSIFICATION OF HEAT ENGINES

1. Based on combustion of fuel:
   (i) External combustion engine
   (ii) Internal combustion engine.
   External combustion engine
   Here, the working medium, the steam, is generated in a boiler, located out side the engine and allowed in to the cylinder to operate the piston to do mechanical work.

   Internal combustion engine
   In internal combustion engine, the combustion of fuel takes place inside the engine cylinder and heat is generated within the cylinder. This heat is added to the air inside the cylinder and thus the pressure of the air is increased tremendously. This high pressure air moves the piston which rotates the crank shaft and thus mechanical work is done.

2. Based on fuel used
1. Diesel engine
2. Petrol engine
3. Gas engine

Diesel engine – Diesel is used as fuel
Petrol engine – Petrol is used as fuel
Gas engines – propane, butane or methane gases are used

3. Based ignition of fuel
1. Spark ignition engine (Carburetor type engines)
2. Compression ignition engine (injector type engines)

Spark ignition engine – a mixture of air and fuel is drawn in to the engine cylinder. Ignition of fuel is done by using a spark plug. The spark plug produces a spark and ignites the air- fuel mixture. Such combustion is called constant volume combustion (C.V.C.).

Compression ignition engine – In compression ignition engines air is compressed in to the engine cylinder,. Due to this the temperature of the compressed air rises to 700-900 C. At this stage diesel is sprayed in to the cylinder in fine particles. Due to a very high temperature, the fuel gets ignited. This type of combustion is called constant pressure combustion (CP.C.) because the pressure inside the cylinder is almost constant when combustion is taking place.

4. Based on working cycle
1. Four stroke cycle engine - When the cycle is completed in two revolutions of the crankshaft, it is called four stroke cycle engines.

2. Two stroke cycle engine. - When the cycle is completed in one revolution of the crankshaft, it is called two stroke cycle engine.

CONSTRUCTION OF AN IC ENGINE

I.C. engine converts the reciprocating motion of piston into rotary motion of the crankshaft by means of a connecting rod. The piston which reciprocating in the cylinder is very close fit in the cylinder. Rings are inserted in the circumferential grooves of the piston to prevent leakage of gases from sides of the piston. Usually a cylinder is bored in a cylinder block and a gasket, made of copper sheet or asbestos is inserted between the cylinder and the cylinder head to avoid ant leakage. The combustion space is provided at the top of the cylinder head where combustion takes place. The connecting rod connects the piston and the crankshaft. The end of the connecting rod connecting the piston is called small end. A pin called gudgeon pin or wrist pin is provided for connecting the piston and the connecting rod at the small end. . The other end of the connecting rod connecting the crank shaft is called big end. When piston is moved up and down, the motion is transmitted to the crank shaft by the connecting rod and the crank shaft makes rotary motion. The crankshaft rotates in main bearings which are fitted the crankcase. A flywheel is provided at one end of the crankshaft for smoothing the uneven torque produced by the engine. There is an oil sump at the bottom of the engine which contains lubricating oil for lubricating different parts of the engine.

WORKING PRINCIPLE OF I.C. ENGINE/ FOUR STROKE CYCLE ENGINE / TWO STROKE CYCLE ENGINE

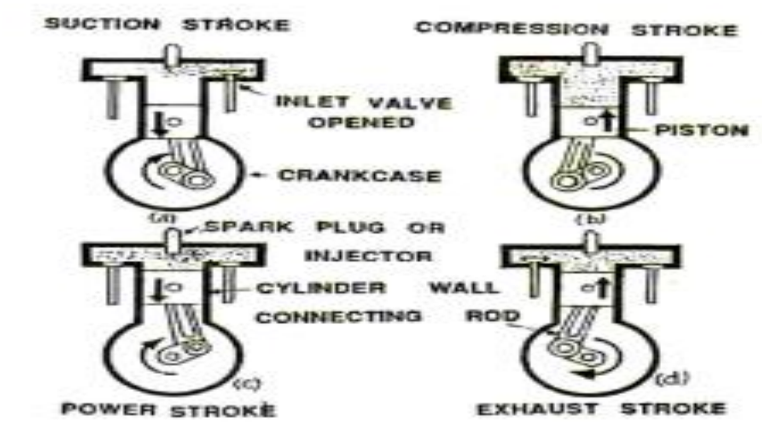
A mixture of fuel with correct amount of air is exploded in an engine cylinder which is closed at one end. As a result of this explosion, heat is released and this heat causes the pressure of the burning gases to increase. This pressure forces a close fitting piston to move down the cylinder. The movement of piston is transmitted to a crankshaft by a connecting rod so that the crankshaft rotates and turns a flywheel connected to it. Power is taken from the rotating crank shaft to do mechanical work. To obtain continuous rotation of the crankshaft the explosion has to be repeated continuously. Before the explosion to take place, the used gases are expelled from the cylinder, fresh charge of fuel and air are admitted in to the cylinder and the piston moved back to its starting position. The sequences of events taking place in an engine is called the working cycle of the engine. The sequence of events taking place inside the engine are as follows

1. Admission of air or air-fuel mixture inside the engine cylinder (suction)
2. Compression of the air or air fuel mixture inside the engine (compression)
3. Injection of fuel in compressed air for ignition of the fuel or ignition of air-fuel mixture by an electric spark using a spark plug to produce thermal power inside the cylinder (power)
4. Removal of all the burnt gases from the cylinder to receive fresh charge (exhaust)

FOUR STROKE CYCLE ENGINE (PETROL ENGINE)

In four stroke cycle engines the four events namely suction, compression, power and exhaust take place inside the engine cylinder. The four events are completed in four strokes of the piston (two revolutions of the crank shaft). This engine has got valves for controlling the inlet of charge and outlet of exhaust gases. The opening and closing of the valve is controlled by cams, fitted on camshaft. The camshaft is driven by crankshaft with the help of suitable gears or chains. The camshaft runs at half the speed of the crankshaft. The events taking place in I.C. engine are as follows:

1. Suction stroke
2. Compression stroke
3. Power stroke
4. Exhaust stroke



Four stroke cycle engine

Suction stroke

During suction stroke inlet valve opens and the piston moves downward. Only air or a mixture of air and fuel are drawn inside the cylinder. The exhaust valve remains in closed position during this stroke. The pressure in the engine cylinder is less than atmospheric pressure during this stroke.

Compression stroke

During this stroke the piston moves upward. Both valves are in closed position. The charge taken in the cylinder is compressed by the upward movement of piston. If only air is compressed, as in case of diesel engine, diesel is injected at the end of the compression stroke and ignition of fuel takes place due to high pressure and temperature of the compressed air. If a mixture of air and fuel is compressed in the cylinder, as in case of petrol engine, the mixture is ignited by a spark plug.

Power stroke

After ignition of fuel, tremendous amount of heat is generated, causing very high pressure in the cylinder which pushes the piston downward . The downward movement of the piston at this instant is called power stroke. The connecting rod transmits the power from piston to the crank shaft and crank shaft rotates. Mechanical work can be taped at the rotating crank shaft. Both valves remain closed during power stroke.

Exhaust stroke

During this stroke piston moves upward. Exhaust valve opens and exhaust gases go out through exhaust valves opening. All the burnt gases go out of the engine and the cylinder becomes ready to receive the fresh charge. During this stroke inlet valve remains closed (Fig.1d). Thus it is found that out of four strokes, there is only one power stroke and three idle strokes in four stroke cycle engine. The power stroke supplies necessary momentum for useful work.

TWO STROKE CYCLE ENGINE (PETROL ENGINE)

In two stroke cycle engines, the whole sequence of events i.e., suction, compression, power and exhaust are completed in two strokes of the piston i.e. one revolution of the crankshaft. There is no valve in this type of engine. Gas movement takes place through holes called ports in the cylinder. The crankcase of the engine is air tight in which the crankshaft rotates.

Upward stroke of the piston (Suction + Compression)

When the piston moves upward it covers two of the ports, the exhaust port and transfer port, which are normally almost opposite to each other. This traps the charge of air- fuel mixture drawn already in to the cylinder. Further upward movement of the piston compresses the charge and also uncovers the suction port. Now fresh mixture is drawn through this port into the crankcase. Just before the end of this stroke, the mixture in the cylinder is ignited by a spark plug. Thus, during this stroke both suction and compression events are completed.

Downward stroke (Power + Exhaust)

Burning of the fuel rises the temperature and pressure of the gases which forces the piston to move down the cylinder. When the piston moves down, it closes the suction port, trapping the fresh charge drawn into the crankcase during the previous upward stroke. Further downward movement of the piston uncovers first the exhaust port and then the transfer port. Now fresh charge in the crankcase moves in to the cylinder through the transfer port driving out the burnt gases through the exhaust port. Special shaped piston crown deflect the incoming mixture up around the cylinder so that it can help in driving out the exhaust gases. During the downward stroke of the piston power and exhaust events are completed.

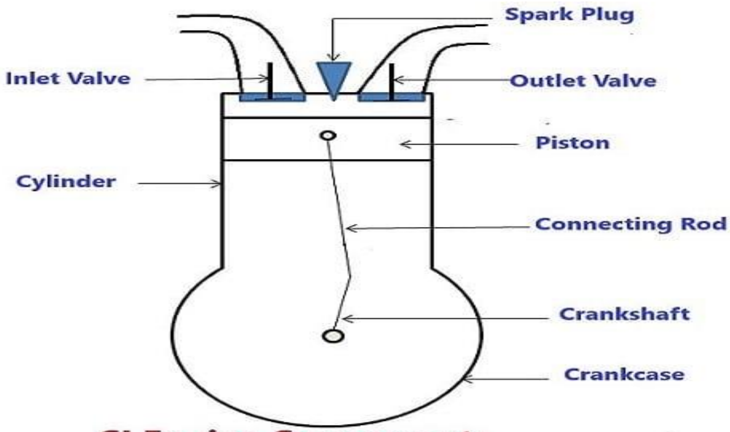
COMPARISON BETWEEN TWO STROKE AND FOUR STROKE ENGINES

Four stroke engine	Two stroke engine
1. One power stroke for every two revolutions of the crankshaft.	One power stroke for each revolution of the crankshaft.
2. There are inlet and exhaust valves in the engine.	There are inlet and exhaust ports instead of valves.
3. Crankcase is not fully closed and air tight.	Crankcase is fully closed and air tight.
4. Top of the piston compresses the charge.	Both sides of the piston compress the charge.
5. Size of the flywheel is comparatively larger.	Size of the flywheel is comparatively smaller.
6. Fuel is fully consumed.	Fuel is not fully consumed.
7. Weight of engine per hp is high.	Weight of engine per hp is comparatively low.
8. Thermal efficiency is high.	Thermal efficiency is comparatively low.
9. Removal or exhaust gases easy.	Removal of exhaust gases comparatively difficult.
10. Torque produced is even.	Torque produced is less even.
11. For a given weight, engine would give only half the power of two stroke	For same weight, two stroke engine gives twice the power that of four stroke engine.

Components of the Petrol Engine

The main parts of the spark-ignition engine are given below:

- Piston
- Cylinder
- Connecting rod
- Valves
- Crankshaft
- Flywheel
- Spark plug



SI Engine Components

PISTON

A piston is a component of reciprocating engines. It is located in a cylinder and is made gas-tight by piston rings. Its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod and/or connecting rod. In two-stroke engines the piston also acts as a valve by covering and uncovering ports in the cylinder wall.

CYLINDER

The cylinder is the space through which the piston travels, propelled to the energy generated from the combustion of the air/fuel mixture in the combustion chamber. In an air-cooled engine, the walls of the cylinders are exposed to the airflow, to provide the primary method of cooling to the engine.

CONNECTING ROD

A connecting rod is the part of a piston engine which connects the piston to the crankshaft. Together with the crank, the connecting rod converts the reciprocating motion of the piston into the rotation of the crankshaft. The connecting rod is required to transmit the compressive and tensile forces from the piston.

VALVES

All four-stroke internal combustion engines employ valves to control the admittance of fuel and air into the combustion chamber. Two-stroke engines use ports in the cylinder bore, covered and uncovered by the piston, though there have been variations such as exhaust valves.

Piston engine valves

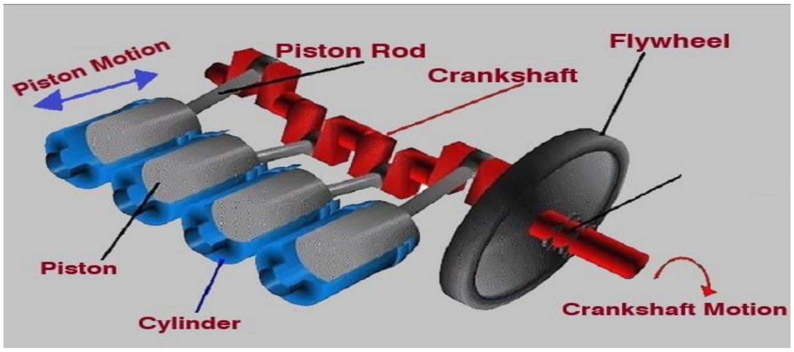
In piston engines, the valves are grouped into 'inlet valves' which admit the entrance of fuel and air and 'outlet valves' which allow the exhaust gases to escape. Each valve opens once per cycle and the ones that are subject to extreme accelerations are held closed by springs that are typically opened by rods running on a camshaft rotating with the engines' crankshaft.

Control valves

Continuous combustion engines—as well as piston engines—usually have valves that open and close to admit the fuel and/or air at the startup and shutdown. Some valves feather to adjust the flow to control power or engine speed as well.

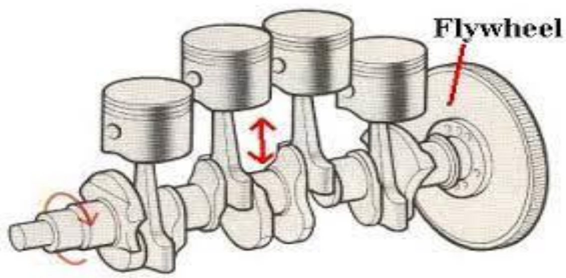
CRANKSHAFT

Crankshafts are commonly used in internal combustion engines and consist of a series of cranks and crankpins to which the connecting rods are attached. The crankshaft rotates within the engine block through use of main bearings, and the crankpins rotate within the connecting rods using rod bearings.



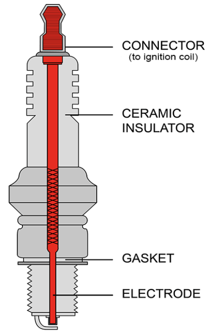
FLYWHEEL

The flywheel is a disk or wheel attached to the crank, forming an inertial mass that stores rotational energy. In engines with only a single cylinder the flywheel is essential to carry energy over from the power stroke into a subsequent compression stroke. Flywheels are present in most reciprocating engines to smooth out the power delivery over each rotation of the crank and in most automotive engines also mount a gear ring for a starter. The rotational inertia of the flywheel also allows a much slower minimum unloaded speed and also improves the smoothness at idle. The flywheel may also perform a part of the balancing of the system and so by itself be out of balance, although most engines will use a neutral balance for the flywheel, enabling it to be balanced in a separate operation. The flywheel is also used as a mounting for the clutch or a torque converter in most automotive applications.



SPARK PLUG

A spark plug is an essential part of your ignition, as your gasoline car won't start without it. Basically, it's an electrical component that can be found in your engine's cylinder head where it receives a high-voltage charge from the connected ignition coil.



CYLINDER ARRANGEMENT

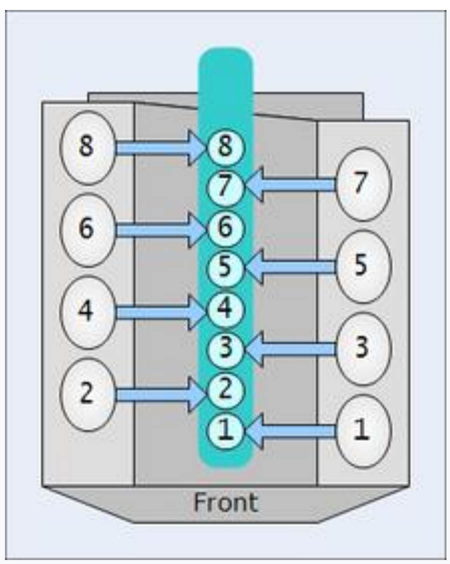
The in-line engine has a single row of cylinders extending vertically upward from the crankcase and aligned with the crankshaft main bearings. The V type has two rows of cylinders, usually forming an angle of 60° or 90° between the two banks.

The numbering system for cylinders is generally based on the cylinder numbers increasing from the front to the rear of an engine (See engine orientation below). However, there are differences between manufacturers in how this is applied; some commonly used systems are as listed below.

Straight engine

Cylinders numbered from front (#1 cylinder) to rear.

V engine



V8 engine with cylinder numbering based on crankshaft position (instead of following each cylinder bank)

The frontmost cylinder is usually #1, however there are two common approaches:

- Numbering the cylinders in each bank sequentially (e.g. 1-2-3-4 along the left bank and 5-6-7-8 along the right bank). This approach is typically used by V8 engines from Audi, Ford and Porsche.

- Numbering the cylinders based on their position along the crankshaft (e.g. 1-3-5-7 along the right bank and 2-4-6-8 along the left bank). This approach is typically used by V8 engines from General Motors, and Chrysler.

Radial engine

The cylinders are numbered around the circle, in clockwise direction with the #1 cylinder at the top.

The following table is a running list of firing orders by application: (Please expand on the list if you see something missing.)

Number of Cylinders	Firing Order	Application
1	1	Curved Dash Oldsmobile
2	1-2	Buick Model B, C, F, G, 14, James and Browne
3	1-2-3	Saab two-stroke, Perodua Kancil engine
	1-3-2	BMW K75 engine, Subaru Justy engine
4	1-3-4-2	Most straight-4s, Ford Taunus V4 engine
	1-2-4-3	Some British Ford and Riley engines, Ford Kent engine, Riley Nine
	1-3-2-4	Subaru 4-cylinder engines, Yamaha R1 crossplane
	1-4-3-2	Volkswagen air-cooled engine
5	1-2-4-5-3	Straight-five engine, Volvo 850, Audi 100
	1-3-5-4-2	GM Atlas engine

6	1-5-3-6-2-4	AMC straight-6 engine, Chrysler Slant-6 engine, Mercedes-Benz M104 engine, Maserati 3500 GT I6, Volkswagen VR6 engine, Opel Omega A, Nissan L Engine
	1-4-3-6-2-5	Mercedes-Benz M272 engine, Volkswagen V6's (both engines are 90-degree V6's)
	1-6-5-4-3-2	GM 3800 engine, Rover KV6 engine
	1-2-3-4-5-6	General Motors 60° V6 engine, Mazda JE 3.0 litre 60-degree V6 engine, Chrysler Pentastar engine
	1-4-2-5-3-6	Ford Cologne V6 engine, Ford Essex V6 engine (UK)
	1-4-5-2-3-6	Chevrolet Corvair
	1-6-3-2-5-4	Subaru Alcyone/XT-6/Vortex ER-27 Flat-6
	1-6-2-4-3-5	Porsche Boxster Flat-6
	1-6-2-5-3-4	Maserati Quattroporte IV V6-4AC-24
	1-4-2-6-3-5	Toyota HZ engine[8]
7	1-3-5-7-2-4-6	7-cylinder single row radial engine
8	1-8-7-3-6-5-4-2	Nissan VK engine
	1-8-7-2-6-5-4-3	GM LS engine
	1-8-4-3-6-5-7-2	Chrysler and Dodge V8s, Chevrolet Small-Block engine, Pontiac, Rover

		V8, Toyota UZ engine
	1-6-2-5-8-3-7-4	Straight-8
	1-5-6-3-4-2-7-8	Cadillac 368, 425, 472, and 500 V8 engines
	1-5-4-8-7-2-6-3	BMW S65
	1-5-4-8-6-3-7-2	Ford Modular 5.0, Ford Flathead, Bentley L410 V8 (from 1959 to 1986)
	1-5-4-8-3-7-2-6	5.2 L "Voodoo" V8
	1-5-4-2-6-3-7-8	Ford Small Block 221/255/260/289/302, FE Series 352/360/390/406/410/427/428, Ford 385 series Big Block 429/460
	1-5-3-7-4-8-2-6	Ferrari V8's, (all are flat-plane crank)
	1-3-7-2-6-5-4-8	Porsche 928, Ford Modular V-8, 351 Windsor, 5.0 H.O., 335 series (351C/351M/400M), Bentley L410 V8 (from 1987 to present)
	1-3-6-8-4-2-7-5	Alfa Romeo 8C
	1-2-7-8-4-5-6-3	Holden V8
	1-2-7-3-4-5-6-8	Cadillac Northstar Engine
9	1-3-5-7-9-2-4-6-8	9-cylinder single row radial engine Lycoming R-680-13 engine]
10	1-10-9-4-3-6-5-8-7-2	Dodge Viper V10

	1-6-5-10-2-7-3-8-4-9	BMW S85, Ford V10
	1-8-7-6-5-4-3-10-9-2	Isuzu 10PE1
12	1-7-5-11-3-9-6-12-2-8-4-10	2001 Ferrari 456M GT V12
	1-7-4-10-2-8-6-12-3-9-5-11	1997 Lamborghini Diablo VT
	1-4-9-8-5-2-11-10-3-6-7-12	Caterpillar 3412, Toyota GZ engine
	1-12-5-8-3-10-6-7-2-11-4-9	Audi VW Bentley W12 engine
	1-12-7-6-3-10-11-2-5-8-9-4	Rolls-Royce Merlin
	1-12-4-9-2-11-6-7-3-10-5-8	2011 Lamborghini Aventador
14	1L-1R-2L-2R-4L-4R-6L-6R-7L-7R-5L-5R-3L-3R	(Wärtsilä)-Sulzer 14ZV40/48 V14 marine diesel
16	1-12-8-11-7-14-5-16-4-15-3-10-6-9-2-13	2003 Cadillac V16 engine
	1-2-5-6-3-4-9-10-15-16-11-12-	Caterpillar 3516

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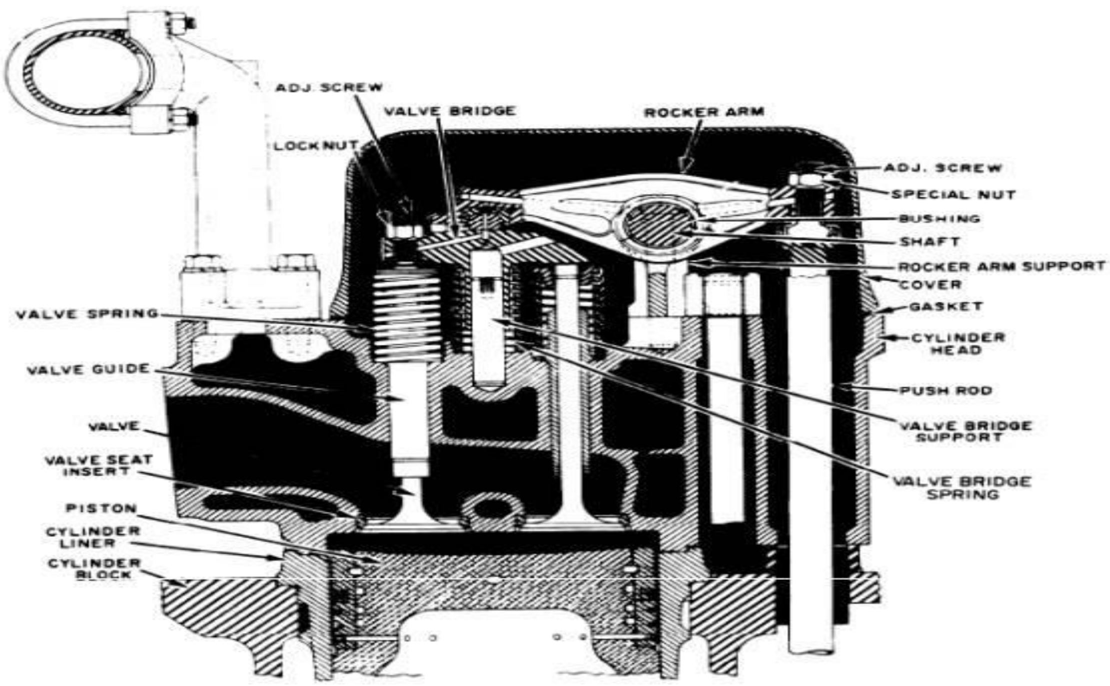
SIDE VALVE ACTUATING MECHANISM OVER HEAD VALVE ACTUATING MECHANISM

Valve mechanisms may vary considerably in construction and design, even though the function remains the same. The basic types of valve mechanisms are described briefly in *Fireman,* NAVEDTRA 10520-H. We will go into more detail in the following paragraphs. ACTUATING MECHANISM, as used in this chapter, is that combination of parts that receives power from the drive mechanism and transmits the power to the engine valves. In order for the intake and exhaust valves, fuel injection, and air start to operate, there must be a change in the type of motion. The rotary motion of the camshaft must be changed to a reciprocating motion. The group of parts that, by changing the type of motion, causes the valves of an engine to operate is generally referred to as the VALVE ACTUATING MECHANISM. A valve-actuating mechanism may include the camshaft, cam followers, pushrods, rocker arms, and valve springs. In some engines, the camshaft is so located that pushrods are not needed. In such engines, the cam follower is a part of the rocker arm.



