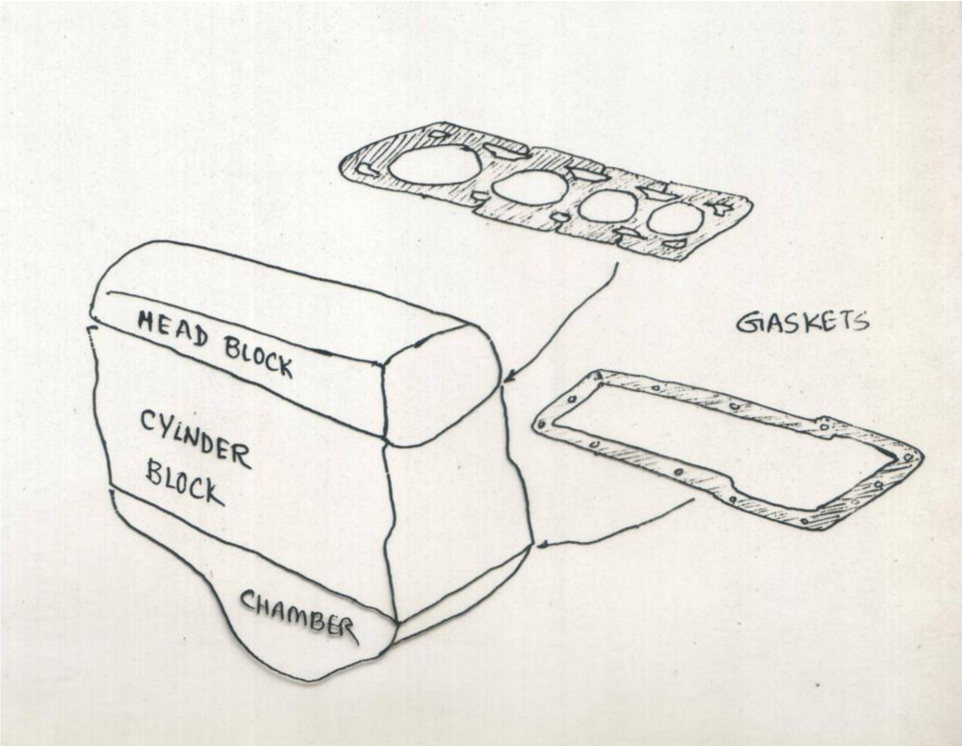
ENGINE CONSTRUCTION

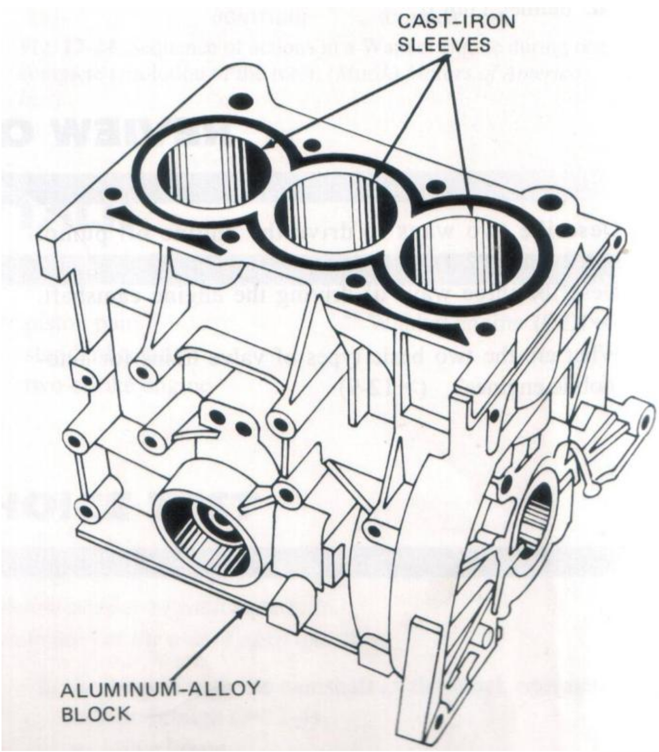


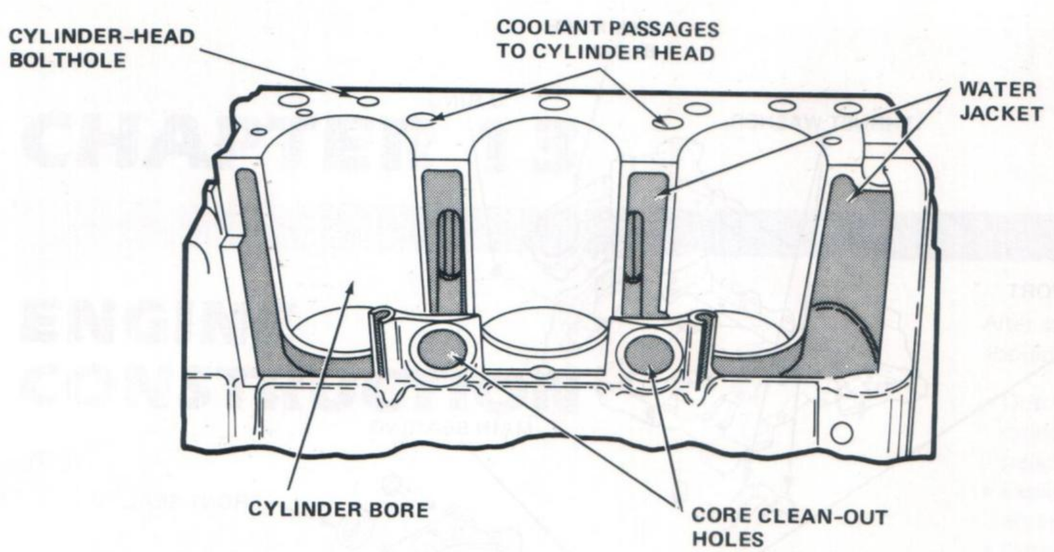
ENGINE HEAD ASSEMBLY/ HEAD BLOCK : Typically the top part of the engine. Head block contains the engine valve assemblies, Clearance volume of combustion chamber and Cam shafts for Overhead Cam engines.

ENGINE CYLINDER BLOCK : The cylinder block is the foundation of the engine. All other engine parts are assembled in or attached to the cylinder block. The cylinder block has large bores for cylinder bores/liners and gaps for water jacket and for coolant passage.