Arrangement of Valves

Engine may be classified according to the location and type of the valve system employed (Fig. 2.31). With both inlet and exhaust valves located on one side of the cylinder, a cross-section view would be an L-shape. This type of valve arrangement is, therefore, called a L-head or flat-head engine. The valves in this case are operated by a single camshaft. This is relatively simple and dependable arrangement, but the design has two drawbacks. It cannot achieve high compression ratio, and causes greater pollution as its exhaust gas contains high amount of HC and CO. The reason is that the combustion chamber surfaces are large and relatively cool. This prevents combustion of the layers of air-fuel mixture close to these surfaces. If one valve on each side of the cylinder is used, as a modification to the above arrangement, it is called a T-head engine and the arrangement uses two camshafts for the operation of valves.

Most current automobile engines have both valves in the cylinder head. This reduces the cost of the engine block and allows better engine breathing by providing a large inlet port on one side of the head and large exhaust port on the other side. The head is a large complex casting that provides openings for valve ports, coolant, valve actuating devices, and lubricant. The added cost and complexity of these type of cylinder head is offset by the reduced cost of the block and by the added performance produced by better engine breathing. This type of engine is called an I-head or overhead valve (OHV) engine. Engines with combined features of both the L-head and the I-head engines have also been produced.

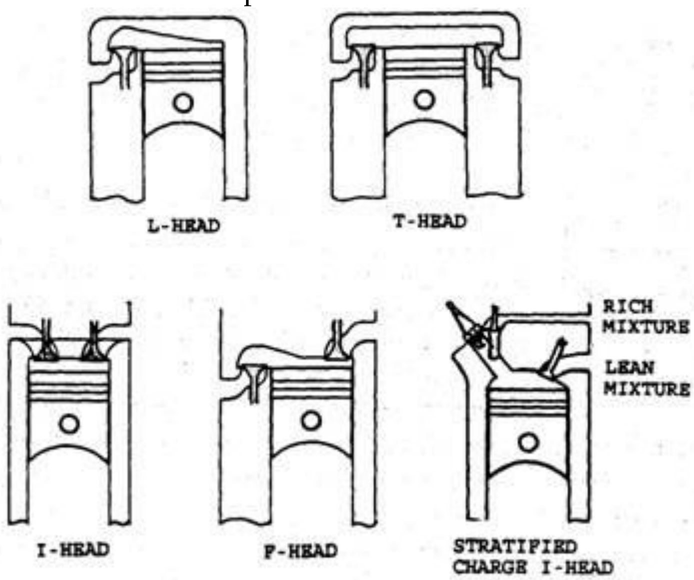


Fig. 2.31. Valve arrangements.

When one valve is in the head and the other valve is in the block, this is called a F-head engine. This arrangement employs one camshaft. This has many of the advantages and disadvantages of both L-head and I-head engines. The F-head engine has seen limited production.

A modification of the I-head engine includes a third small valve located with the spark plug in a pre-combustion chamber connected by a passage to the combustion chamber. During the intake stroke a rich fuel mixture is inducted through the small valve and a lean mixture through the normal intake valve. During compression, with all valves closed, some of the mixture is pushed back into the pre-combustion chamber. Ignition occurs easily in the rich charge located in the pre-combustion chamber. The hot burning gases rush from the pre-combustion chamber into the lean charge in the main combustion chamber, igniting it. In this way a very lean charge can be burned in the engine to minimize emission. Engines of this type are called stratified charge I-head engines.

In I-head engine, with valves in the head, the camshaft is usually located in the block. An alternate location in some engines is that the camshaft is placed above the valves on the head. This is called an overhead cam engine. When the camshaft is located in the block, the overhead valves are driven through a lifter, push rod and rocker arm assembly. When the camshaft is lo-

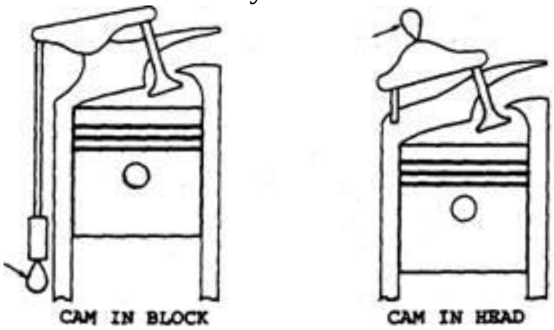


Fig. 2.32. Camshaft location.

cated on the head, the valves are actuated by some type of cam follower. The arrangements are shown in Fig. 2.32.

An I-head V type engine is shown in Fig. 2.23. Figure 2.34 illustrates an F-head engine, where the intake valves are in the head, and the exhaust valves are in the block. A six-cylinder flat head engine is shown Fig. 2.35. An in-line six-cylinder OHV engine is shown in Fig. 2.36. An overhead camshaft arrangement is shown in Fig. 2.37.

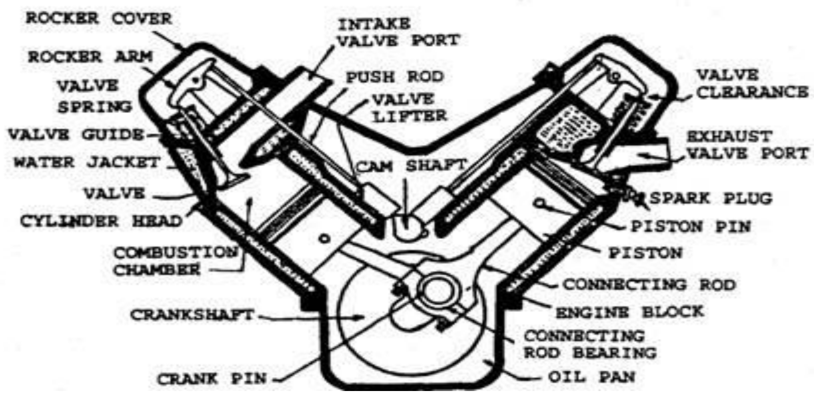


Fig. 2.33. I-head V-type engine.

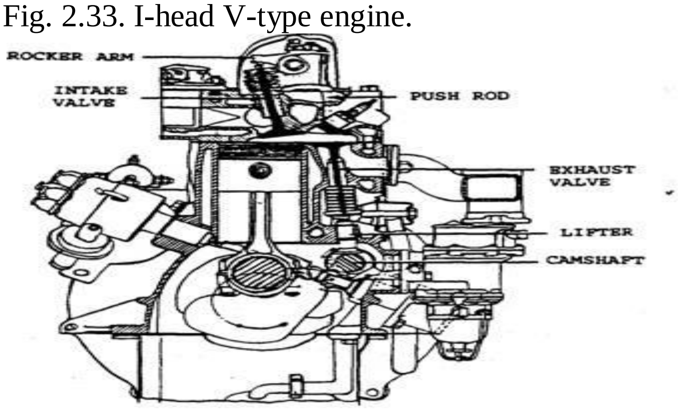


Fig. 2.34. F-head engine.

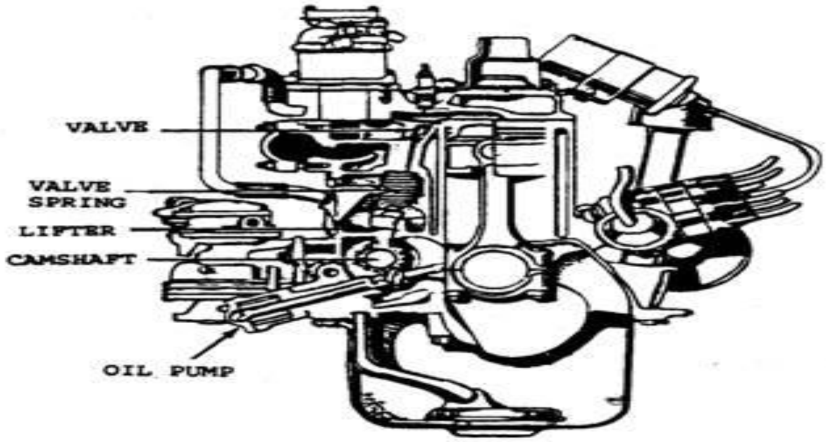


Fig. 2.35. A six-cylinder flat head engine.

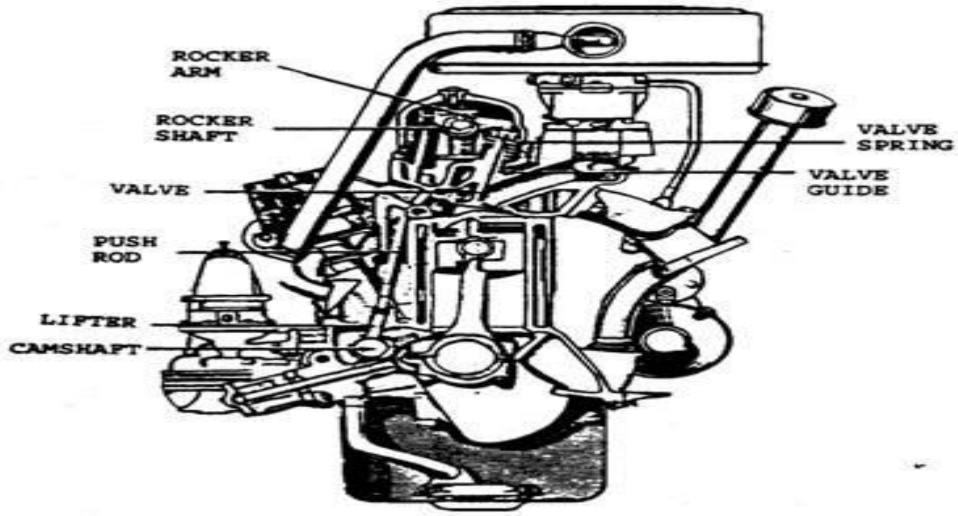


Fig. 2.36. An in-line, six-cylinder OHVengine.

Main advantages of side valve engines are as follows :

(a) Overall engine height can be low.
(b) Less complicated head casting.
(c) A side valve engine generally retains its 'tune' longer than an overhead valve unit and shows greater tolerance for fuel.

(d) No push rods and rocker arms etc. are required to operate valves, therefore fewer moving parts are found.
(e) Special valve stem, oil-sealing arrangements are not required.

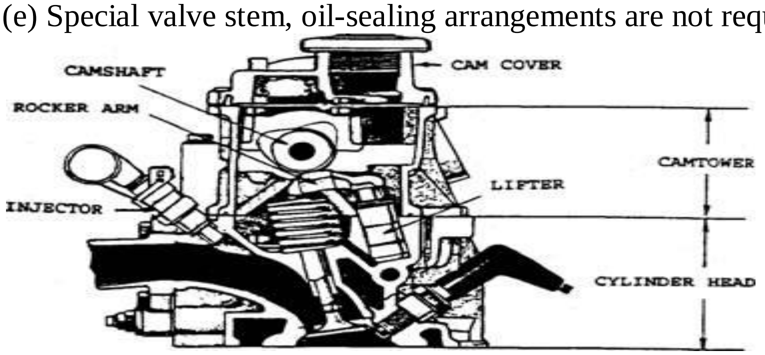


Fig. 2.37. An overhead camshaft engine.

On the other hand an overhead valve engine has the following main advantages :

(a) Greater accessibility.
(6) Better filing of cylinders as induction of gas in helped by the action of gravity and ports can be made of better shape.
(c) Cylinder block casting is less complicated.
(d) Higher compression ratio can be obtained.
(e) Design of combustion chamber can be easily varied than with a side valve engine.

2.7.1.

Valve Timing

The valves are made to open or close very slowly to provide quiet operation under high-speed conditions. The timing of opening and closing of both the valves is controlled by the design of the cams on the engine camshaft. In practice, the events of four-stroke cycle do not start and finish exactly at the ends of the strokes. For better breathing and exhausting, both the inlet and exhaust valves have lead, lag and overlap periods. These early and the late opening and closing events can be presented on a valve-timing diagram. The opening and closing points of the valves in relation to piston and crankshaft positions are called the valve timing.

Lead is the opening of the valve before the piston has reached either TDC or BDC.

Lag is the closing of the valve after the piston has reached BDC and closing or opening (some cases) after the piston has reached TDC. f

Overlap is the period during which both the valves are open.

The amount of lead or lag during valve opening or closing and the amount of overlap depend on the design of the engine (particularly the port arrangement, and inlet and exhaust systems) and on the required performance characteristics the engine. The opening point of the inlet valve and the closing point of the exhaust valve depend upon the following conditions :
(a) The velocity of the flow of exhaust gases along the exhaust manifold, which in turn depends upon engine speed, throttle opening, the length and diameter of the exhaust pipe, and the flow restriction in the silencer.
(b) The pressure in the inlet manifolds, which is dependent upon engine speed and throttle opening.
(c) The position of the ports with respect to the combustion chamber and to each other.

Inlet Valve Timing.

In most engines the inlet valve opens slightly before the piston starts downward on the suction stroke and closes after the piston has started upward following completion of the suction stroke. This is necessary to permit the valve to be open sufficiently for full induction of the charge. The inlet valve remains open until the piston reaches a point in the next upward stroke (the compression stroke) so that the pressure in the cylinder equals that of outside. This period varies in different designs of the automobile engines ranging from 28 to 71 degrees of crankshaft rotation. Figure 2.38 illustrates the valve timing data for the inlet valve of a typical automobile engine, where the valve starts to open 5 degrees before TDC i.e. during 5 degrees of the exhaust stroke, remains open during the 180 degrees of the normal suction stroke and in addition during 45 degrees of the beginning of the compression stroke. This gives the

inlet valve a total opening of 230 degrees of crankshaft
rotation.
Exhaust Valve Timing.
The exhaust valve opens before the completion of the expansion stroke. Due to this the gases
have an outlet for expansion, which removes the greater part of the burned gases, reducing the amount of work to be done by the piston on its return stroke. This compensates for the waste of the some of the force of the expansion due to opening of exhaust valve. However, the valve should not be opened too early. During the next upward stroke i.e. exhaust stroke, the remaining gases are forced out of the exhaust valve. The gases are slightly under compression and some amount of compressed exhaust gases are left in the clearance space when the piston is at TDC. Therefore, for best performance of the engine the exhaust valve remains open for a short time after the commencement of the suction stroke. The chances of drawing the exhaust gas back into the cylinder due to this opening of exhaust valve is small as the compressed exhaust gases are at higher pressure than that in the

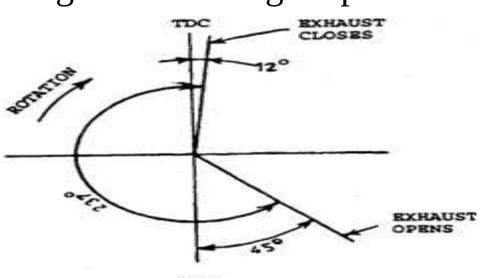


Fig. 2.38. Inlet valve timing diagram.

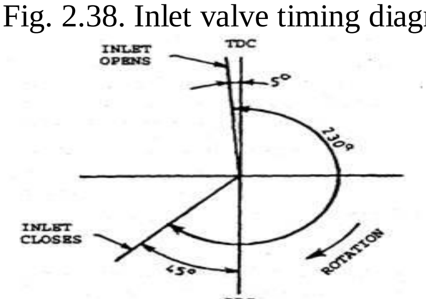


Fig. 2.39. Exhaust valve timing diagram.
manifold and the movement of piston is very little, for 10 to 15 degrees movement of the crankshaft.
Figure 2.39 shows the exhaust valve timing data where the valve opens 45 degrees before

BDC and closes 12 degrees after the TDC. Considering the normal opening of 180 degrees in the exhaust stroke, the total exhaust valve opening becomes 237 degrees.

Valve Overlap.

Thus it can be seen in Figs. 2.38 and 2.39 that the 5 degrees pre-admission of the inlet valve causes it to overlap 5 degrees with the exhaust valve. The closing of exhaust valve 12 degrees after the TDC produces 12 degrees overlap. Hence the total overlap is 17 degrees.

CHAPTER-2

2.DIESEL ENGINE AND ITS CONSTRUCTIONAL DETAILS

Working principle of four stroke Diesel engine.

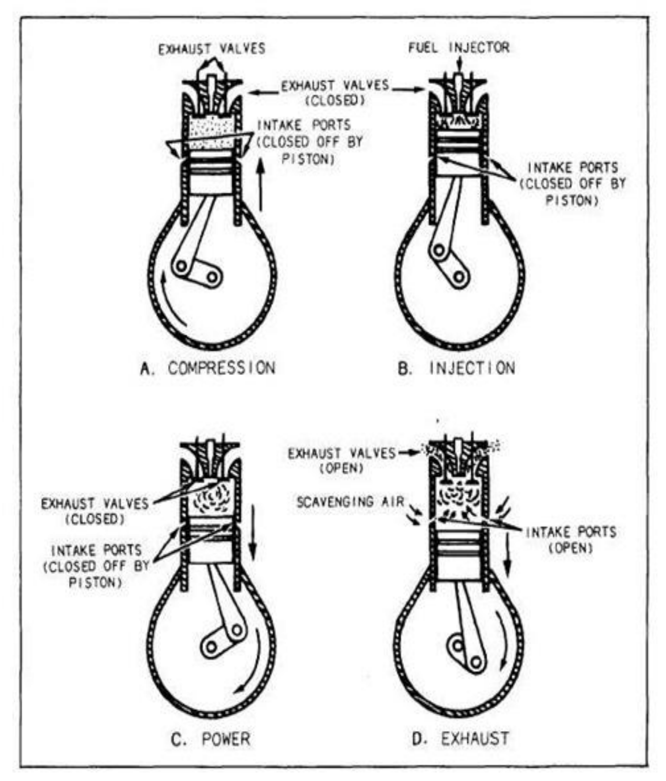
There are four strokes as:

1. Suction Stroke
2. Compression stroke
3. Expansion stroke
4. Exhaust stroke

1. Suction stroke: This stroke starts with the piston at top dead centre position. The inlet value is opened and the exhaust value is closed. The downward movement of the piston creates vacuum in the cylinder due to which air is drawn into the cylinder. The movement of the piston is obtained either by the starter motor or by the momentum of the fly wheel.

2. Compression stroke: This stroke starts with the piston at B.D.C. position. Both the inlet and exhaust values are closed.

The air sucked during the suction stroke is compressed as the piston moves in the upward direction. A few degree before the completion of compression stroke, a very fine spray of diesel is injected into the compressed air. The fuel ignites spontaneously.



3. Expansion stroke: Both the inlet and exhaust valves remain closed. The heat energy released by the combustion of the fuel, results in the rise in pressure of the gases. This high pressure rise drives the piston in the downward direction, thereby producing some useful work. This stroke is called as power stroke.

4. Exhaust stroke: This stroke starts with the piston at the B.D.C. position. The inlet value remains closed whereas the exhaust value is opened. The upward movement of the piston pushes the burnt gases out of the cylinder through the exhaust valve. At the end of exhaust stroke, the exhaust valve is also closed.

WORKING PRINCIPLE OF 2 STROKE DIESEL ENGINE

1. 1st Stroke – As the piston starts rising from its B.D.C. position, it closes the transfer and the exhaust port. The air which is already there in the cylinder is compressed. At the same time with the upward movement of the piston, vacuum is created in the crank case. As soon as the inlet port is uncovered the fresh air is sucked in the crank case. The charging is continued until the crank case and the space in the cylinder beneath the piston in filled with the air.

2. 2nd Stroke – Slightly before the completion of the compression stroke a very fine spray of diesel is injected into the compressed air (which is at a very high temperature). The fuel ignites spontaneously.

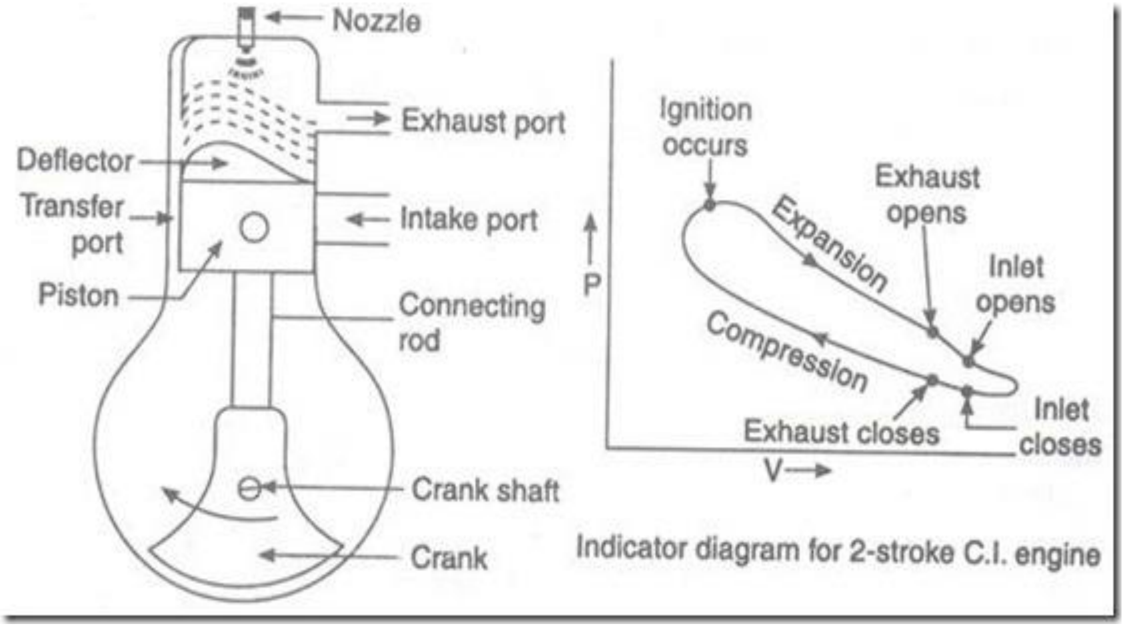


Figure of Two stroke CI Engine

Pressure is exerted on the crown of the piston due to the combustion of the air and the piston is pushed in the downward direction producing some useful power. The downward movement of the piston will first close the inlet port and then it will compress the air already sucked in the crank case.

Just at the end of power stroke, the piston uncovers the exhaust port and the transfer port simultaneously. The expanded gases start escaping through the exhaust port and at the same time the fresh air which is alredy compressed in the crank case, rushes into the cylinder through the transfer port and thus the cycle is repeated again.

ADVANTAGES AND DISADVANTAGES OF DIESEL VEHICLES

Advantages

- Diesels get great mileage. They typically deliver 25 to 30 percent better fuel economy than similarly performing gasoline engines.
- Diesel fuel is one of the most efficient and energy dense fuels available today. Because it contains more usable energy than gasoline, it delivers better fuel economy.
- Diesels have no spark plugs or distributors. Therefore, they never need ignition tune-ups.
- Diesel engines are built to withstand the rigors of higher compression. Consequently, they usually last much longer than gas-powered vehicles before they require major repairs.

Disadvantages

- Although diesel fuel used to be cheaper than gasoline, it now often costs the same amount or more.
- Although diesel fuel is considered to be more efficient because it converts heat into energy rather than sending the heat out the tailpipe as gas-powered vehicles do, it doesn’t result in flashy high-speed performance.

- Diesels still need regular maintenance to keep them running. You have to change the oil and the air, oil, and fuel filters.
- If you neglect the maintenance and the fuel injection system breaks down, you may have to pay a diesel mechanic more money to get things fixed than you would to repair a gasoline system because diesel engines are more technologically advanced.

Difference Between Diesel and Petrol Engine	
Diesel Engine	Petrol Engine
These engines work on the Diesel cycle	Works on the Otto cycle
The fuel is mixed with air inside the cylinder	Air and the fuel are mixed in a carburettor
Ignition is achieved with the help of the hot, compressed air.	Fuel is ignited with an electric spark
High compression ratio	Relatively low compression ratio
High power production	Relatively low amounts of power are produced in a Petrol engine
These engines work with fuels that have low volatilities	Highly volatile fuels are used in these internal combustion engines
Generally used in heavy vehicles such as trucks and buses	Used in light vehicles such as motorcycles and cars.
Relatively low fuel consumption	High fuel consumption.
High initial and maintenance costs	Comparatively low initial cost and maintenance cost

DIFFERENT TYPES OF COMBUSTION CHAMBERS FOR CI ENGINES

Unlike spark Ignition combustion chambers, the main important function of the combustion chamber of CI engines is to allow the injected fuel to properly mix with the pre-compressed air in a short time. In this article, we are going to discuss the different types of combustion chambers for CI Engines.

ombustion chambers are classified into two categories.

Types of combustion chambers for CI Engines

There are two different types of combustion chambers for CI Engines.

- Direct Injection type

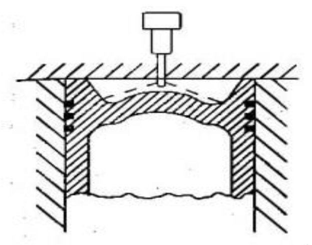
- Indirect Injection type

Direct Injection type combustion chambers
[illegible]

There are four design variants available in Direct Injection type combustion chambers. those are

1. Shallow depth chamber
2. Hemispherical chamber
3. cylindrical chamber
4. Toroidal chamber

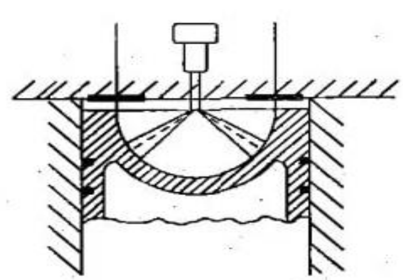
1. *Shallow depth chamber*


1. Shallow depth chamber

1. Shallow depth chamber

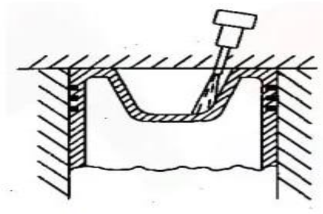
Shallow depth combustion chambers are mostly used in the heavy engines running with the low speeds. As you can see the shallow depth chamber diagram, the depth of the cavity provided in the piston is quite small and the diameter is large. Due to the large diameter, there will be almost negligible squish.

2. **Hemispherical chamber**


2. Hemispherical chamber

As you can see the hemispherical chamber, the depth to the diameter ratio can be varied. so that the squish can be controlled to attain better performance.

3. Cylindrical Chamber



3. Cylindrical Chamber

In a few modern diesel engines, this type of combustion chambers was implemented. As you can see the Cylindrical Chamber diagram, the shape of the combustion chamber is truncated cone with the base angle of 30°. The Squish can be varied by varying the depth. The swirl can be produced by masking the valve for nearly 180°of the circumference. Squash also can be controlled by varying the depth.

4.Turbulence Chamber

The turbulence chamber is similar in appearance to the pre-combustion chamber, but its function is different. There is very little clearance between the top of the piston and the head, so a high percentage of the air between the piston and cylinder head is forced into the turbulence chamber during the compression stroke. The chamber is usually spherical, and the small opening through which the air must pass causes an increase in air velocity, as it enters the chamber. This turbulence speed is about 50 times crankshaft speed. The fuel injection is timed to occur when the turbulence in the chamber is greatest. This ensures a thorough mixing of the fuel and air, causing the greater part of combustion to take place in the turbulence chamber. The pressure, created by the expansion of the burning gases, is the force that drives the piston downward on the power stroke.

Advantages of Direct Injection type combustion chambers

- Minimum Heat loss during the compression because of lower surface area to volume ratio results in better efficiency.
- Cold starting problems can be avoided.
- The multi-hole nozzle can be possible and hence fine atomization can be achieved.

Disadvantages of Direct Injection type combustion chambers

- High fuel injection pressure required. Hence complex design of fuel injection system.
- Metering of fuel should be accurate. Particularly for small engines.

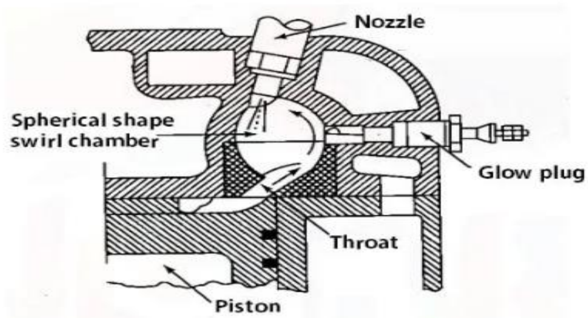
Indirect Injection type combustion chambers

In this type of combustion chambers, they are having two parts. One part will be located in the cylinder and the other part will be in the cylinder head. The fuel will be injected into the part which is located in the cylinder head.

There are three variant designs available in indirect Injection type combustion chambers. those are

1. Swirl Chamber
2. Pre-combustion chamber
3. Air cell chamber

1. Swirl Chamber

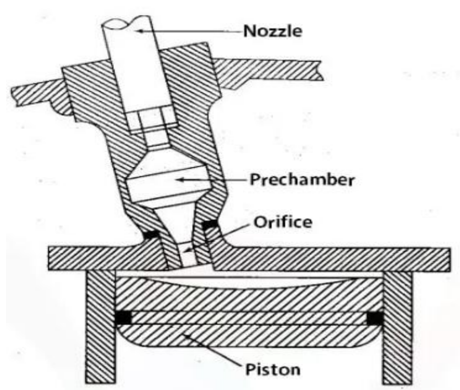


This is also known as the Ricardo swirl chamber. Swirl combustion chamber consists of the spherical-shaped chamber located in the cylinder head separated from the engine cylinder. During the compression stroke, 50% of the air will be transferred to this swirl chamber. In this spherical shaped swirl chamber, the fuel will be injected with the help of a nozzle and the combustion will be initiated.

The main drawback of this chamber is that the heat loss is greater compared to the open combustion chambers.

These chambers are used where the less quality of fuels are used. Where reliability is the main objective than the fuel economy.

2. Pre-combustion chamber

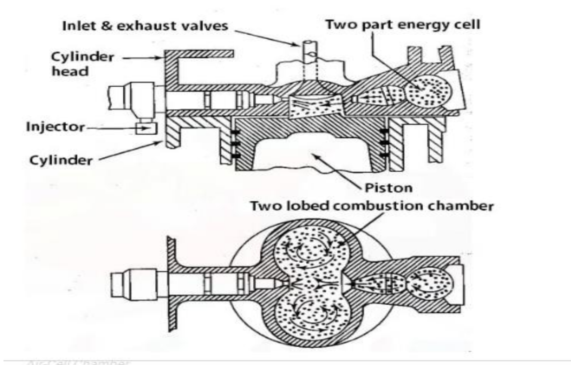


As you can see the above diagram of the Pre-combustion chamber. It consists of the Pre-chamber connected to the main chamber. This Pre-chamber located in the cylinder head. This Pre-chamber volume accounts for 40% of the total combustion space.

During the compression stroke, the air will be injected into the Pre-chamber the combustion will be initiated in it. But the bulk combustion will be taken place in the main chamber only. About 80% of the energy will be released in the main combustion chamber.

The rate of pressure rise and the maximum pressure attain during the combustion process is comparatively low than the open combustion chambers.

3.Air-Cell Chamber



In this combustion chamber, the clearance volume will be shared by the two parts. One portion of the clearance will be in the main cylinder. The second portion will be called the energy cell. In energy cell itself, there will be two parts again. One is major and the other one is minor which were separated by the main chamber connected by the narrow orifices.

The nozzle injects the fuel across the main combustion chamber space towards the open neck the air cell.

During the compression stroke, the main chamber pressure will be more than the energy cell pressure. When the temperature reaches high in the main chamber, The combustion will starts in the main chamber initially. In the energy, the cell contains the well-mixed charge, due to the heat release in the main chamber the high-pressure combustion particles will blow out thru the small passages into the main chamber. This high-velocity jet produces swirling motion in the main chamber thereby thoroughly mixes the fuel with the air, therefore the combustion will be completed.

Advantages of indirect Injection type combustion chambers

The main advantage of the indirect injection combustion chambers are

- Injection pressure required is low.
- The direction of the spray is not that important.

Disadvantages of indirect Injection type combustion chambers

- Poor cold starting performance.
- Specific fuel consumption is high.

These are the different types of combustion chambers for the CI engines.

CHAPTER-3

PERFORMANCE OF I.C ENGIN

(a) Mechanical efficiency. It is the ratio of brake power (B.P.) to the indicated power (I.P.).

Mathematically, mechanical efficiency,

$$\eta_m = \frac{\text{B.P.}}{\text{I.P.}}$$

Since B. P. is always less than I.P. , therefore mechanical efficiency is always less than unity (i.e. 100%).

(b) Overall efficiency. It is the ratio of the work obtained at the crankshaft in a given time to the energy supplied by the fuel during the same time. Mathematically, overall efficiency,

$$\eta_o = \frac{\text{B.P.} \times 3600}{m_f \times C}$$

where

B.P. = Brake power in kW,
mf = Mass of fuel consumed in kg per hour, and
C = Calorific valve of fuel in kJ / kg of fuel.

(c) Indicated thermal efficiency. It is the ratio of the heat equivalent to one kW hour to the heat in the fuel per I.P. hour, Mathematically, indicated thermal efficiency,

$$\eta_i = \frac{\text{Heat equivalent to one kW hour}}{\text{Heat in fuel per I.P. hour}} = \frac{\text{I.P.} \times 3600}{m_f \times C}$$

Note : The following ratio is Known as specific fuel consumption per I.P. hour:

$$\frac{m_f}{\text{I.P.}}$$

(d) Brake thermal efficiency. It is the ratio of the heat equivalent to one kW hour to the heat in the fuel per B.P. hour. Mathematically, brake thermal efficiency,

$$\eta_b = \frac{\text{Heat equivalent to one kW hour}}{\text{Heat in fuel per B.P. hour}} = \frac{\text{B.P.} \times 3600}{m_f \times C}$$

Note: The following ratio is known as specific fuel consumption per B. P. hour:

$$\frac{m_f}{\text{B.P.}}$$

(e) Air standard efficiency. The general expression for the air standard efficiency is given as

(For petrol engines)

$$\eta_{air} = 1 - \frac{1}{r^{\gamma-1}}$$

(For diesel engines)

$$= 1 - \frac{1}{r^{\gamma-1}}\left[\frac{\rho^{\gamma}-1}{\gamma(\rho-1)}\right]$$

r = Compression ratio,
γ = Ratio of specific heats, and
ρ = Cut-off ratio.

(f) Relative efficiency. It is also known as efficiency ratio. The relative efficiency of an I. C. engine is the ratio of the indicated thermal efficiency to the air standard efficiency.

(g) Volumetric efficiency. It is the ratio of the actual volume of charge admitted during the suction stroke at N.T.P to the swept volume of the piston.

In Reciprocating Internal Combustion engines, it is the measure of the capacity to do the work. The Mean effective pressure means the simply average pressure acting on the piston during the complete thermodynamic cycle in a Reciprocating internal combustion Engine.

Mean Effective Pressure

As we said it is an average pressure acting on the piston during the complete thermodynamic cycle in a Reciprocating internal combustion Engine.

There are different Mean Effective Pressures that we need to understand completely. Those are listed below.

- IMEP – Indicated Mean Effective Pressure
- BMEP –Brake Mean Effective Pressure
- FMEP – Friction Mean Effective Pressure

Indicated Mean Effective Pressure (IMEP)

The Indicated Mean Effective Pressure is the average pressure, that induced in the combustion chamber during the complete thermodynamic cycle in Internal Combustion engines. In here we will have two more different Indicated Mean effective pressures. Those are Gross Indicated Mean Effective Pressure and Net Indicated Mean Effective Pressure.

Gross Indicated Mean Effective Pressure ($IMEP_g$)

It is the average pressure in the cylinders during the Compression and the Expansion Strokes only. Not the complete Thermodynamic cycle.

Net Indicated Mean Effective Pressure ($IMEP_n$)

But where the Net Indicated Mean Effective Pressure is the average pressure in the cylinders during the complete Thermodynamic cycle.

This Indicated Mean Effective Pressure can be obtained by a direct measurement such as a cylinder pressure sensing Equipment is required to measure this.

Pumping Mean Effective Pressure (PMEP)

The difference between the Net Indicated Mean Effective Pressure and the Gross Indicated Mean Effective Pressure will give the Pumping Mean Effective Pressure (PMEP).

Pumping Mean Effective Pressure (PMEP) = $IMEP_g$ – $IMEP_n$

Brake Mean Effective Pressure (BMEP)

Unlike the Indicated Mean Effective Pressure (IMEP), we can calculate the Mean Effective Pressure from the torque generated at the crankshaft.

The torque generated at the crankshaft is called the Brake Torque. So the Mean effective pressure calculated from the Brake torque is called the Brake Mean Effective Pressure.

Friction Mean Effective Pressure (FMEP)

We can understand that the Mean Effective pressure at the cylinders ($IMEP_n$) and the Mean effective pressure (BMEP) calculated from the brake torque are different. In fact, the Mean effective pressure (BMEP) calculated from the brake torque is less than the Mean Effective pressure at the cylinders ($IMEP_n$). Because of the friction losses.So the Friction Mean Effective pressure can be defined as the Mean Effective Pressure lost due to the friction. This can be calculated from the Net Mean Effective Pressure and the Brake Mean Effective Pressure. (See the following formula)

$$FMEP = IMEP_n - BMEP$$

Well, now we have a full understanding of Mean Effective Pressure terminology.

Let's see how we can calculate them with the different parameters.

How to calculate the Mean Effective Pressure?

Generally, Mean Effective Pressure can be calculated from work done by the engine and the engine displacement.

$$p_{me} = W/V_d$$

Where:

p_{me} – Mean Effective Pressure

W – Work performed in a complete engine cycle (Units In Joules)

V_d – Engine (cylinder) displacement (Units in m^3)

We can write the above equation in terms of the power or torque also.

as we know Power (P)= Work × (Engine Speed in RPM / Revolutions per power stroke)

$$P = W \times (N/n_r)$$

Where n_r = Number of revolutions per power stroke (4 Stroke engine = 2; for 2 Stroke Engine = 1)

And also we know the power in terms of Torque (P) = 2π N T

By substituting P in the above equation, we can write

$$W = 2\pi\ T \times n_r$$

We can rewrite the MEP from the above equations

$$p_{me} = (2\pi\ T \times n_r)/V_d$$

For an engine with multiple cylinders, we have to take into account the total volumetric capacity.

Here n_c will be the number of cylinders, so the Mean effective pressure for the multiple cylinder engines is

$$p_{me} = (2\pi\ T \times n_r)/n_c V_d$$

AIR–FUEL RATIO (AFR):-Air–fuel ratio is the mass ratio of air to a solid, liquid, or gaseous fuel present in a combustion process. The combustion may take place in a controlled manner such as in an internal combustion engine or industrial furnace, or may result in an explosion.

The air-fuel ratio determines whether a mixture is combustible at all, how much energy is being released, and how much-unwanted pollutants are produced in the reaction. Typically a range of fuel to air ratios exists, outside of which ignition will not occur. These are known as the lower and upper explosive limits.

Fuel Calorific Values

The calorific value of a fuel is the quantity of heat produced by its combustion – at constant pressure and under "normal" (standard) conditions (i.e. to 0^{o}C and under a pressure of 1,013 mbar).

The combustion process generates water vapor and certain techniques may be used to recover the quantity of heat contained in this water vapor by condensing it.

- Higher Calorific Value (or Gross Calorific Value – GCV, or Higher Heating Value – HHV) – the water of combustion is entirely condensed and that the heat contained in the water vapor is recovered;
- Lower Calorific Value (or Net Calorific Value – NCV, or Lower Heating Value – LHV) – the products of combustion contains the water vapor and that the heat in the water vapor is not recovered.

Fuel Calorific Values

Natural gas	12500 kcal/kg
Propane-butane	11950 kcal/kg
Disel	10000 kcal/kg
Fuel oil	9520 kcal/kg
Brown coal	3500 kcal/kg
Woods	2500 kcal/kg

Electricity	860 kcal/kWh

LPG has more calorific value when compared to diesel, petrol, and kerosene.

A detailed list of foods and their calorific values:

The calorific value of food indicates the total amount of energy, a human body could generate during its metabolism which is expressed in Kilojoules per 100 grams or 100 ml. The calorific value of food is generally expressed in kilocalories i.e. kcal.

The below table shows the type of food and its calorific value:

Category of food	Quantity(Grams)	Calorific value (Approximately)	
		Kilojoules(KJ)	Kilocalories(Kcal)
Dietary fibre	1	8	2
Polyhydric Alcohols	1	10	2.4
Alcohols	1	29	7
Carbohydrates	1	17	4
Protein	1	17	4
Fats	1	37	9

Fats have more calorific value when compared to carbohydrates, protein, alcohols, roughage and other biomolecules involved in the maintenance and metabolic processes.

Importance of Calorific Value

It is very important to have a knowledge of the calorific value of fuel to carry out our day-to-day activities. This knowledge helps us to determine the amount of energy we transport. The gas shippers and suppliers require this information to bill gas consumers. It also helps to determine transportation charges of gas shippers and suppliers.

The human body requires calories to carry out daily activities. Without calories, the body would stop working and the cells in the body would die. But, if people consumed only a specific amount of calories each day, they would lead a healthy life. Too high or too low calorie consumption eventually leads to health problems.

Difference Between Octane Number and Cetane Number

Definition

Octane Number: Octane number is a measure of the performance of a fuel.
Cetane Number: Cetane number is the measure of the delay of the ignition of a fuel.

Importance

Octane Number: Octane number is important for predicting the knocking of an engine.
Cetane Number: Cetane number is important for predicting the ignition of an engine.

Application

Octane Number: Octane number is given for gasoline.
Cetane Number: Cetane number is given for diesel.

Comparison

Octane Number: Octane rating is done considering the octane number of isooctane as 100.
Cetane Number: Cetane rating is done considering the ignition of cetane.

Sr. no	**Octane number**	Cetane number
1	Octane number of a petrol sample is defined as the % of iso-octane Octane in the mixture of iso-octane & n-heptane, which has similar,knocking to the petrol sample.,.	Cetane number of diesel sample is defined as % of nhexadecane,in the mixture of n-hexadecane & 2-methyl naphthalene which,has same ignition character like the ignition character of the diesel under,test.
2	Octane rating is used for petrol	Cetane rating is used for diesel
3	The fuel with high octane rating has low cetane number	The fuel with high cetane rating has low octane number
4	Octane number of good petro should be atleast,85 for motorcycle and cars 100 for aeroplanes and helicopters	Cetane number for good diesel should be 25 for low speed egine,35 for medium speed engine and 45 for high speed engine
5	Octane number of petrol can be increased by adding benzene or toluene	Cetane number diesel can be increased by adding by adding ethyl nitrate or acetone peroxide
6	Significance : High octane in gasoline allows the fuel to resist preignition	Significance : High cetane has a low resistance to preignition, while high,octane has a high resistance to preignition; both high cetane and high octane

Sr. no	**Octane number**	Cetane number
	under high pressure and heat	provide the ability to extract more power from fuel.

Heat Balance Sheet

A heat balance sheet is an account of heat supplied and heat utilized in various ways in the system. Necessary information concerning the performance of the engine is obtained from the heat balance.

The performance of an engine is generally given by a heat balance sheet. To draw a heat balance sheet for the I.C. engine, it is run at constant load and constant speed. The Indicator diagram is drawn with the help of an indicator. The quantity of fuel used in a given time and its calorific value, the amount, inlet, and outlet temperature of cooling water and the mass of exhaust gases are recorded.

The heat balance sheet is generally done on a second basis or a minute basis or an hourly basis.

The engine should be equipped with a suitable loading arrangement to measure the brake power of the engine. Provisions are also made to measure the amount of air intake. amount of fuel consumed, the temperature of cooling water at inlet and outlet of the engine amount of cooling water circulated and temperature of exhaust gases.

Use Of Heat Balance sheet :

1. To know an account of heat supplied and heat distributed in various ways in the system.
2. To analyses the performance of the engine.

Heat Balance Sheet Calculation :

The heat balance is generally done on a second basis or a minute basis or an hourly basis.

The heat supplied to the engine is only in the form of fuel-heat and that is given by

Qs = mf X CV

Where mf is the mass of fuel supplied per minute or per sec. and CV is the lower calorific value of the fuel.

The various ways in which heat is used up in the system is given by

(a) Heat equivalent of BP = kW = kJ/sec. = kJ/min.

(b) Heat carried away by cooling water
= Cpw X mw (Two – Twi) kJ/min.
Where,

- mw is the mass of cooling water in kg/min or kg/sec circulated through the cooling jacket
- (Two – Twi) is the rise in temperature of the water passing through the cooling jacket of the engine
- Cpw is the specific heat of water in kJ/kg-K.

(c) Heat carried away by exhaust gases
= mg Cpg (Tge – Ta) (kJ/min.) or (kJ/sec)

Where,

- mg is the mass of exhaust gases in kg/min. or kg/sec and it is calculated by using one of the methods already explained.
- Tg= Temperature of burnt gases coming out of the engine.
- Ta = Ambient Temperature.
- Cpg = Sp. The heat of exhaust gases in (kJ/kg-K)

(d) A part of the heat is lost by convection and radiation as well as due to the leakage of gases. Part of the power developed inside the engine is also used to run the accessories as a lubricating pump, camshaft and water circulating pump. These cannot be measured precisely and so this is known as unaccounted 'losses'.

Heat input per minute	*kcal (kj)*	*%*	*Heat expenditure per minute*	*kcal (kj)*	*%*
Heat supplied by the combustion fuel	Q_s	100%	(a) Heat in BP.	--	--
			(b) Heat carried by jacket cooling water	--	--
			(c) Heat Carried by exhaust gases	--	--
			(d) Heat unaccounted for $= Q_s - (a + b + c)$	--	--
Total	Q_s	100%			100%

How to calculate heat Balance Sheet For IC Engine

The results of the above calculations are tabulated in a table and this table is known as "Heat Balance Sheet". It is generally practice to represent the heat distribution as percentage of heat supplied. This is also tabulated in the same heat balance sheet.This unaccounted heat energy is calculated by the different between heat supplied Qs and the sum of (a) + (b) (c).

Heat Balance sheet Example :

Problem : An I.C. engine uses 6 kg fuel having calorific value 44000 kJ/kg. in one hour. The brake power developed is 18kW. The temperature of 11.5 kg of cooling water found to rise through 25 0C per minute. The temperature of 4.2 kg of exhaust gas with specific heat 1 kJ/kg K was found to rise though 220 0C. Draw heat balance sheet for the engine.

Answers :

Given data :

Mass of Fuel = 6 Kg/hr = 6/60 = 0.1 Kg/min. BP = 18 KW CV = 44000 kJ/kg

Mass of cooling water Mw = 11.5 Kg/min Cpw = 4.187 kJ/kg K

Temp rise of cooling water Δtw= 25 0C

Mass of exhaust gas Meg = 4.2 Kg/hr =4.2/60 Kg/min = 0.7 Kg/min

Temp rise of gas Δtg= 220 0C Cpg = 1 kJ/kg K

i) Heat equivalent in Fuel (Hf) = Mf x C V = 0.1 x 44000 = 4400 Kg/min

ii) Heat converted in B P (Hb) = B P x 60 = 18 x 60 = 1080 Kg/min

iii) Heat carried by cooling water (Hw) = Mw x Cpw x Δtw

Hw = 11.5 x 4.187 x 25 = 1203.76 Kg/min

iv) Heat in Exhaust Gas (Hg)= Mg x Cpg x Δtg

Hg = 0.7 x 1 x 220 = 154 Kg/min

v) Heat lost as Unaccounted (Ha)= Hf- (Hb+Hw+Hg)

Ha = 4400 – (1080+1203.76+154) = 1962.24 Kg/min

Parameter	Value (Kg/min)	Parameter	Value (Kg/min)
Heat equivalent in Fuel Hf	4400 Kg/min	Heat converted in B P Hb	1080 Kg/min
		Heat carried by cooling water Hw	1203.76 Kg/min
		Heat in Exhaust Gas Hg	154 Kg/min
		Heat lost as Unaccounted Ha	1962.24 Kg/min
Hf	4400 KJ/min	Total	4400 KJ/min

CHAPTER-4

FUEL FEED SYSTEM FOR PETROL & DIESELS ENGINE

There are many *types of fuel supply system in petrol engine*. The basic fuel supply system in an automobile petrol engine consists of a fuel tank, fuel Lines, fuel pump, fuel filter, air cleaner, carburetor, intake manifold.

For the supply of fuel from fuel tank to engine cylinder following fuel feed systems are used:

- Gravity system
- Air pressure system
- Vacuum system (suction and gravity system)
- Pump feed system
- Fuel injection system

GRAVITY FUEL FEED SYSTEM:

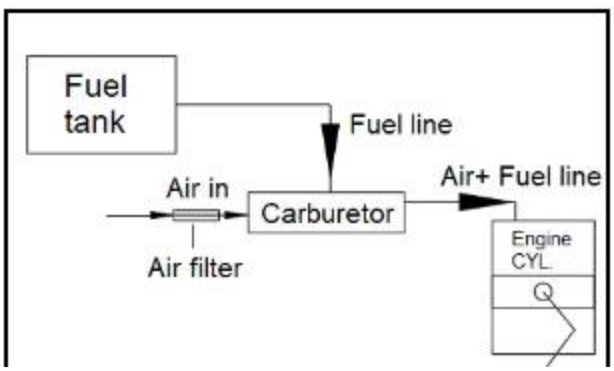
In this system, the fuel tank is mounted at the highest point of the SI engine. this system is quite simple and cheap as the fuel drops into the float Chamber of the carburetor under Gravity. it is used in a small engine having low fuel consumption as sufficient head is not developed for large engine.

- Advantages:

1. The system is quite simple and cheap as of other fuel feed system

- Disadvantages:

1. The rigidity of placing the fuel tank necessarily over carburetor is its disadvantage



AIR PRESSURE FEED SYSTEM:

In this system, an airtight fuel tank is used and is placed under the seat or near the engine. the hand operated a pump or mechanically operated pump supplies the high-pressure air to the fuel tank for supply the fuel to the carburetor.

- Advantages:

1. The fuel tank can be placed at any suitable location

- Disadvantages:

1. There are chances of pressure leak within the chamber

VACUUM FEED SYSTEM (Suction and Gravity system:

In this system, fuel from the fuel tank which is placed near the engine is sucked by means of suction from the induction manifold. by means of gravity, the fuel is supplied to the float of the carburetor.

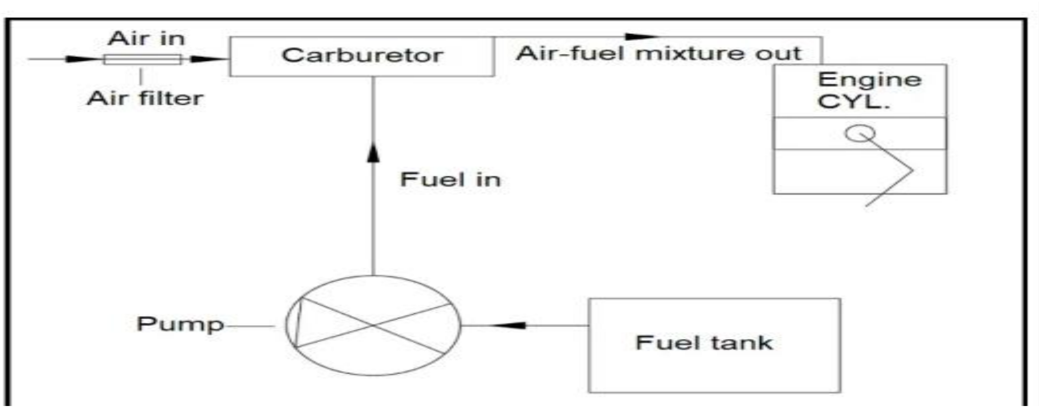
- Advantages:

1. The cost of the total system is less

PUMP FEED SYSTEM:

In this system, a steel pipe carries petrol to the fuel pump which Pumps it into the float Chamber of the carburetor through the pipe. here we use a mechanical or electrical or a diaphragm pump supplies the fuel from the fuel tank is placed at any suitable location and is vented to the atmosphere.

This system is used in most vehicles in the present days.



FUEL INJECTION SYSTEM:

The petrol injection system now comes to modern vehicles. the fuel is atomized by means of an air injector nozzle then delivered into an air stream. there may be separate fuel injectors are used for separate cylinder or one single fuel injector is used.

- **Advantages:**

1. This is the most accurate fuel supply system
2. High power is developed

3. It has quick starting and warms up
4. Low specific fuel consumption rate

- Disadvantages:

1. Back-flow of petrol may take place
2. High initial cost

THE COMPONENTS OF FUEL SUPPLY SYSTEM:

Fuel tank:

The fuel tank holds the fuel for the engine. It is made of steel or aluminum or synthetic rubber compounds and fiber reinforced plastics which are flame resistant. And these tanks are coated with lead-tin alloy to protect the tank from the corrosion effect.

This tank is placed in any suitable position of a vehicle. For front engine vehicle, the fuel tank is in the underside of a luggage compartment at the rear end or directly above the rear axle, and for rear engines, the fuel tank is placed in the front behind the compartment.

There are a couple of baffle plates inside the fuel tanks because of when brakes are applied to the vehicle the fuel surge inside the vehicle or when a car turn around then also fuel surge inside the tank so this baffle plate helps to reduce the surge of fuel inside the tank. These plates divide the tank in a number of the compartment which is interconnected through a pipe.

Petrol is filled by the small opening cap. A filter is placed at the tank end of the fuel line and a small hole is provided for vented to the atmosphere

A drain plug is fitted at the bottom of the tank to remove sediments and the fuel tank is also provided with a fuel gauge sensing unit for checking of fuel level inside the tank.

USE:

- It is used to store the fuel.

Fuel pump:

The fuel pump is used to deliver the fuel from the fuel tank to the carburetor.

There are generally two pumps are used:

1. A.C. Mechanical Pump
2. S.U. Electrical pump

USE:

- It supplies the high-pressure fuel from tank to the carburetor.

Fuel lines:

These tubes are used for connects the fuel tank with the pump and pump to the carburetor. Generally, these tubes are made of Copper or Steel.

The two joints of the tubes are made flexible because of the flexible joints help the fuel tank to moves back or front with the body, and also pump is moves according to the body. This joint prevents the loosening of fuel line by front-back movement of the body.

USE:

- This pipeline helps to deliver the fuel from the fuel tank to pump and to the carburetor.

Air cleaner:

This is very necessary for an engine to get fresh air, otherwise, the polluted air causes several damages to the engine chamber. Particularly Piston, Piston chamber, Piston ring, and Valves. And if the polluted air enters the crankcase where we store engine oil that can be damaged the lubrication parts like bearings. Therefore we need to install an air filter which purifies the air before entering the engine cylinder.

This can also act as a silencer for the carburetion system and also as a flame arrester when the engine has backfired.

The air filter will clean regularly. If you don't clean it can cause much fuel consumption, and reduce the engine efficiency.

The air cleaners generally used are two types:

1. Heavy duty types air cleaner
2. Light duty types air cleaner

USE:

- It used to clean the air.

Fuel filters:

A fuel filter is necessary for a vehicle to clean the fuel.

For this, a very affected device is used and that is chamois leather, which only allows to passing the petrol into it and the water is intercepted by this. And also fine particles can not pass through it.

USE:

- It is screened off the dirt or foreign matter from the fuel and prevents entry to the pump.

Fuel gauge unit:

A fuel gauge is an instrument which is fitted to the dashboard of the vehicle so that driver can know the amount of fuel inside the fuel tank.

USE:

- It indicates the fuel level in the tank.

Carburetor:

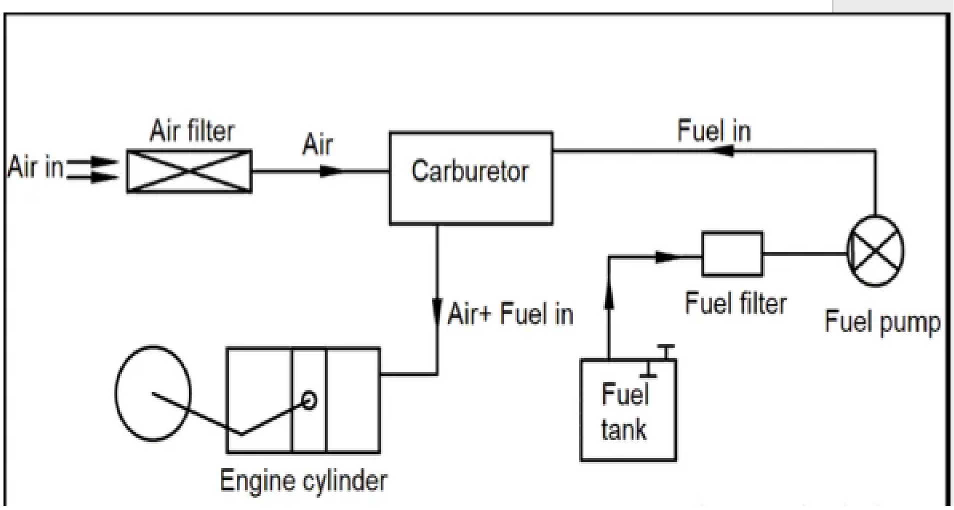
A perfect air-fuel mixture is necessary for a petrol engine to run. So, therefore, we use a carburetor. It is device which controlled the air-fuel mixture.

There are two chambers in carburetor one is float chamber which is used to maintain the fuel level with the help of needle valve and another one is mixing chamber where the mixture of air-fuel takes place.

I already wrote an article on Internal Combustion Engine where I mentioned the types of the carburetor and their working you can check that article for your reference.

The air-fuel ratio in the carburetor is about 15: its mean 15 kg of air has sufficient oxygen to burn 1 kg of petrol.

LAYOUT OF THE FUEL SUPPLY SYSTEM IN S.I. ENGINE:



Carburetor Definition:

It is a device (Use in Internal combustion engine) for mixing air with fuel in a system for the proper burn of fuel.

The carburetor is only used in a petrol engine, where spark ignition happens.

Parts of a simple carburetor:

So *what are the parts of a* Carburetor? A simple carburetor is constructed of the following parts:

1. **Throttle Valve**
2. **Strainer**
3. **Venturi**
4. **Metering system**
5. **Idling system**
6. **Float Chamber**
7. **Mixing Chamber**
8. **Idle and Transfer port**
9. **Choke Valve**

And also a modern carburetor consist of additional these parts:

1. Throttle return check
2. Anti-dieseling solenoid
3. Automatic mixture control

Throttle Valve:

Throttle Valve is an important part of a Carburetor. It controls the mixture of charge (air+fuel) supplied to the engine cylinder. The driver opens the throttle valve by pressing the accelerator.

Strainer:

It is a device that is used to filter the fuel before entering the float chamber.

It consists of a fine wire mesh which filters the fuel and removes dust and other suspended particles from it.

If these particles not removed, it can cause blockage of the nozzle.

Venturi:

The venturi is the gradually decreasing cross-sectional hollow tube. It helps to decrease the air pressure of the chamber. For which fuel comes out from the fuel pipe.

Metering system:

The metering system controls the flow of fuel into the nozzle. It is responsible to form a correct mixture of air-fuel.

It consists of two main parts:

1. Metering orifice and
2. Fuel discharge nozzle

When the air passes through venturi, it generates a low-pressure field across the throat. Due to this pressure difference, fuel is discharged into the air stream.

The quantity of fuel is control by the metering orifice and discharge hole at the exit of the fuel discharge nozzle.

Idling system:

The idling system consists of passage directly from the float chamber to the venturi tube.

It provides a rich mixture during idling and at low speed. It works during idling or when the throttle is open below 15%.

Float Chamber:

The float chamber serves as a storage tank of fuel for a continuous supply of fuel. It contains a float valve that maintains the level of fuel in the float chamber.

When the level of fuel decreases in the float chamber the float moves downward, which opens the fuel supply valve and allows the flow of fuel into the float chamber.

As the fuel level increases, the float moves upward which close and stop the fuel supply.

Mixing Chamber:

In the mixing chamber, the mixture of air + fuel occurred. And then supplied to the engine cylinder.

Idle and Transfer port:

In addition to the main nozzle in the venturi portion of the carburetor, two other nozzles, or ports, deliver fuel to the engine cylinder.

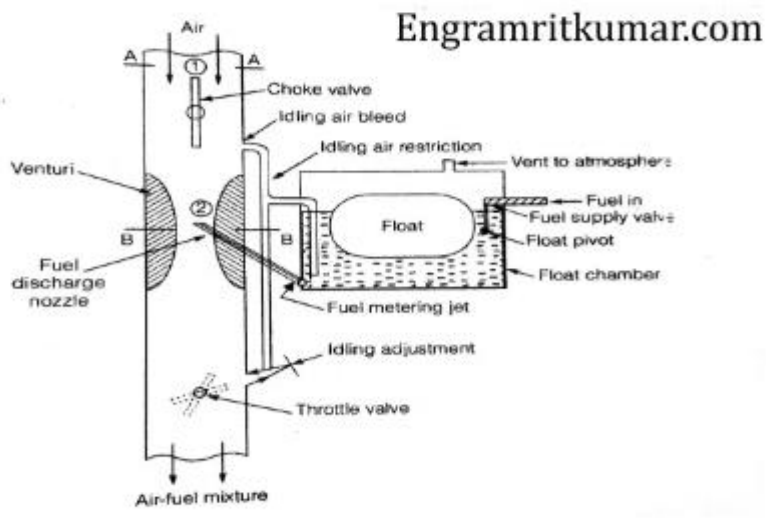
Choke valve:

Choke Valve is a valve that controls the mixture of air-fuel. The main function of this valve is to control the quantity of the air inside the mixing chamber.

This valve normally is in semi-open condition, but when we need a rich mixture of air-fuel we operate this valve and this valve is close the inlet of the air within the chamber, so we get a rich mixture of air-fuel because the quantity of fuel in the mixture is more because of less air in the chamber.

In the winter season when the engine is not starting we use this valve to get supply rich air-fuel mixture to the engine cylinder.

So these are some important parts of a Carburetor, hopefully, you understand these parts.



Schematic diagram of a carburetor

Now take a look at the parts with Special features of Modern Carburetors:
Throttle return check:

The total throttle suddenly on an engine running very high speed will cause a very high intake manifold vacuum, which will draw exhaust into the engine intake during v/v overlap.

This will dilute the intake chart to cause misfiring or even stall.

To prevent this a throttle return check v/v is connected to the throttle linkage in some modern carburetors

Anti-dieseling solenoid:

Modern emission control engine usually runs hotter, which may result in some hot spots on the combustion chamber.

These hot spots result in pre-ignition in the combustion chamber.

To avoid this some carburetors are equipped with an anti-dieseling solenoid to turning off the pre-ignition

Automatic mixture control:

A plunger shaped valve is operated by a solenoid and Spring and controls of the separate jet in the float chamber.

when the solenoid is turned on, the v/v is lifted which increases the fuel supply to the jet, and when the solenoid is turned off the spring pushes the valve down to decrease the fuel supply.

The solenoid is operated by a computer, according to the signals received by it on engine speed, coolant temperature.

These types of computer control carburetors are called feedback- controlled calculators.

Working of a Carburetor:

As we already knew, the Simple carburetor mainly consists of

1. Throttle Valve
2. Strainer
3. Venturi
4. Metering system
5. Idling system
6. Float Chamber
7. Mixing Chamber
8. Idle and Transfer port
9. Choke Valve

The Float and needle valve system maintains a constant level of gasoline in the float chamber.

If the amount of the fuel in the float chamber falls below the designed level, the float goes down, thereby opening the fuel supply valve and admitting fuel.

When the designed level has been reached, the float closes the fuel supply valve thus stoping additional fuel flow from the supply system.

The float chamber is vented either to the atmosphere or to the upstream side of the venturi.

During the suction stroke, the air is drawn through the venturi. Venturi is a tube of decreasing cross-section with a minimum area at the throat.

Venturi tube is also known as a choke tube and is so shaped that it offers minimum resistance to the airflow. As the air passes through the venturi the velocity increase reaching a maximum at the venturi throat.

Correspondingly, the pressure decreases reaching a minimum.

From the float chamber, the fuel is fed to a discharge jet, the tip of which is located in the throat of the venturi.

Because of the differential pressure between the float chamber and the throat of the venturi, known as carburetor depression, fuel is discharged into the air stream.

The fuel discharged is affected by the size of the discharge jet and it is chosen to give the required Air fuel ratio.

Types of Carburetor:

What are the types of a carburetor? There are three types of carburetors according to the direction in which the mixture is supplied.

- *Up-draft carburetor*
- *Horizontal type carburetor*
- *Down-draft type carburetor*

If the air is supplied from the bottom of the mixing chamber then it is called an up-draft type.

If the air is supplied from one side of the carburetor then it is called horizontal type carburetor.

And last if the air is supplied from the above portion of the mixing chamber then it is called down-draft carburetor.

In most cases down-draft type carburetor is generally used because of the following advantages:

- The gravity assists the flow of the mixture. so found that the engine pulls better at lower speeds under load.
- The engine can achieve a higher value of volumetric efficiency.
- The carburetor position is rendered more accessible.

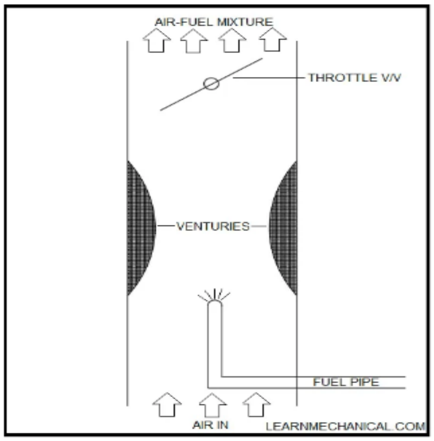
And the only disadvantage is:

- The possibility of leakage going directly into the inlet manifold if the float is defective and the jet is overflowing.

Also use of a particular carburetor is depends on the fuel supply system too. Here is another article where I mentioned the types of the Fuel supply system, you may check this for a better idea.

UP-DRAFT TYPE CARBURETOR:

In this type of Carburetor, air goes through the bottom of the carburetor. And fuel comes from the float chamber and due to the pressure difference within the two-chamber with the help of venturi, fuel comes out from the fuel pipe and mix with the inlet air and make a mixture of air-fuel, which is passed through the throttle valve which is directly connected with the accelerator. And goes to the engine cylinder where the combustion of charge (air+fuel) takes place.



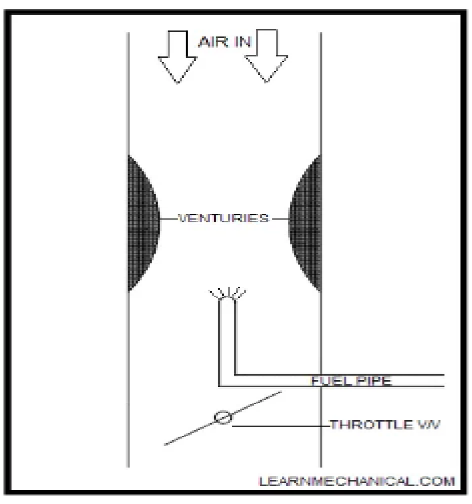
UP-DRAFT CARBURETOR

DOWN-DRAFT CARBURETOR:

In this type of carburetor air comes from the top of mixing chamber, and the fuel comes from the bottom of the mixing chamber, here also the same principle works, due to low pressure created by the two venturies fuel comes out through the pipe and then the mixing of fuel and air occurred here.

The mixture of fuel and air is controlled by the choke valve, and the quantity of charge supplied to the engine cylinder is controlled by the throttling valve.

In this time most vehicles used down-draft carburetor systems because of the advantages I mentioned above.

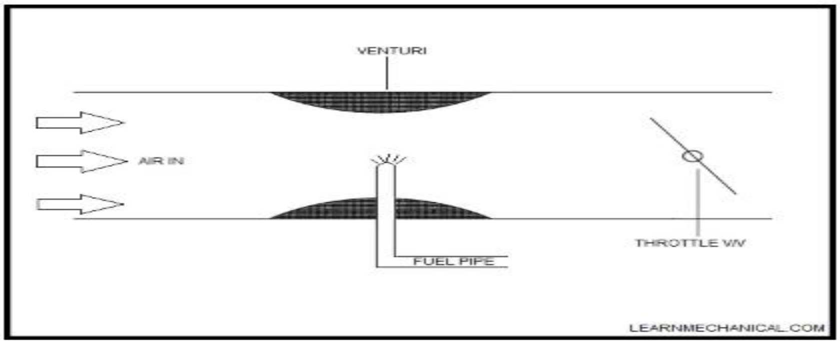


DOWN-DRAFT CARBURETOR

Horizontal Type Carburetor:

When you rotate the down-draft carburetor in the horizontal direction then its become horizontal type carburetor

The working principle of this type of carburetor is very simple. Here the carburetor stays in the horizontal position where the air is coming in through the one end of the carburetor shown in the below figure. And mixing with fuel to make the air-fuel mixture and then the air-fuel mixture is going to the engine cylinder for combustion.



HORIZONTAL CARBURETOR

Functions of a carburetor:

The main functions of a carburetor are

1. The main function of carburetors to mix air and gasoline and provides a high combustion mixture.
2. It controls the engine speed.
3. It also regulates the air-fuel ratio.
4. Increase or decrease the amount of mixture according to the engine speed and load changing.
5. To keep certain head of fuel in the float chamber all the time.
6. Vaporize the fuel and mix to air to a homogeneous air-fuel mixture.
7. To supply the correct amount of air-fuel mixture at the correct strength under all conditions of load and speed of the engine.

Advantages of the carburetor:

1. Carburetor parts are not as expensive as that of fuel injectors.
2. With the use of a carburetor, you get more air and fuel mixture.
3. In terms of a road test, carburetors have more power and precision.
4. Carburetors are not restricted by the amount of gas pumped from the fuel tank which means that cylinders may pull more fuel through the carburetor that would lead to the denser mixture in the chamber and greater power as well.

Disadvantages of the carburetor:

1. At very low speed, the mixture supplied by a carburetor is so weak that, it will not ignite properly and for its enrichment, at such conditions, some arrangement in the carburetor is required.
2. The working of a carburetor is affected by changes in atmospheric pressure.
3. More fuels are consumed since carburetors are heavier than fuel injectors.

4. More air emissions than fuel injectors.
5. The maintenance costs of a carburetor are higher than the fuel injection system.

Applications of Carburetor:

- Used for Spark-Ignition Engine.
- It used to control the speed of the vehicles.
- It converts the main fuel petrol into fine droplets and mixes with air to burn in smoothly and properly without any problem.

SIMPLE CARBURETOR

A simple carburetor consists of different parts such as the float chamber, main fuel jet, venturi, jet tube, and throttle valve. Where there is a float in the float chamber. With the help of a fuel pump, fuel is supplied to the float chamber from the fuel tank through the strainer. We can call this full assembly a simple carburetor.

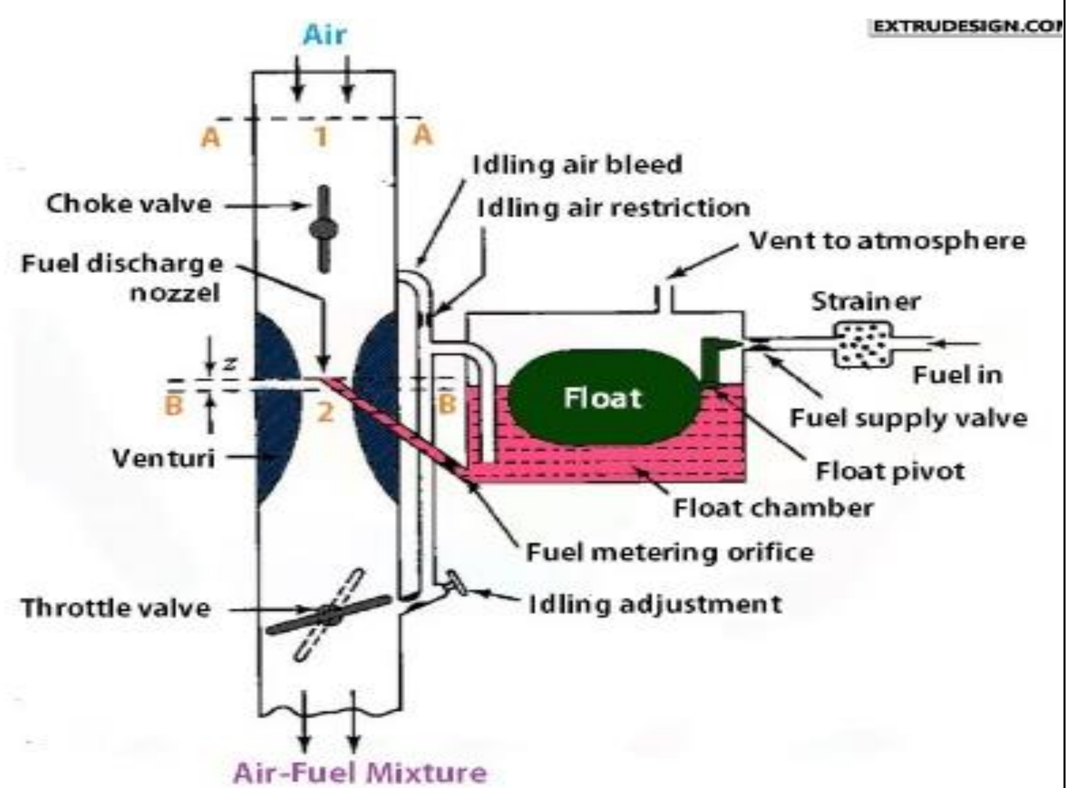


Diagram of a simple carburetor

WORKING OF A SIMPLE CARBURETOR:

We are going to learn the working of this carburetor stepwise-

1. As we know, there is a float chamber in a simple carburetor that is open to the atmosphere. It keeps atmospheric pressure in the float chamber.
2. Fuel from the external fuel tank is supplied to the float chamber with the help of the fuel pump. This fuel from the fuel tank is filtered using the strainer which removes any solid particles from the fuel.
3. Now fuel from the float chamber is supplied to the main nozzle which is a part of the jet tube. This flow of fuel from the float chamber to the main nozzle is carried out by the main fuel jet.
4. The engine sucks air from the atmosphere through the choke valve. This air passes through the venturi, it causes a reduction of the area of a cross-section at the throat of venturi.
5. Due to this, the pressure at the main nozzle decreases and the velocity of air increases.
6. This difference in pressure-induced at the float chamber and the main nozzle causes the mixture of fuel and incoming atmospheric air.
7. Increased velocity of air after the venturi partially vapourize the engine fuel which is then totally evaporated by the heat in the intake manifolds of the combustion chamber and cylinder walls.
8. Carburetors only install in a petrol engine because petrol engines are quantity governed.
9. When we open the throttle valve present at the bottom of the jet tube, it allows more air flows through the venturi tube and a more quantity of the air-fuel mixture is supplied to the engine, causes, the engine develops more power.
10. When we close the throttle valve, reverse action takes place and the power of the engine reduces.

What is nozzle lip in the simple carburetor?

To avoid the overflow of the fuel from the nozzle, the end of the main nozzle is slightly kept higher than the level of fuel in the float chamber. This difference of level between the tip of the main nozzle and fuel level in the float chamber is called nozzle lip. You can see the nozzle lip level in the diagram above.

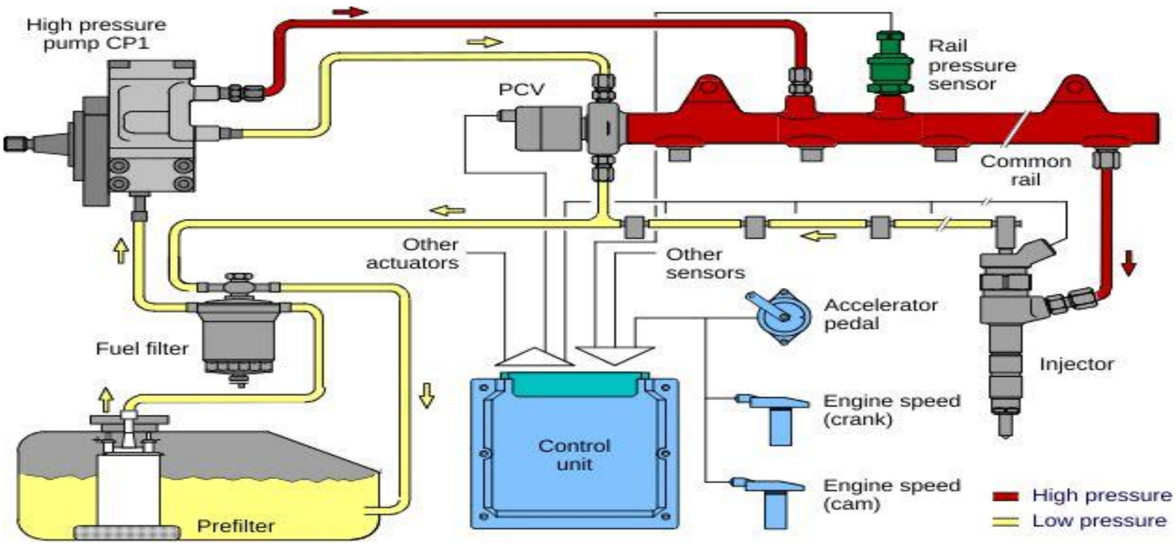
Limitations of a simple carburetor:

- In this carburetor, the air-fuel mixture totally depends upon the position of the throttle valve.
- Also, the air-fuel ratio decreases when the speed of the engine increases.
- The main limitation or disadvantage of a simple carburetor is that when speed is too low, we get a strong mixture which causes trouble in the ignition of the mixture.

Application of simple carburetor:

- This is only used in small and stationary engines, not any modern engines.

LINE DIAGRAM OF DIESEL ENGINE FUEL SUPPLY SYSTEM



Types Of Fuel Injection Systems in CI Engines

Introduction to Fuel Supply System for CI Engines:

The fuel supply system of a diesel engine can be called as the heart of the engine, since the engine performance directly depends upon the proper functioning of this system—which must supply, meter, inject and atomize the fuel.

Fuel injection systems are manufactured with great accuracy, hence they are costlier.

Fuel will flow either because of gravity or fuel feed pump, which is provided to supply fuel through the filter to the injection pump. Which pumps the fuel to the injectors which are provided in the cylinder heads.

Fuel injection system for diesel engine

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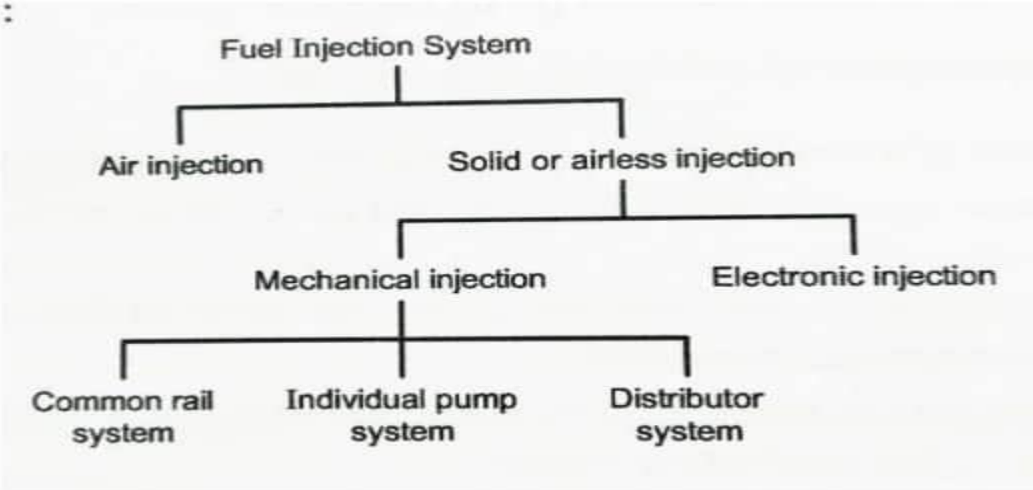


The fuel injection systems are of 2 types:

1. Air Injection System:

In this case fuel is injected under the pressure of air. For supplying high pressure air multistage air compressors are required, which are very much costly and hence this system is not in use.

2. Solid Injection System:

In this case diesel fuel is directly injected by fuel pump (Bosch Pump).

Further these are of 3 types of solid injection systems:

A. Individual Pump System :

As shown fuel will flow from the storage tank to filters to low pressure pumps. This low pressure pump pumps the fuel to 4 separate metering and pressure pumps.

These separate metering and pressure pumps will pump the fuel to individual injectors which are provided in the cylinder heads. These are used in large slow speed engines.

B. Distributor System :

Fuel will flow from storage tank to low pressure pump through filters, then to metering and pressure pumps. This metering and pressure pump pumps the fuels to distributor unit which distributes and sends required quantity of fuel to each injectors/each cylinders. Used in small and medium size engines.

C. Common Rail System :

In this case fuel flows from storage tank to low pressure pump through filters. Low pressure pump, pumps the fuel to high pressure pump, which pumps the fuel to high pressure pump, which pumps the fuel to common rail. Thus high pressure fuel is collected in common rail and from here through the metering devices required quantity of fuel goes to injectors/cylinders. Generally Cummins and multi-cylinder engines use this system.

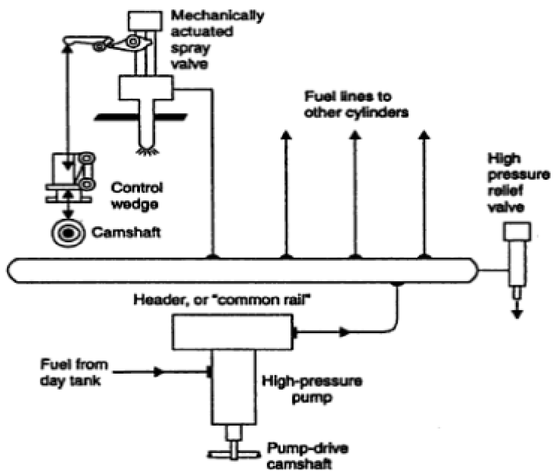
Electronic Fuel Injection (EFI) System:

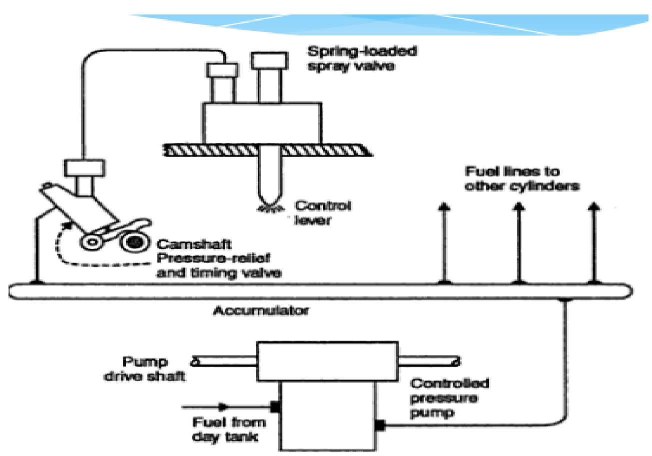
Electronics is introduced in automobiles in 1965. About 30—40% of cost of vehicles is for electronic items. Max power and best economy are attained by using electronics and computers in automobiles.

EFI systems was various sensors to sense various parameters like temperature, pressure of gases, position of throttle valve, air flow rate etc.

Sensors feed this data to Electronic Control Unit (ECU)—which is basically a computer. This ECU—processes the data and operates injectors and other devices to have maximum power, with best economy, and low emissions.

Multipoint Fuel Injection System (MPFI):





Multipoint Fuel Injection system is used to supply air-fuel mixture of proper strength and in required quantity to each cylinder of a multi-cylinder engine, at all engine speeds loads.

MPFI—Systems Functions under 2-Basic Arrangements:

1. Port Injection:

In this case injector is placed in the intake manifold, near the inlet valve. The injector sprays petrol into air flowing through the intake manifold. Homogenous air-fuel mixture produced enters cylinder. Note that each cylinder has a separate injector placed in its intake manifold.

Advantages:

1. Uniform fuel distribution

2. Increase in power output

3. More precise control of air-fuel ratio.

2. Throttle Body Injection:

In this case injector is provided at a single point in the throttle body. Throttle valve controls the amount of air entering intake manifold.

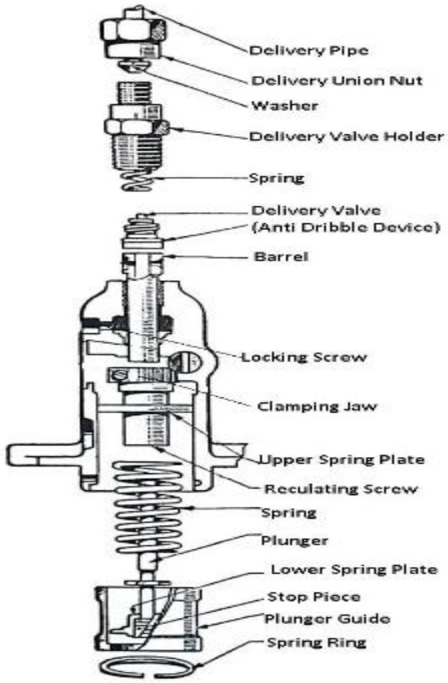
Fuel Pump

The purpose of the fuel pump is to meter the correct quantity of fuel and deliver it at the correct time to the engine cylinder according to the varying load and speed requirements.

Construction and Working of a Fuel Pump

The plunger is driven by a cam and tappet mechanism at the bottom. The plunger reciprocates in the barrel. There are as many plungers as the number of cylinders in the engine. The plunger has a rectangular vertical groove.

The delivery valve is lifted off its seat under the pressure of the fuel against the spring. The fuel from the delivery valve goes to the injector. When the plunger is at the bottom of its stroke, the supply port and spill are uncovered, the fuel from a low-pressure pump after filtration is forced into the barrel.



Now the plunger is pushed up by the cam movement and both the parts are closed. On further movements of the plunger, the fuel above it is compressed which lifts the delivery valve and the fuel through it goes to the injector.

The plunger rises up still further, and at a particular moment, the helical groove connects the spill port, through the rectangular groove to the fuel in the upper part of the plunger. Consequently, there is a sudden pressure drop due to which the delivery valve falls back on its seat under the spring force. The pressure in the delivery pipe also drops. Thus the discharge from the nozzle of the injector is cut off suddenly. The cycle is repeated again and again.

During each stroke of the plunger, the duration of the delivery is more or less according to as the spill port is made to communicate earlier or later, the high-pressure fuel in the upper part of the barrel. This depends upon the position of the helical groove which can be changed by rotating the plunger by the rack.

The rack is connected to the accelerator. It meshes with a geared quadrant. The motion of the rack rotates the gear quadrant which ultimately rotates the plunger. The driver simply operates the accelerator which controls the fuel supply to the engine cylinder.

Types of Fuel Pump

The fuel pump is used in the fuel system to deliver fuel from the fuel tank to the carburetor. Many types of fuel pumps are used in modern automobile vehicles.

Two general types of fuel pump are as follows:

1. Mechanical Fuel Pump
2. Electrical Fuel Pump

The performance of fuel is tested by pressure, volume and vacuum. A pump must produce certain pressure on the outlet side as specified by the manufacturer. To test a pump for pressure, connect a pressure gauge between the pump and the carburetor and run the engine at a specified speed. The gauge will indicate the pressure created by the fuel pump.

For the volume test, disconnect the fuel from the carburetor and run the engine at idling speed. Measure the volume of fuel coming out from the pump by collecting it in a separate container.

For a vacuum test, connect a suitable vacuum gauge between the gauge tank and then run the engine at idling speed. The gauge indicates the vacuum generated inside the pump to suck the fuel from the fuel tank.

The vacuum must be retained for at least ten seconds after closing the engine. The fuel pump found connected in the above three tests should be used in the fuel system.

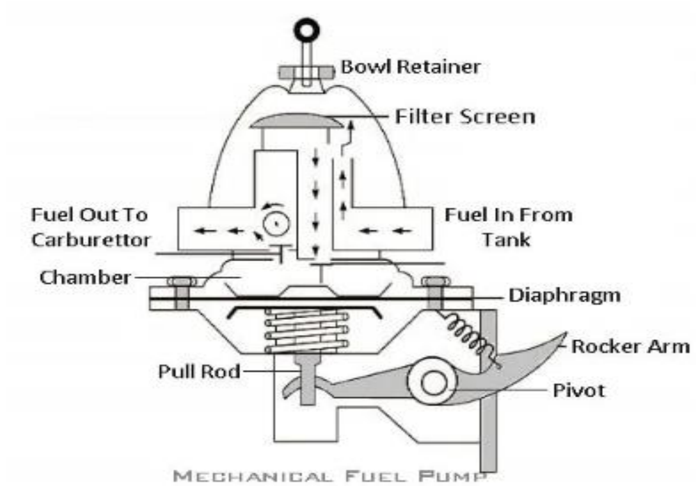
Mechanical Fuel Pump

The mechanical fuel pump is operated by an eccentric on the engine camshaft. It is mounted on the side of the cylinder block inline engines. In some V-8 engines, it is fitted between the two cylinder banks.

Construction and Working of Mechanical Fuel Pump

The figure shows a diaphragm type A.C mechanical fuel pump it is bolted to the engine block or crankcase so that the rocker arm slides on a pump operating can on the engine camshaft or in front of the timing gear or timing chain sprocket.

It consists of a high-grade cotton diaphragm impregnated with synthetic rubber. The movements of the diaphragm suck fuel from the fuel tank and pusher it to the carburetor.



As the cam rotates, it operates the rocker arm which in turn pushes the diaphragm up and down. The downward movement of the diaphragm sucks the fuel through the strainer from the fuel tank. The upward movement of the diaphragm pushes the fuel up which causes the inlet to close an outlet valve to open. The fuel through the outlet valve goes to the carburetor.

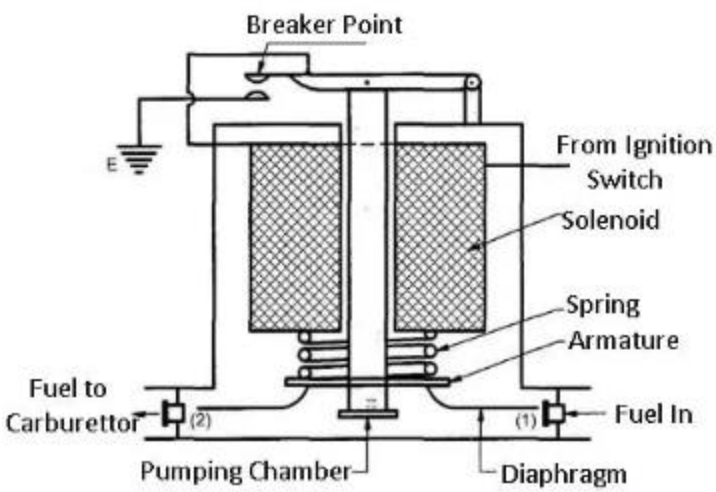
If the float chamber of the carburetor is completely filled up and there is no need of pumping more fuel till some of it is consumed, and the engine continues to run, the pump will be built up excessive pressure in it which may damage the pump itself.

To avoid this, the connection between the rocker arm and the pull rod is made flexible with the help of springs. When the fuel pressure in the pump increases it compresses the diaphragm spring and rocker arm spring which separate the rocker arm from the eccentric.

Thus although the cam is running continuously the pump is not operated till the fuel pressure decreases in it. In this manner, the fuel supply to the carburetor is regulated in accordance with its need.

Electric Fuel Pump

The electrical fuel pump is mounted in the fuel tank. It contains an impeller which is driven by an electric motor. This pushes the fuel through the fuel line to the carburetor. Another type of electric fuel pump is mounted in the engine compartment.



ELECTRIC FUEL PUMP

he figure shows an S.U.elcetric fuel pump. It also consists of a diaphragm, but it is operated electrically. But turning on the ignition switch, the solenoid winding generates magnetic flux, which pulls the armature and the diaphragm moves up.

The upward movement of the diaphragm creates suction, and the fuel is drawn into the chamber through the inlet valve. But as soon as the armature moves up it disconnects the electric supply, the magnetic flux dies and the armature falls down, causing the case's outlet valve to open and the inlet valve to close.

The fuel goes out to the carburetor. The downward movement of the armature again sets electric supply to the solenoid, and the same process is repeated, the pump continues to operate until the ignition switch is turned off.

FUEL INJECTORS

Fuel injection is the introduction of fuel in an internal combustion engine, most commonly automotive engines, by the means of an injector. This article focuses on fuel injection in reciprocating piston and rotary piston engines.

All diesel (compression-ignition) engines use fuel injection, and many Otto (spark-ignition) engines use fuel injection of one kind or another. All fuel injection systems comprise three basic components: they have at least one fuel injector (sometimes called an injection valve), a device that creates sufficient injection pressure, and a device that meters the correct amount of fuel. These three basic components can either be separate devices (fuel injector(s), fuel distributor, fuel pump), partially combined devices (injection valve and an injection pump), or completely combined devices (unit injector).

External mixture formation

BMW M88 engine with multi-point injection

In an engine with external mixture formation, air and fuel are mixed outside the combustion chamber, so that a premixed mixture of air and fuel is sucked into the engine. External mixture formation systems are common in petrol-fueled engines such as the Otto engine, and the Wankel engine. There exist two main external mixture formation systems in internal combustion engines: carburettors, and manifold injection. The following description focuses on the latter. Manifold injection systems can also be considered *indirect injection*, but this article primarily uses the term indirect injection to describe internal mixture formation systems that are not direct injection. There exist two types of manifold injection: *single-point injection*, and *multi-point injection*. They can use several different injection schemes.

Single-point injection

Single-point injection uses one injector in a throttle body mounted similarly to a carburetor on an intake manifold. As in a carbureted induction system, the fuel is mixed with the air before the inlet of the intake manifold. Single-point injection was a relatively low-cost way for automakers to reduce exhaust emissions to comply with tightening regulations while providing better "drivability" (easy starting, smooth running, no engine stuttering) than could be obtained with a carburetor. Many of the carburetor's supporting components - such as the air filter, intake manifold, and fuel line routing - could be used with few or no changes. This postponed the redesign and tooling costs of these components. Single-point injection was used extensively on American-made passenger cars and light trucks during 1980–1995, and in some European cars in the early and mid-1990s.

Multi-point injection

Multi-point injection injects fuel into the intake ports just upstream of each cylinder's intake valve, rather than at a central point within an intake manifold. Typically, multi-point injected systems use multiple fuel injectors, but some systems such as the GM central port injection use tubes with poppet valves fed by a central injector instead of multiple injectors.

Injection schemes

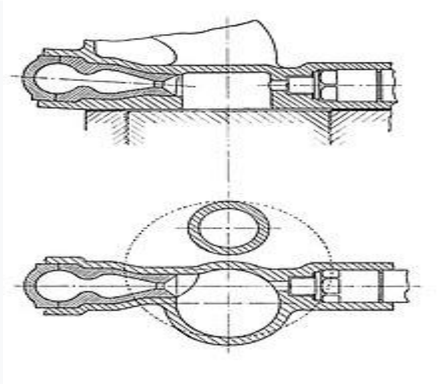
Manifold injected engines can use several injection schemes: continuous, and intermittent (simultaneous, batched, sequential, and cylinder-individual).

In a continuous injection system, fuel flows at all times from the fuel injectors, but at a variable flow rate. The most common automotive continuous injection system is the Bosch K-Jetronic, introduced in 1974, and used until the mid-1990s by various car manufacturers. Intermittent injection systems can be *sequential*, in which injection is timed to coincide with each cylinder's intake stroke; *batched*, in which fuel is injected to the cylinders in groups, without precise synchronization to any particular cylinder's intake stroke; *simultaneous*, in which fuel is injected at the same time to all the cylinders; or *cylinder-individual*, in which the engine control unit can adjust the injection for each cylinder individually.

Internal mixture formation

In an engine with an internal mixture formation system, air and fuel are mixed only inside the combustion chamber. Therefore, only air is sucked into the engine during the intake stroke. The injection scheme is always intermittent (either sequential or cylinder-individual). There are two different types of internal mixture formation systems: indirect injection, and direct injection.

Indirect injection



Air-cell chamber injection – the fuel injector (on the right) injects the fuel through the main combustion chamber into the air-cell chamber on the left. This is a special type of indirect injection and was very common in early American diesel engines.

This article describes indirect injection as an internal mixture formation system (typical of Akroyd and Diesel engines); for the external mixture formation system that is sometimes called indirect injection (typical of Otto and Wankel engines), this article uses the term manifold injection.

In an indirect injected engine, there are two combustion chambers: a main combustion chamber, and a pre-chamber (also called an ante-chamber) that is connected to the main one. The fuel is injected only into the pre-chamber (where it begins to combust), and not directly into the main combustion chamber. Therefore, this principle is called indirect injection. There exist several slightly different indirect injection systems that have similar characteristics. All Akroyd (hot-bulb) engines, and some Diesel (compression ignition) engines use indirect injection.

Direct injection

Direct injection means that an engine only has a single combustion chamber, and that the fuel is injected directly into this chamber. This can be done either with a blast of air (air-blast injection), or hydraulically. The latter method is far more common in automotive engines. Typically, hydraulic direct injection systems spray the fuel into the air inside the cylinder or combustion chamber, but some systems spray the fuel against the combustion chamber walls (M-System). Hydraulic direct injection can be achieved with a conventional, helix-controlled injection pump, unit injectors, or a sophisticated common-rail injection system. The latter is the most common system in modern automotive engines. Direct injection is well-suited for a huge variety of fuels, including petrol (see petrol direct injection), and diesel fuel.

In a common rail system, the fuel from the fuel tank is supplied to the common header (called the accumulator). This fuel is then sent through tubing to the injectors, which inject it into the combustion chamber. The header has a high pressure relief valve to maintain the pressure in the header and return the excess fuel to the fuel tank. The fuel is sprayed with the help of a nozzle that is opened and closed with a needle valve, operated with a solenoid. When the solenoid is not activated, the spring forces the needle valve into the nozzle passage and prevents the injection of fuel into the cylinder. The solenoid lifts the needle valve from the valve seat, and fuel under pressure is sent in the engine cylinder .Third-generation common rail diesels use piezoelectric injectors for increased precision, with fuel pressures up to 300 MPa or 44,000 lbf/in^2.

GOVERNORS

In a spark ignition engine, the carburettor is responsible for delivering a correct mixture of air and petrol but in compression ignition engine, the situation is different. The air sucked inside the cylinder depends upon the breathing characteristics of the cylinders and varies with the speed and operating temperature of the engines.

The fuel delivered is determined quite independently by the characteristics of the pump, which for a fixed control piston may show a rising characteristic with speed.

The problem of matching the characteristics of engine and pump is difficult, where it is necessary to provide for running at varying speeds on a definite acceleration position. **Here a governor serves the purpose.** It controls both maximum and idling speeds.

Governor Serves The Following Purposes:

1. It controls fuel delivery at all engine speeds and varying load conditions. The quantity of fuel for idling and maximum speed is controlled and correct fuel delivery is ensured for all conditions in between these two extremes.

2. It ensures that adequate fuel is delivered to the engine when idling, to avoid stalling and also to limit the maximum amount of fuel that can be supplied to the injectors to prevent excessive engine speed, but accelerator pedal to piston the control rod for all other speeds.

In a gasoline engine, the governor is usually placed between the carburettor and the intake manifold. Centrifugal governor is attached to the camshaft by a gear drive.

The movement of the flywheel attached to the pivot arms of centrifugal governors is used to control the flow of gasoline in the carburetor, thus controlling the engine speed.

Types of Governors

Following are the three different **types of governors** used in automobile vehicle:

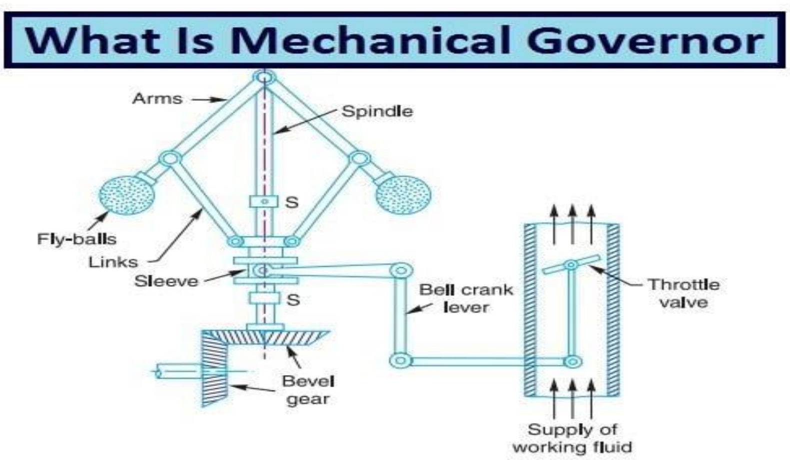
1. Mechanical or centrifugal governor.
2. Pneumatic governor.
3. Hydraulic governor.

Mechanical or Centrifugal Governor

Mechanical governors are fitted to large engines on an extension of the pump camshaft.

Working of Mechanical Governor

When the engine starts, the weights take up a position to maintain a stable idling speed. As the accelerator pedal is depressed against the spring, the weight moves inwards, and since the weight are linked to the control rod, the fuel delivery is increased and hence the engine speed also increases .The increased engine speed causes the pump camshaft to rotate faster, which moves the weights outward against the action of control springs, so reducing the fuel delivery until the correct balance is arrived at for a particular engine operating condition .Thus, the accelerator does not increase delivery directly but delays the action of the governor. The relative position of governor-weight and control-rod positions when the engine is at idling and full-load positions.

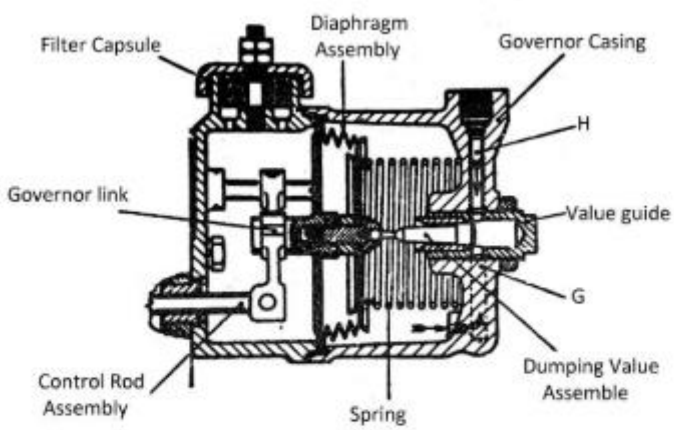


Pneumatic Governor

Pneumatic governors are most successfully used in small and medium-sized engines. They are sensitive to variations in torque loading and ensure stable idling control. As with pneumatic induction pipe control, the air supply at light loads is throttle by a butterfly valve placed in a choke.

This valve is directly operated by the accelerator pedal. The throttle unit is placed between the air cleaner and the entry to the inlet manifold. Which results in the reduced air pressure at the end of induction. Injection then takes place into less dense air than with unrestricted induction, and the control thus becomes quantity rather than quality control. The fuel injection is controlled by the depression at the choke to a diaphragm chamber mounted on the end of the injection pump. The diaphragm plate is mounted on the end of the control rack of the pump. It is pushed to the full load position (to the right) by the main control spring. Again, the increased depression at the throttle, arising when the accelerator pedal is released. It will pull the diaphragm and control rod to the left, thus reducing the fuel supply.

An auxiliary spring is also used to balance the height depression at idling speed. It is brought into action progressively by the action of a cam.



Pneumatic Governor

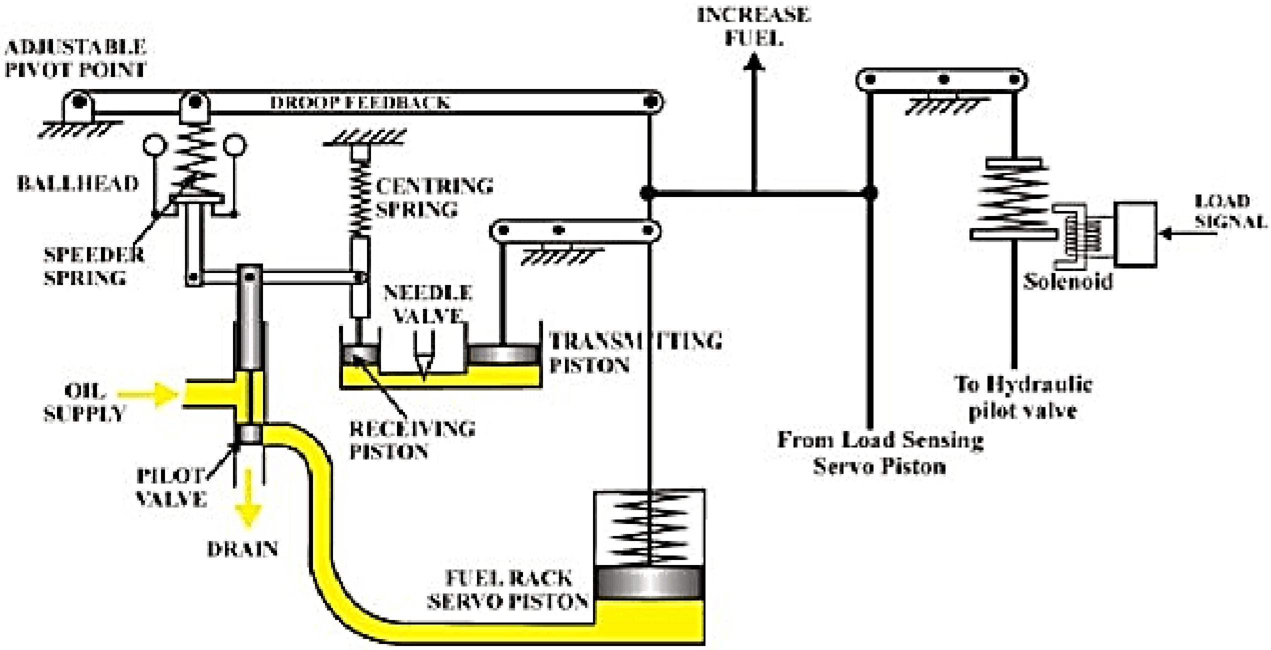
Hydraulic Governor

Hydraulic governors eliminate the high mechanical forces bearing loads and possible torsional vibrations in the drive. And, hence they are preferred over mechanical governors.

In a mechanical governor, the operative agent is the centrifugal force which governs the speed. In a hydraulic governor, it is the pressure difference across an orifice required to pass the oil flow from a positive oil pump driven by an engine.

The pressure difference varies as the square of the engine speed. And it is determined at equilibrium by the pressure of the driver’s foot on the accelerator pedal.

A hydraulic governor, like a mechanical governor, is an all-speed governor i.e., the governor is in control throughout the whole rack is operated by the governor and not directly by the accelerator to the supply to maintain the speed, no matter what the power requirements may be from moment to moment.



CHAPTER-5

5. COOLING SYSTEM

We know that in case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases will be around 2300-2500°C. This is a very high temperature and may result into burning of oil film between the moving parts and may result into seizing or welding of the same. So, this temperature must be reduced to about 150-200°C at which the engine will work most efficiently. Too much cooling is also not desirable since it reduces the thermal efficiency. So, the object of cooling system is to keep the engine running at its most efficient operating temperature. It is to be noted that the engine is quite inefficient when it is cold and hence the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attains to maximum efficient operating temperature, then it starts cooling.

It is also to be noted that :

(a) About 20-25% of total heat generated is used for producing brake power (useful work).

(b) Cooling system is designed to remove 30-35% of total heat.

(c) Remaining heat is lost in friction and carried away by exhaust gases.

Objectives After studying this unit, you should be able to

- understand the methods of cooling of IC engine,
- explain the air cooling system, and
- know the water cooling system of IC engine.

There are mainly two types of cooling systems :

(a) Air cooled system,

and (b) Water cooled system

AIR COOLED SYSTEM

Air cooled system is generally used in small engines say up to 15-20 kW and in aero plane engines. In this system fins or extended surfaces are provided on the cylinder walls, cylinder head, etc. Heat generated due to combustion in the engine cylinder will be conducted to the fins and when the air flows over the fins, heat will be dissipated to air.

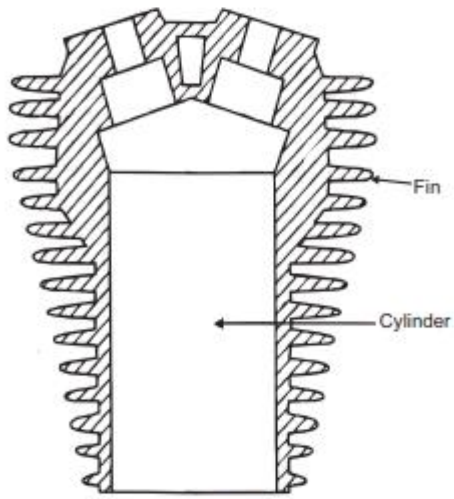


Figure 5.1 : Cylinder with Fins

The amount of heat dissipated to air depends upon :

(a) Amount of air flowing through the fins.

(b) Fin surface area.

(c) Thermal conductivity of metal used for fins.

Advantages of Air Cooled System

Following are the advantages of air cooled system

(a) Radiator/pump is absent hence the system is light.

b) In case of water cooling system there are leakages, but in this case there are no leakages.

(c) Coolant and antifreeze solutions are not required.

(d) This system can be used in cold climates, where if water is used it may freeze.

Disadvantages of Air Cooled System

(a) Comparatively it is less efficient.

(b) It is used in aero planes and motorcycle engines where the engines are exposed to air directly.

WATER COOLING SYSTEM

In this method, cooling water jackets are provided around the cylinder, cylinder head, valve seats etc. The water when circulated through the jackets, it absorbs heat of combustion. This hot water will then be cooling in the radiator partially by a fan and partially by the flow developed by the forward motion of the vehicle. The cooled water is again recalculated through the water jackets.

Types of Water Cooling System

There are two types of water cooling system :

Thermo Siphon System

In this system the circulation of water is due to difference in temperature (i.e. difference in densities) of water. So in this system pump is not required but water is circulated because of density difference only.

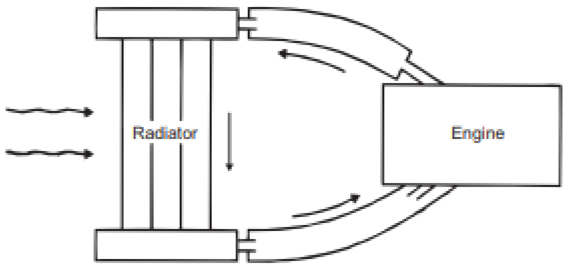


Figure 5.2 : Thermo Siphon System of Cooling

Pump Circulation System

In this system circulation of water is obtained by a pump. This pump is driven by means of engine output shaft through V-belts.

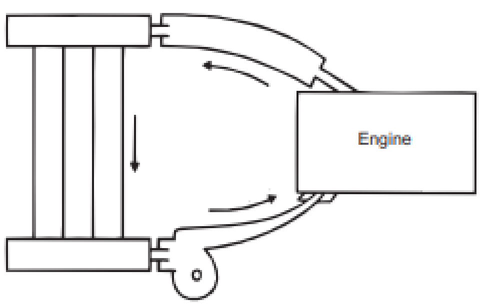


Figure 5.3 : Pump Circulation System

Components of Water Cooling System

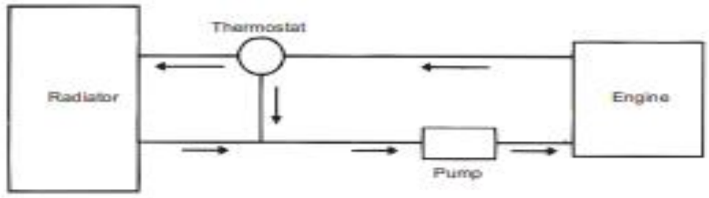


Figure 5.4 : Water Cooling System using Thermostat Valve

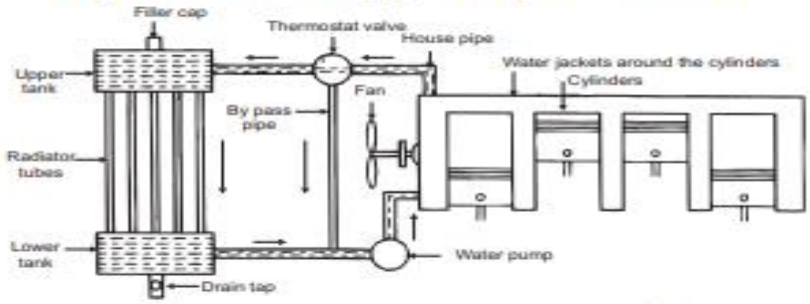


Figure 5.5 : Water Cooling System of a 4-cylinder Engine

Water cooling system mainly consists of :

(a) Radiator,

(b) Thermostat valve,

(c) Water pump,

(d) Fan,

(e) Water Jackets,

and (f) Antifreeze mixtures.

Radiator

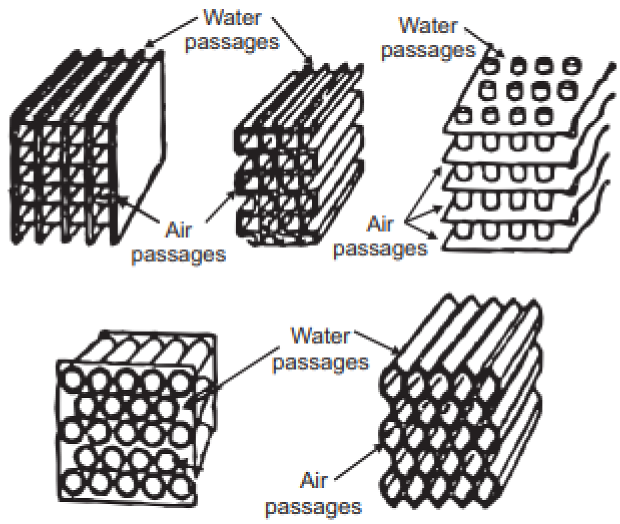
It mainly consists of an upper tank and lower tank and between them is a core. The upper tank is connected to the water outlets from the engines jackets by a hose pipe and the lover tank is connect to the jacket inlet through water pump by means of hose pipes.

There are 2-types of cores :

(a) Tubular

(b) Cellular as shown.

When the water is flowing down through the radiator core, it is cooled partially by the fan which blows air and partially by the air flow developed by the forward motion of the vehicle. As shown through water passages and air passages, wafer and air will be flowing for cooling purpose. It is to be noted that radiators are generally made out of copper and brass and their joints are made by soldering.



Thermostat Valve

It is a valve which prevents flow of water from the engine to radiator, so that engine readily reaches to its maximum efficient operating temperature. After attaining maximum efficient operating temperature, it automatically begins functioning. Generally, it prevents the water below 70°C.

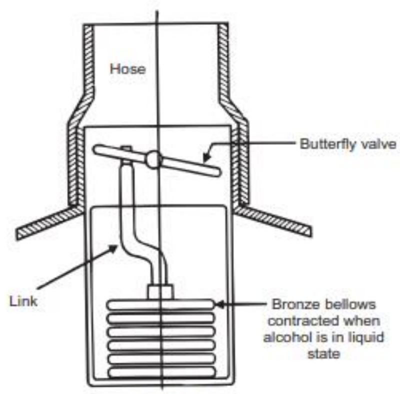


Figure 5.7 : Thermostat Valve

Figure 5.7 shows the Bellow type thermostat valve which is generally used. It contains a bronze bellow containing liquid alcohol. Bellow is connected to the butterfly valve disc through the link. When the temperature of water increases, the liquid alcohol evaporates and the bellow expands and in turn opens the butterfly valve, and allows hot water to the radiator, where it is cooled.

Water Pump

It is used to pump the circulating water. Impeller type pump will be mounted at the front end. Pump consists of an impeller mounted on a shaft and enclosed in the pump casing. The pump casing has inlet and outlet openings. The pump is driven by means of engine output shaft only through belts. When it is driven water will be pumped.

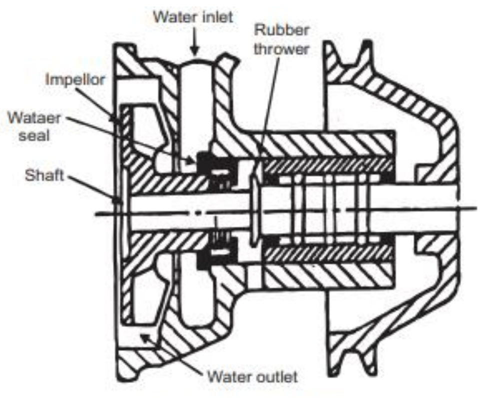


Figure 5.8 : Water Pump

Fan

It is driven by the engine output shaft through same belt that drives the pump. It is provided behind the radiator and it blows air over the radiator for cooling purpose.

Water Jackets

Cooling water jackets are provided around the cylinder, cylinder head, valve seats and any hot parts which are to be cooled. Heat generated in the engine cylinder, conducted through the cylinder walls to the jackets. The water flowing through the jackets absorbs this heat and gets hot. This hot water will then be cooled in the radiator (Referred Figure 5.9).

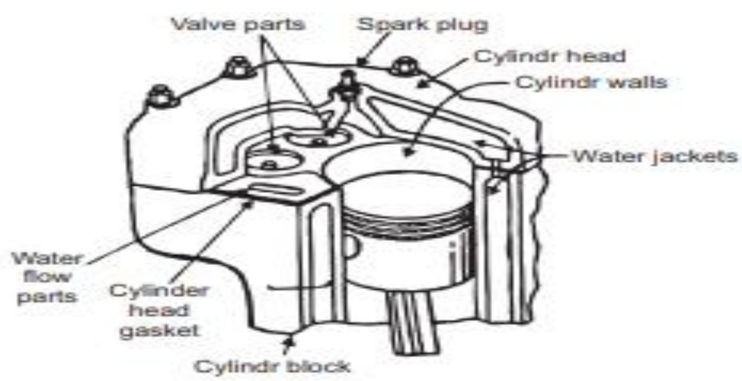


Figure 5.9 : Water Jackets

ANTIFREEZE MIXTURE

In western countries if the water used in the radiator freezes because of cold climates, then ice formed has more volume and produces cracks in the cylinder blocks, pipes, and radiator. So, to prevent freezing antifreeze mixtures or solutions are added in the cooling water.

The ideal antifreeze solutions should have the following properties:

(a) It should dissolve in water easily.

(b) It should not evaporate.

(c) It should not deposit any foreign matter in cooling system.

(d) It should not have any harmful effect on any part of cooling system.

(e) It should be cheap and easily available.

(f) It should not corrode the system.

No single antifreeze satisfies all the requirements.

Normally following are used as antifreeze solutions :

(a) Methyl, ethyl and isopropyl alcohols.

(b) A solution of alcohol and water.

(c) Ethylene Glycol.

(d) A solution of water and Ethylene Glycol.

(e) Glycerin along with water, etc.

ADVANTAGES AND DISADVANTAGES OF WATER COOLING SYSTEM

Advantages

(a) Uniform cooling of cylinder, cylinder head and valves.

(b) Specific fuel consumption of engine improves by using water cooling system.

(c) If we employ water cooling system, then engine need not be provided at the front end of moving vehicle.

(d) Engine is less noisy as compared with air cooled engines, as it has water for damping noise

Disadvantages

(a) It depends upon the supply of water.

(b) The water pump which circulates water absorbs considerable power.

(c) If the water cooling system fails then it will result in severe damage of engine.

(d) The water cooling system is costlier as it has more number of parts.

SAQ 1 (a) Why is cooling necessary for IC engine? (b) Explain in brief the methods of cooling of IC engine. (c) Differentiate between air cooling system and water cooling system. (d) What is the purpose of the fins in an air-cooled system?

CHAPTER-6

6. LUBRICATION SYSTEM

In an I.C engine, moving parts rub against each other causing frictional force. Due to the frictional force, heat is generated and the engine parts wear easily. Power is also lost due to friction. To reduce the power loss and also wear and tear of the moving parts, a foreign substance called lubricant is introduced in between the rubbing surfaces. The lubricant keeps the mating surfaces apart. Lubrication system may be solid (graphite), or semi-solid (grease) or liquids (oil). The liquid lubricant generally used is mineral oil. This is obtained by refining petroleum. Grease is also used to lubricate certain parts of the engine.

Purposes of lubrication (or) Functions of lubrication:

a. It reduces friction between moving parts.
b. It reduces wear and tear of the moving parts.
c. It minimizes power loss due to friction.
d. It provides cooling effect: During circulation, it carries heat from the hot moving parts and delivers it to the surrounding through crankcase.
e. It provides cushion effect:- It serves as a cushion against the shocks of the engine.
f. It provides cleaning action:- Impurities such as carbon particles are dissolved during its circulation.
g. It provides a sealing action:- It helps the piston rings to provide an effective seal against high pressure gases in the cylinder from leaking out.
h. It reduces noise.

Parts of lubrication system

a. Internal surface of cylinder walls.
b. Crank shaft bearings
c. Crank pin
d. Camshaft
e. Cam shaft bearing
f. Valve mechanism
g. Piston rings
h. Piston pin or gudgeon pin
i. Timing gears
j. Big end and small end of the connecting rod bearing.

PROPERTIES OF LUBRICANT

The lubricant used in I.C engine should have some properties for the successful performance of the engine. The properties required for a good lubricant are listed below:

Viscosity :

Viscosity is defined as the measure of fluid resistance to flow. Viscosity of the lubricant is depending upon its temperature. Viscosity of lubricant decreases as temperature increases and vice versa. This property is very important property of lubricant because it determines how efficiently the oil film separates the moving surfaces from each other and prevents them rubbing. If high viscosity (i.e. too thick) oil is used, it will lead to power loss, higher operating temperature and excessive wear. If low viscosity oil is used, it cannot lubricate properly and leads to rapid wear of moving parts.

Oilness :

It is the property of an oil to spread and attach itself firmly to the bearing surfaces. In general, high oiliness is required for better lubrication.

Flash point :

Flash point of the lubricant is the temperature at which it forms vapours and produces combustible mixture with air. The high flash point is always desirable because low flash point leads to burning of lubricant. The minimum flash point of lubricating oil used in I.C. engine varies from 200 to 250°C.

Fire point :

The fire point is the lowest temperature at which the fuel burns continuously. Fire point should be higher than the flash point.

Volatility :

When the lubricating oil is exposed to a high temperature for long time, it may evaporate. This property is known as volatility. The lubricating oil should have low volatility.

Pour point :

It is defined as the temperature below which oil will cease to flow in the pipeline under controlled test conditions lubricants having lesser pour point are always recommended as its flow will start even when the engine is started in cold weather.

Delergency :

The lubricating oil should carry away small particles worn out carbon particles) to keep the interior of the engine clean known as delergency.

Neutralisation :

The lubricating oil should be neither acidic nor alkaline otherwise it will have corrosive action on the parts of the engine.

(Ex) Foaming : It is the condition in which minute air bubbles are held in the oil. It will reduce the mass flow and also accurate oxidation. Therefore, the oil should force from foaming trouble.
(x) Emulsification : The lubricating oil should not form an emulsion when brought in contact with water. A good lubricating oil must not emulsify easily.

Methods of Lubrication

The various methods adopted for lubrication of I.C. engines are

1. Petroil lubrication or mist lubrication system,
2. Wet sump system, and
3. Dry sump system.

Petroil or Mist lubrication system :

It is the simplest of all types of lubrication. This method is used in light vehicles such as motor cycles and scooters. About 3 to 6% of lubricating oil is mixed with petrol in the fuel tank. Here, there is no separate sump and pump. The oil mixing with petrol acts as a lubricant.

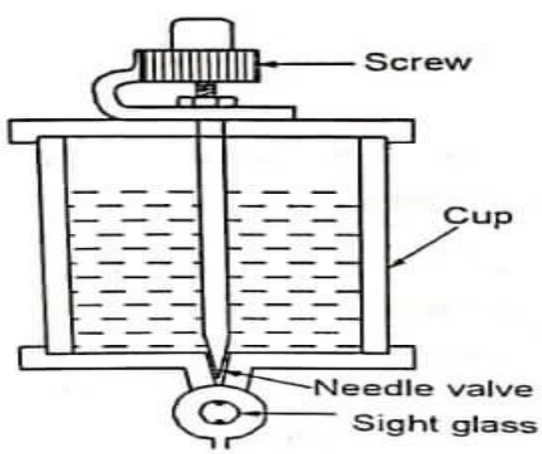
The disadvantage of this method is, if the engine remains idle for long time, the oil will get separated and cause clogging of fuel passage in carburetor thereby resulting in starting trouble. If the quantity of mixing oil is less, lubrication is insufficient which causes damage to the engine. If the quantity of oil is more, it will release more carbon deposits in the cylinder. So, the engine will give dark smoke.

Wet sump system :

In this method, the lubrication oil is stored in the oil sump. From the oil sump, the oil is supplied to various parts of the engine. This system may be further classified as:

(a) Gravity lubrication system
(b) Splash lubrication system
(c) Pressure lubrication system
(d) Semi-pressure lubrication system

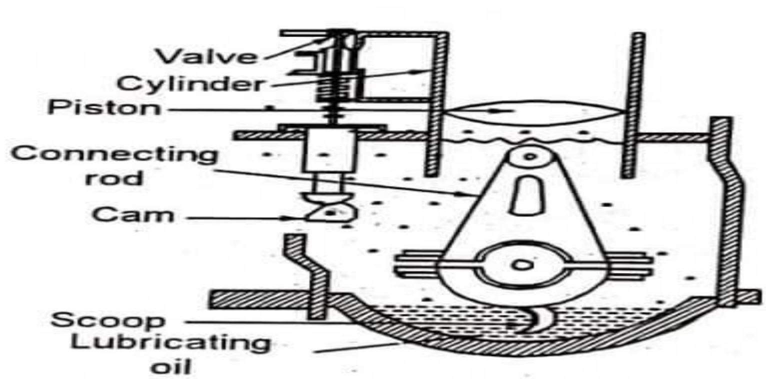
Gravity lubrication System



In this method, oil is supplied to the parts to be lubricated by means of gravity. This system uses a drop feed oiler shown fig. It consists of a cup and needle valve arrangement. The needle valve is operated by means of screw. The valve is raised to increase the flow of oil and lowered to decrease the oil flow. This system is used for lubricating external moving parts such as bearings, cross head, crank pins of simple steam engine.

Splash lubrication system :

In this system, oil is stored in the crank case. A small scoop is attached with the big end of connecting rod as shown in fig.
When the crank is rotated, the scoop dips in the oil and splashes the oil. The oil is splashed on cylinder wall, connecting rod ends and valve mechanisms. This method is used in some motorcycles and single cylinder stationary engines. Greater care should be taken that the oil in the crank case is filled up to the desired mark. There will be insufficient lubrication when the oil level is low.



Splash lubrication

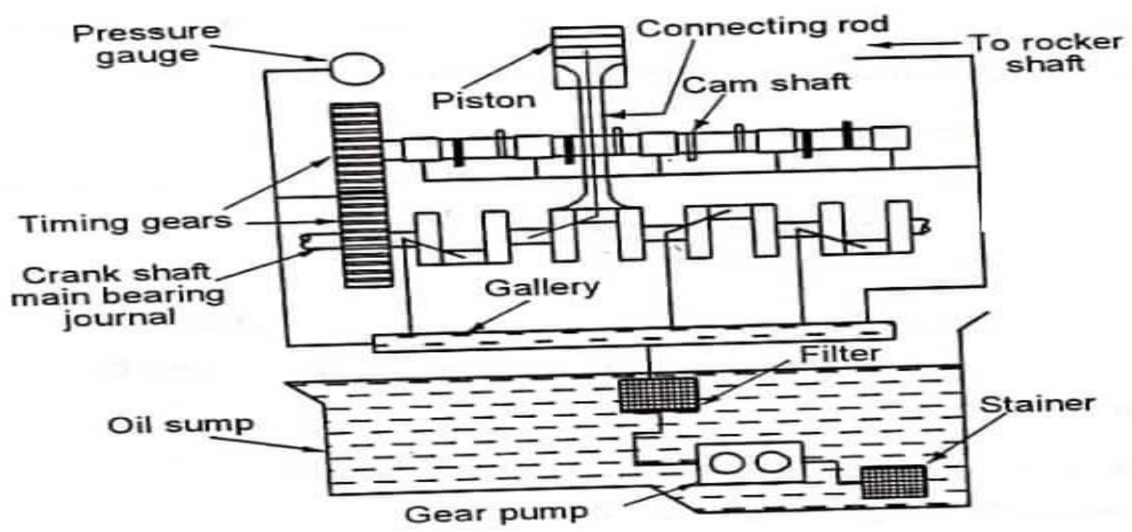
Disadvantages

- It is not efficient, if the bearing loads are heavy.
- It is very difficult to introduce oil in the minute gaps between the sliding surfaces.

Pressure lubrication system :

In this system, lubricating oil is forced under pressure by a pump at a pressure of 2 to 4Mpa. Fig shows a line diagram of this system. It consists of oil sump, oil pump, oil gallery, pressure release valve, oil filter, oil pressure gauge and oil dipstick. The lubricating oil from the sump or. oil pan is sucked by oil pump and lifted to oil main gallery through oil filter and strainer. The oil pump is driven by the camshaft. Oil pump and filter are always immersed in the oil.

From the oil gallery, the oil is distributed under pressure to various parts of the engine to be lubricated by the oil tubes. Oil from gallery enters the crank pin bearing through a taper hole in the crank shaft. A through hole is provided at the centre of the connecting rod. The oil from the big end bearing enters the gudgeon pin bearing (small end bearing) through the hole in the connecting rod. Separate oil tubes carry oil for lubricating timing gears, rocker arm assembly, cam shaft etc. Another oil line is connected to the pressure gauge to show the pressure of the oil.



The excess supplied oil drips back into the oil sump. A pressure relief valve is provided to avoid any damages in case of excess oil pressure. An oil dipstick is provided to measure the oil level in the sump.

Advantages :

- All the parts of the engine are efficiently lubricated.
- The minute gap between the sliding surfaces can be lubricated since the oil is supplied under pressure.

Engine parts lubricated under pressure: Crank shaft main bearings, cam shaft main bearings, big end bearings of the connecting rod, timing gears, chain and sprocket, rocker arm, springs, valve stems, valve guides etc.

Semi pressure lubrication system:

It is also called as partial pressure lubrication system. This is a modification of splash lubrication system. This system is used if the bearing loads are heavy and splash lubrication is not sufficient. It is a combination of splash and pressure lubrication.

This system consists of oil pump, oil gallery, oil filter, oil pressure gauge and scoops attached to connecting rod big end. The pump pumps the oil to the main gallery. From the gallery, oil is forced under pressure to the engine parts to be lubricated. Scoops or dippers are attached to the big end of the connecting rod.

The lubricating oil is directed to the scoops through oil jets from gallery. The scoops splash this oil in all directions to lubricate the engine parts such as piston, cylinder wall etc.

Engine parts lubricated by splash: Piston, cylinder walls, cams, piston pin and rings, spring and guides of valve stems, oil pump drive gear etc.

Dry sump lubrication system:

The lubricating oil stored in the oil sump is called wet sump system. But the system in which the lubricating oil is not kept in the oil sump is known as dry sump system. In this system, oil is carried in separate tank and fed to the engine.

The oil which falls into the oil sump after lubrication is sent back to the oil tank by a separate delivery pump. Thus the system consists of two pumps. One pump is used to feed the oil. The other pump is used to deliver the oil to the oil tank. This system is used in aircrafts.

The main advantage of this system is that there is no chance of break down in the oil supply during up and down movement of the vehicle.

Parts of Lubrication System

Following are the 8 different **parts of lubrication system:**

1. Oil sump
2. Oil pump
    1. Gear pump
    2. Rotor pump
    3. Plunger pump
    4. Vane pump
3. Oil filter
    1. By-pass system
    2. Full flow system
4. Oil strainer
5. Oil cooler
6. Oil level indicator
7. Oil pressure gauge
    1. Pressure expansion type
    2. Electric-type Balancing coil type
    3. Bimetal-thermostat type
8. Oil pressure Indicating light

Oil Sump

The oil sump is the lowest part of the crank chamber. It provides a covering for the crankshaft and contains oil in it. In wet sump lubricating system, the oil is taken out from the sump and after lubricating different parts, it drops in the sump.

The oil sump is also known as the oil pan. It usually made of steel pressings. Sometimes it is produced of aluminum or cast iron. It contains a drain plug at its lowest part to drain out the oil. In some cases, it contains oil strainer a barrel for dipstick and a connection for oil line. In a dry-sump lubricating system, the oil is contained in a separate oil tank.

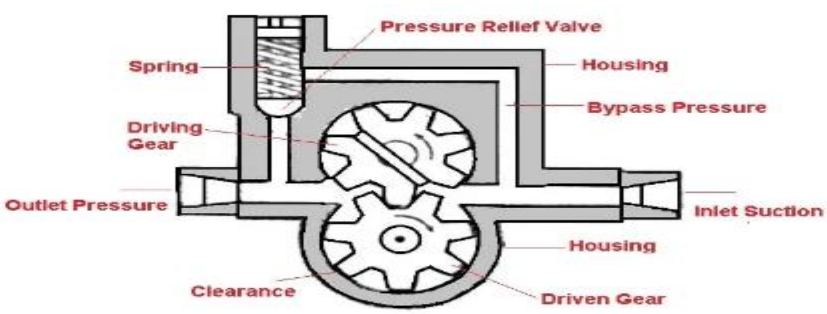
Oil Pump

The oil pump is typically placed inside the crankcase below the oil level. The function of the oil pump is to supply oil under pressure to the varies engine parts to be lubricated. The different types of oil pumps used for engine lubrication are as follows,

1. Gear pump
2. Rotor pump
3. Plunger pump
4. Vane pump

1. Gear Pump

It consists of two meshed spur gears and closed in a housing. There is very little clearance between the teeth and housing of the gear. A gear is attached to a shaft that is driven from the engine camshaft or crankshaft through the appropriate gear.The other gear free to revolve on its own bearing. When the pump is in action, the oil-driven between the gear teeth from the inlet side. Carried around between the gears and pump housing, and forced out the outlet side. The pressure and volume of oil supplied by the pump depends on the speed of the gear.

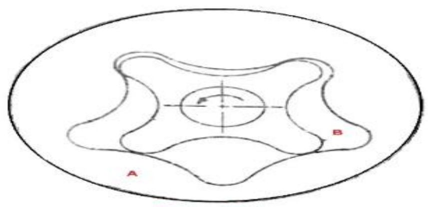


Gear Pump With Pressure Relief Valve

This type of gear pump is almost generally employed in automotive engines due to its simplicity in construction. It can transfer oil at a pressure of about 2-4 kg/. A pressure relief valve is also provided in many oil pumps to relieve the excessive pressure due to high engine speeds or clogged oil lines.

2. Rotor Pump

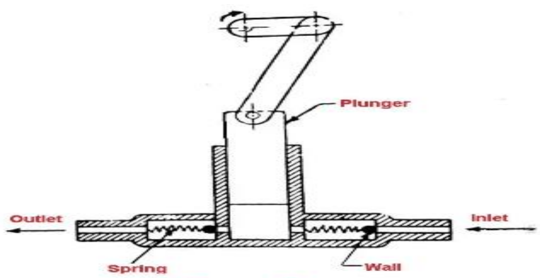
It consists of an inner and outer rotor within the pump body in place of gears, that is, two gears mesh internally. The external gear has the number of teeth one more than on the internal gear. The oil is displaced from the inlet to the outlet side just like the gear pump.



Rotor Valve

3. Plunger Pump

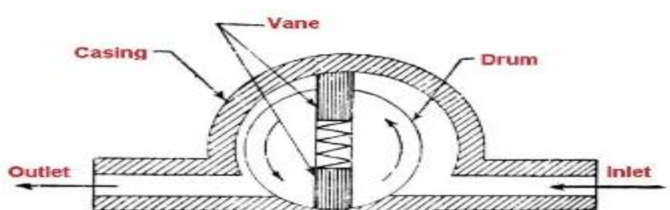
It consists of the plunger which reciprocates in the pump body while moving up, the plunger sucks oil from the inlet and while moving down it forces out the oil from the outlet. This type of sump is used to deliver oil under low pressure to the troughs of splash systems.



Plunger Pump

4. Vane Pump

It contains the cylindrical casing with outlet and inlet and drum. The drum is mounted eccentrically in the casing and contains two vanes with spring. With the drum rotates, the vanes wipe the oil from the inlet to the outlet side .Because the drum is mounted eccentrically, the volume between the drum and casing constantly decreases and oil pressure increases at the outlet.



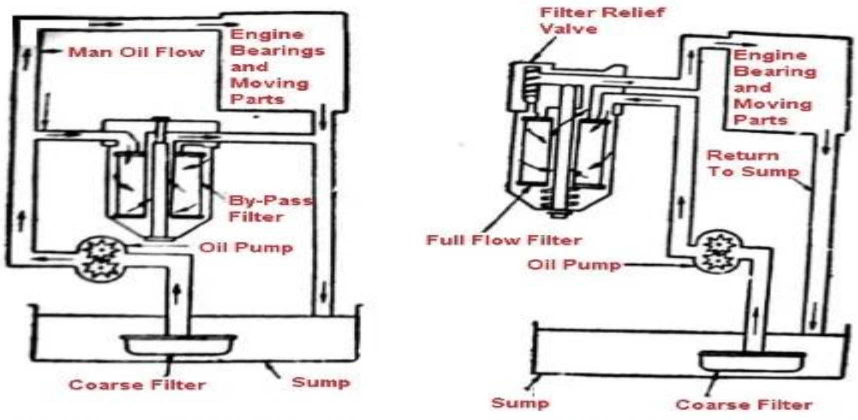
Vane Pump

Oil Filter

The oil filter is used in the engine lubricating system of most of the motor vehicles to filter out the dirt or grit particle from the oil.

The oil filter systems are of the two types:

1. By-pass system
2. Full flow system



(a) By-pass System (b) Full-flow System

1. By-pass system

In the by-pass system, the whole of the oil does not pass through the filter at the same time, but some of the oil without being filtered goes to the bearings. The remaining oil passes through the filter and then to the bearing. When the engine is run continuously for a long period of time, the entire oil is filtered out.

2. Full flow system

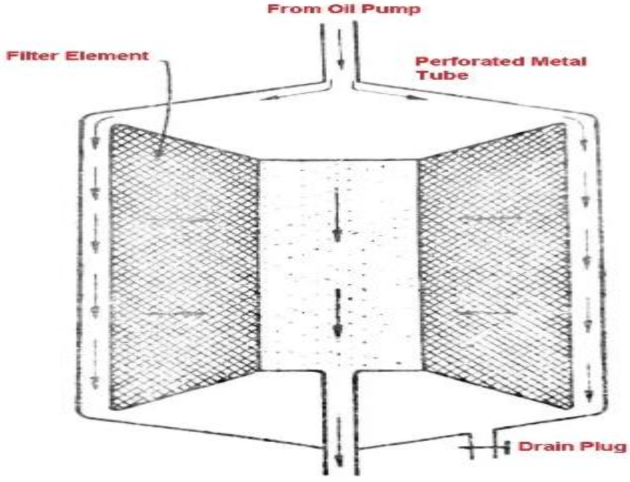
In full flow system, the whole passes first through the filter and then goes to the bearing. If the filter is stopped for some reason, the system completely fails and the bearings will starve.

The different types of oil filters used in automotive engines. Are as follows:

1. Cartridge type
2. Edge type
3. Centrifugal type

1. Cartridge type oil filter

It contains a filtering element placed in a metallic casing. The casing has an inlet and outlet oil pump enters casing through the filtering element, which takes up all the impurities.

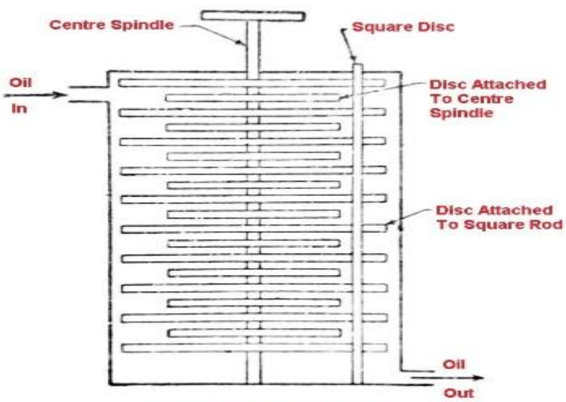


Cartridge Type Oil Filter

The filtered oil then comes out from the casing and goes to the oil gallery. The filtering element may be cleaned when clogged. If it is not in condition to be cleaned properly it should be replaced.

2. Edge type oil filter

It contains a number of the disc in the casing through which the oil passes. The alternate disc is mounted over a central spindle and the disc, between these, are fixed to a separate square rod. The clearance between the two discs in is only a few thousand of a centimetre.

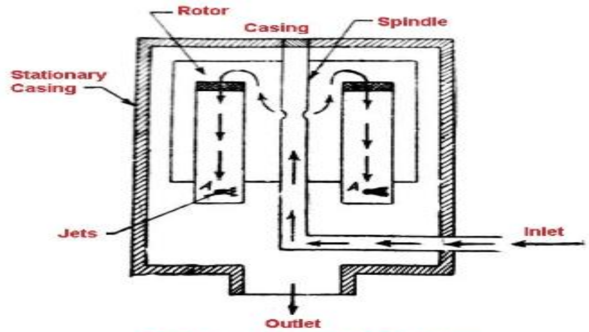


Edge Type Oil Filter

When the oil flows through this small clearance, it leaves impurities on the disc peripheries by operating the central spindle periodically the impurities so collected on the discs are removed.

3. Centrifugal type oil filter

Fig shows a centrifugal type oil filter. It contains a stationary casing, rotor casing, central spindle and tubes with jets. The impure oil enters the hollow central spindle and through whole around its periphery,



Centrifugal Type Oil Filter

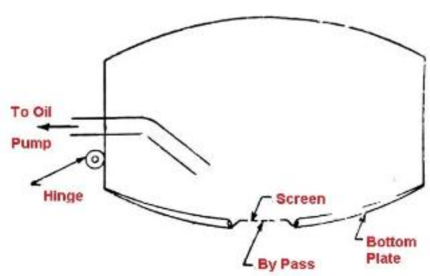
the oil goes to the rotor casing.

From the rotor causing the oil goes in the tubes, at the ends of which jets are attached. The oil passes through these jets under pressure, the reaction of which provides the motion to the rotor casing so that it begins to rotate.

The oil from the jets impinges on the walls of the stationary casing under heavy pressure, where the impurities are retained and the clean oil falls below, which is taken for use. The filter walls are cleaned periodically.

Oil Strainer

Oil strainer is simply a wire mesh screen. It is attached to the inlet of the oil pump so that the oil going in the oil pump is free from impurities. The strainer retains the dirt or grit of the oil. Usually, a floating strainer installed which is hinged to the oil pump inlet.

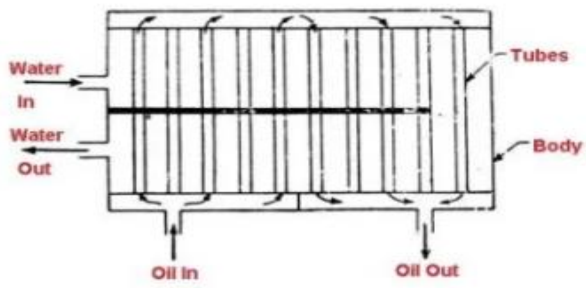


Oil Strainer

It is so adjusted that it floats at the oil surface and the impurities remain at the bottom of the crankcase. By doing so only a small amount of impurities goes to the strainer screen and hence it has less chances of being clogged. A by-pass is also kept in the strainer to allow the oil to pass when the screen is completely clogged.

Oil Cooler

The purpose of an oil cooler is to cool the lubricating oil in the heavy-duty engine where the oil temperatures become quite high. Because the viscosity of the oil decreases with the temperature rise and also the oil film may break at high temperatures, the oil must be kept cold in the lubricating system.



Oil Cooler

An oil cooler is just like a simple heat exchanger. The oil can be cooled with cold water from the radiator or air stream. Water type oil coolers are more commonly used in lubricating system because then act as reversible coolers.

At the time of starting when the water is hotter than the oil, the oil is heated to provide complete circulation in the system. At higher temperatures, when the oil becomes hotter than water, the water cools the oil.

A water type oil cooler, as shown in fig, simply consists of tubes in which oil circulates. The water circulates outside the tubes in the casing of the cooler. The heat of the oil carried away by the circulating water.

Oil Level Indicator

The level of the oil in the crankcase is checked by a dipstick. It is a long stick with a handle at one end for holding. It is graduated with marks full, half and empty. To check the oil level, the stick is dipped into the crankcase, and taken out.

The oil sticks on the stick which shows the oil level in the crankcase. The oil should fall below a critical mark. Before starting a vehicle particularly for a long journey. The oil level must be checked.

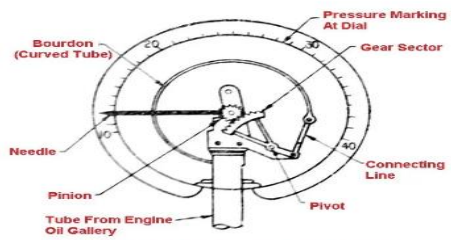
OIL PRESSURE GAUGE

An oil pressure gauge is mounted on the instrument panel of all cars equipped with a pressure lubricating system to tell the driver what the oil pressure is in the engine. The oil pressure gauges are of the following types:

1. Pressure expansion type
2. Electric-type
    1. Balancing coil type
    2. Bimetal-thermostat type

1. Pressure Expansion Type Oil Pressure Gauge

Fig shows pressure expansion type oil pressure gauge. It contains hollow bourdon (curved) tube, that is fastened at one end and free at the other.

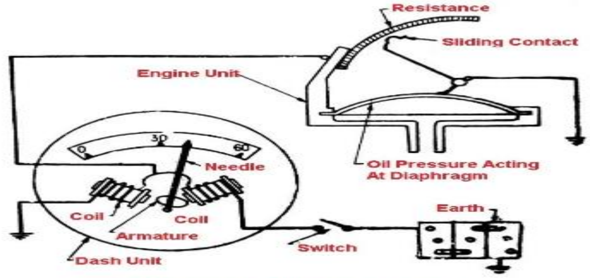


Pressure Expansion Type Gauge

The oil pressure is applied to the curved tube through an oil line from the engine which causes the tube to straighten out. This movement is transmitted to a needle by linkage and gears from the end of the tube. The needle moves across the face of the dial indicating the oil pressure.

2. Balancing Coil Type Oil Pressure Gauge

It consists of two separate units/the engine and the indicating a unit. The engine unit consists of a moving contact that moves over a resistance according to the varying oil pressure against a diaphragm.



Balancing Coil Type Gauge

As the pressure increases, the diaphragm moves inward by which the contact moves along the resistance so that more resistance is placed in the circuit between the engine and indicating unit. This reduces the amount of current flowing in the circuit.

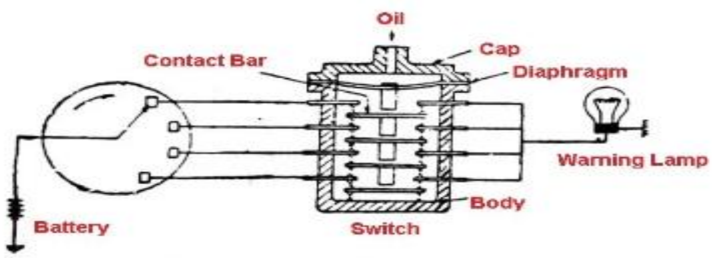
The indicating unit consists of two coils that balance the movement of the pointer on a scale, in a manner similar to the electrically operated fuel gauge.

3. Bimetal-Thermostat Type Oil Pressure Gauge

The metal thermostat type oil pressure indicator is similar to the bimetal thermostat furl gauge. It consists of an engine unit and a dash unit. The oil pressure on a diaphragm distorts the engine unit thermostat blade, and this distortion produces a similar distortion in the dash unit thermostat blade, causing the oil pressure to indicate on the dial.

Oil Pressure Indicating Light

In many motor vehicles, the engine oil pressure is indicated by a warning light. The light comes when the ignition switch is turned on and the oil pressure is low. The circuit user four-stage diaphragm switch which operates a warning a lamp according to the oil pressure required for different engine feeds.



Oil Pressure Warning Lamp

Fig shows an oil pressure warning lamp with a four-stage diaphragm operated switch. When the oil exerts pressure on the diaphragm the projection attached to it presses the uppermost contact bar, breaking the contact between the two projection further movement of the diaphragm deflects the second bar, and so on up to the fourth stage.

Each of these four stages is brought into a circuit with the warning lamp by a selector switch operated in conjunction with the speed-o-meter. In this way, the warning lights up only when the oil pressure falls below the value corresponding to the minimum engine speed.

OIL FILTER

An oil filter **is a filter designed to remove contaminants from engine oil, transmission oil, lubricating oil, or hydraulic oil. Their chief use is in internal-combustion engines for motor vehicles (both on- and off-road), powered aircraft, railway locomotives, ships and boats, and static engines such as generators and pumps**

Types of Oil Filters

Although there are several different types of oil filters available out there in the market, all of them serve the sole purpose of cleaning engine oil and filtering out all kinds of contaminants and impurities. These oil filters constantly remove any and all kinds of impurities and will keep your oil clean while it does its job of lubricating your car's engine. Here are some types of oil filters that you can choose from according to your vehicle's requirements.

1. Magnetic Oil Filter:

The magnetic oil filter can successfully clean out any metallic impurities and contaminants from your engine oil and is equipped with secondary support to a full-flow filter. But this magnetic oil filter is not equipped to effectively remove any non-metallic dust and filth. This magnetic oil filter does not require any replacements. It is a really good feature because it saves a lot of time as well as money. Some oil filters must be replaced over time since they will lose their quality and efficiency, but in the case of magnetic oil filters, there is no such need for replacement as it lasts longer and does need to be replaced. Magnetic filters only require regular cleaning and maintenance for their smooth functioning and operation.

If you want to avoid replacing your oil filter every now and then, this magnetic oil filter is a perfect fit for your needs. All you need to do is make sure that you regularly clean and maintain this magnetic oil filter every once in a while.

2. Full Flow Oil Filter:

The primary oil filter gets its name from the fact that this is the oil filter most vehicle manufacturers use. The primary oil filter is a full-flow oil filter, which is more valuable and works efficiently in cold temperatures. Since cold weather makes the engine oil thicker, the oil filter should not be limiting as the engine will not receive the right amount of oil to do its job of lubricating the engine's working parts. Unlike Some oil filters that can only clean a few impurities and contaminants on the oil, this full-flow oil filter is capable of removing and filtering out all the contaminants present in your oil. This full-flow oil filter is capable of making your oil run its course freely and with no distraction, which is not the case with other oil filters.

3. Secondary Oil Filter:

Some vehicle manufacturers install a secondary oil filter whose main purpose is to support the car's full-flow filter. The secondary oil filter is actually responsible for cleaning less than ten percent of the oil being used by the vehicle's engine. In the event where the full-flow filter might have missed some of the impurities and contaminants when it filtered the oil, the secondary oil filter works to filter some more contaminants.

Having a secondary oil filter increases your oil's life as well as its purity and provides more protection to your engine. Since the secondary oil filter works independently from the primary oil filters, it can efficiently clean your motor oil and effectively remove any contaminants or impurities present in your motor oil. As a result, you are required to change your oil filters less frequently. You can install a secondary oil filter even if you already have a primary oil filter in your vehicle.

4. Spinner Oil Filter:
This spinner oil filter is a type of secondary oil filter which uses centrifugal force to trap the contaminants and impurities present in the motor oil of your vehicle. The spinner oil filter is capable of removing even the smallest and tiniest impurities present in your car's motor oil. The spinner oil filter is equipped to produce a force that is about is two thousand times greater. This oil filter gets its name since these oil filters use a spinning motion in order to separate out dust and other impurities. This oil filter will continuously spin in a circular motion at high speeds and trap the contaminants mixed in the engine oil.

5. Cartridge Oil Filter:
This cartridge oil filter also falls in the category of full-flow oil filters. This cartridge oil filter is effortless and easy to use. Once installed in your vehicle in an upright position, there is no more need to remove the oil to inspect it. This cartridge oil filter also has no metal used in its manufacturing, which is the main reason why it is so easy to use. If you are looking for a simple oil filter that can be used effortlessly and works efficiently, you can try the cartridge oil filter.

6. Spin-On Oil filter:
Similar to the cartridge filter, the spin-on oil filter also falls under the category of full-flow oil filters. Aside from the sleet side canister, the spin-on oil filter also contains a steel canister inside. Apart from the steel canisters, the spin-on oil filter is also paired with a paper element. Since the spin-on oil filter is effortless and easy to install and use, this oil filter is very popular among those who prefer to do things independently. This spin-on oil filter is best suited for filtering out the contaminants that are mixed in with your oil.

FULL-FLOW LUBRICATING OIL SYSTEM

The strainers and filters used with Navy diesel engines are a part of what is generally referred to as the LUBRICATING OIL FIL-TERING SYSTEM. Currently, engines use a system known as the FULL-FLOW FILTER-ING SYSTEM. You should refer to figures 8-9 and 8-10 as you read the descriptions of this system.

In the full-flow filtering system, all the oil supplied to the engine by the oil pump normally passes through the filter elements, which remove impurities of 25 microns and larger.

There are only two conditions where unfiltered lubricating oil is supplied to the engine: (1) when the lubricating oil is cold (high viscosity), and (2) when the filter element is clogged. When one of these conditions exists, a bypass valve opens and a portion of the oil is bypassed around the filter element. The action of the bypass valve results from the resistance of the filter element to allow the oil to pass through it. The resistance creates enough back pressure for the spring-loaded bypass valve to open.

A secondary filtering system, which operates independently of the primary system, is currently being installed on various marine diesel engines.

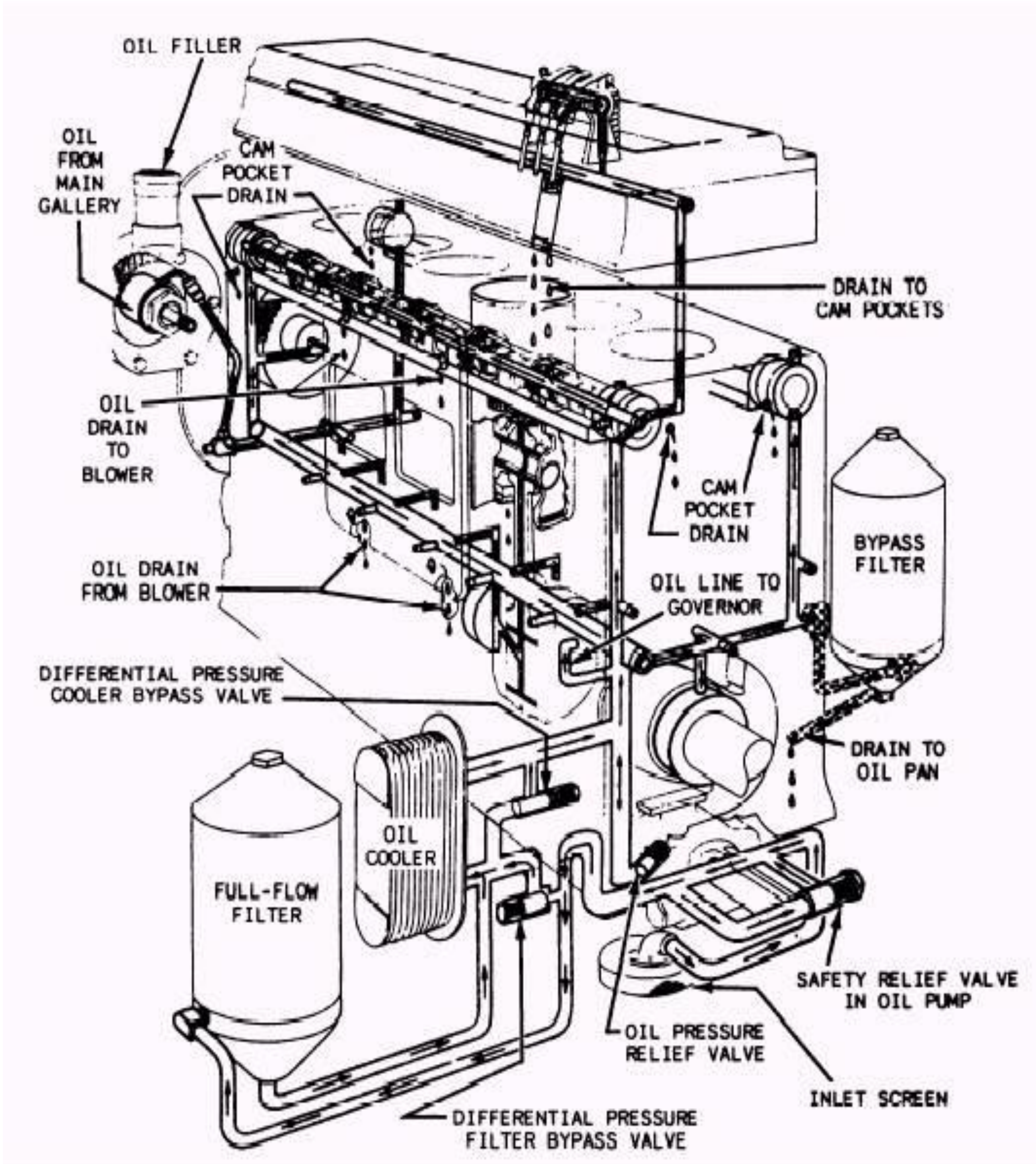


Figure 8-9.-Schematic diagram of a typical lubricating oil system in a General Motors series 71 in line diesel engine.

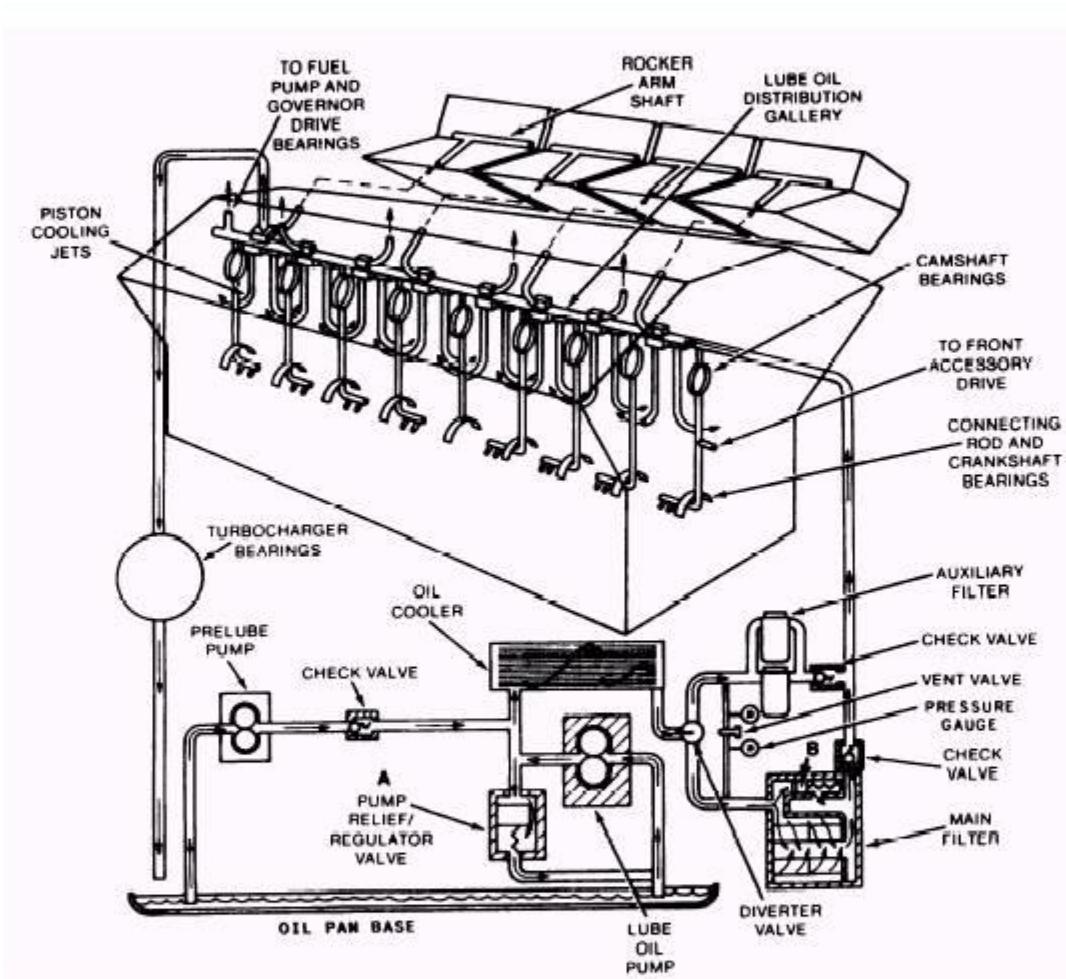


Figure 8-10.-Lubricating oil system in a Caterpillar diesel engine.

The secondary system will filter impurities from the lubricating oil through a 5-micron filter, which is a much finer medium than the 25-micron filter used in the primary system.

FLOW OF OIL THROUGH THE DIESEL ENGINE LUBRICATING OIL SYSTEM

Even though the design and arrangement of various diesel engine lubricating oil systems may appear to be different, the systems of most engines are similar in many aspects. So far our discussion has covered the external components of the engine lubricating oil system. Our discussion will now cover the flow of the oil through both the external and internal components of the General Motors series 71 diesel engine and the Caterpillar diesel engine. Learning to trace the flow of oil through the complete lubrication oil system of a diesel engine will be quite helpful to you when you are dealing with lubrication difficulties.

Bypass Filtration

Physical Size

Often limited by physical size, engine oil filters are relatively small when compared to their industrial counterparts. This small size coincides with less filter media surface area through which to pass the lubricant.

Pressure Differential

The pressure differential is the change in pressure from the inlet to the outlet side of the filter. If the pressure differential is too high, a valve will open, allowing the oil to bypass the filter. All engine oil filters or heads are equipped with a bypass valve. This valve is needed so the engine does not become starved of oil as the filter clogs with debris.

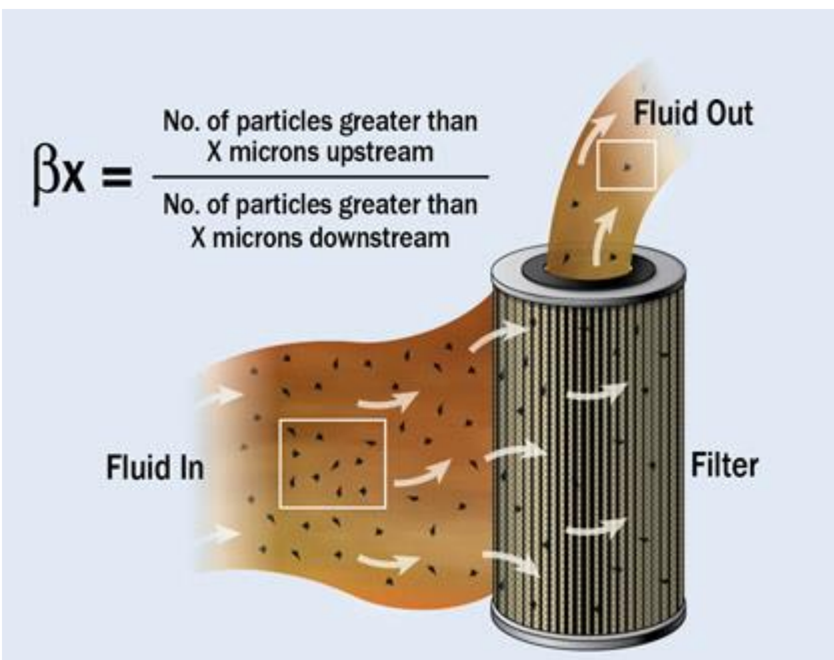
The Beta Ratio Test

Oil filters can be tested in a variety of ways, but one of the most common methods is the beta ratio test. This test incorporates online particle counters positioned upstream and downstream of the filter, a continuous flow of test contaminant into the main system reservoir and oil flowing through the filter.

The beta ratio is calculated by dividing the number of particles larger than a certain size upstream of the filter by the number of particles of the same size downstream of the filter. For example, you may have a beta ratio or a beta sub 5 (meaning particles larger than 5 microns) equal to 10. This means 10 particles upstream of the filter would be divided by 1 downstream of the filter. In other words, for every 10 particles coming in, one gets through.

If you have a higher beta ratio, say a beta ratio of 100 or a beta sub 5 equal to 100, for every 100 particles coming into the filter larger than 5 microns, one makes its way through.

Every filter will have multiple beta ratios. There could be a beta ratio for 2 microns, 5 microns, 10 microns, 50 microns, 100 microns, etc.



You can also use the beta ratio to calculate capture efficiency, which is the average performance over the filter’s life, with the following formula:

((Beta – 1)/Beta) x 100

As an example, a beta ratio of 10 would yield a capture efficiency of 90 percent:

((10 – 1) / 10) x 100 = 90 percent

Therefore, 90 percent of the particles larger than 5 microns are removed by a filter that has a beta ratio of 10.

Flow Rate

In most engine designs, oil must flow through the filter before entering the engine components. Therefore, the filter must be able to handle 100 percent of the flow rate needed to feed the moving components of the engine.

Media Pore Size

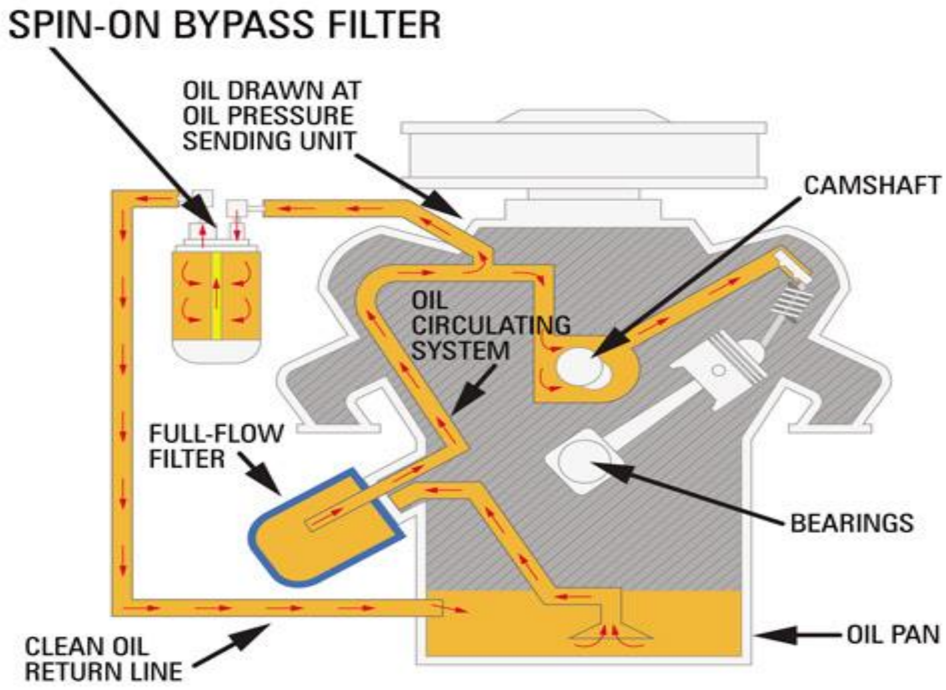
The media pore size is the major determinant in how efficient and how small of a particle the filter can remove.

When these factors are combined, a problem arises. The physical size is usually constrained by design. The filter can't be too large because of all the other components that we are trying to fit under the hood. The flow rate must be high enough to feed all the lubricated components. This means you can't make the pore size too small or it will raise the pressure differential and the bypass valve will open, effectively rendering the filter useless.

There are a few things you can do to remedy this problem. Enter bypass filtration. Bypass filtration systems take 5 to 10 percent of the flow that would have gone to feed the engine and cycle it through an ultra-efficient filter and back to the sump.

With bypass filtration, the flow rate can be greatly reduced, allowing for a much smaller pore size while retaining a normal pressure differential. The result is much cleaner oil being returned to the sump. Smaller soot suspension and polar insolubles that are not controlled by the full-flow filter can now be taken out of the system. When combined with a full-flow filter, bypass filtration offers the benefits of lower wear generation rates, lower oil consumption, higher combustion efficiency and longer oil life.

In a case study performed by General Motors and published by the Society of Automotive Engineers (SAE), it was determined that engine service life could be extended eight times when 5-micron filtration is implemented vs. the standard 40-micron filtration.



Obviously, having cleaner oil is better for the reliability of the engine. There's an old saying that oil doesn't wear out; it just gets dirty. Although there is some validity to the idea that dirtier oil will "age" quicker than clean oil, the engine oil will have a finite life. It will need to be changed eventually no matter how clean you keep it.

While it's true that a system can remove the majority of suspended soot, wear debris and dirt, the oil and additives are still being decomposed by oxidation and nitration. The depletion of these additives will ultimately be the reason for the oil change. The system should slow down the rate of this depletion, but it cannot eliminate it. Acids, fuel and coolant are just a few of the contaminants that bypass filtration cannot address. They too can shorten the life of the oil.

If you are shopping for one of these systems, it is vital that you do your homework. Not all bypass systems are created equal, and there is a plethora of marketing material out there to make you feel thoroughly confused. Keep in mind that while testimonials may seem impressive, they are not scientific proof. Make sure the manufacturer has SAE and ISO testing to back up its claims.

When installed and maintained properly, a bypass system can provide great benefits. Just be sure to ask all the right questions and have a firm grasp on the concept before settling on a system.

CRANKCASE VENTILATION

A crankcase ventilation system removes unwanted gases from the crankcase of an internal combustion engine. The system usually consists of a tube, a one-way valve and a vacuum source (such as the intake manifold). The unwanted gases, called "blow-by", are gases from the combustion chamber which have leaked past the piston rings. Early engines released these gases to the atmosphere simply by them leaking through the crankcase seals. The first specific crankcase ventilation system was the *road draught tube*, which used a partial vacuum to draw the gases through a tube and release them to the atmosphere. Positive crankcase ventilation (PCV) systems— first used in the 1960s and present on most modern engines— send the crankcase gases back to the combustion chamber, in order to reduce air pollution.

Two-stroke engines with a crankcase compression design do not need a crankcase ventilation system, because normal operation of the engine involves sending the crankcase gases to the combustion chamber.