ENGINE CHAMBER : Typically the lowest part of the engine. The chamber/sump mainly contains the lubricating oil and its strainer/filters.

Engine Head Assembly and Chamber are joined to the Engine Block with elastomeric composite gaskets in between to make the whole assembly leak proof.





CYLINDER LINERS

This the wear resistant part which faces the rubbing friction of the piston and piston rings.

Allow to use cheaper materials for the other parts of the cylinder block

Cylinder Liner Materials: Cast Iron (CI), CI with Ni and Cr as an Alloy.
Cylinder Block Materials: Aluminium or Cast Iron

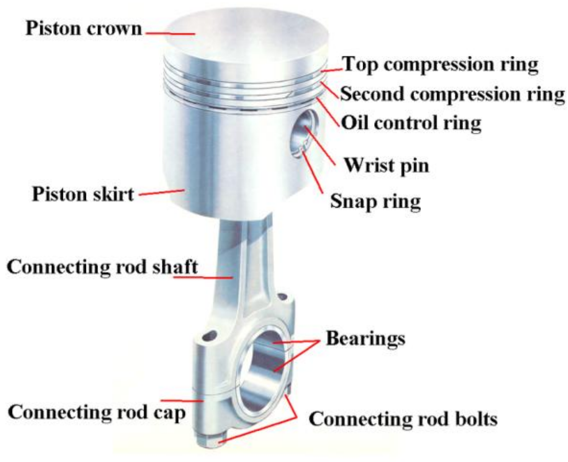
PISTONS

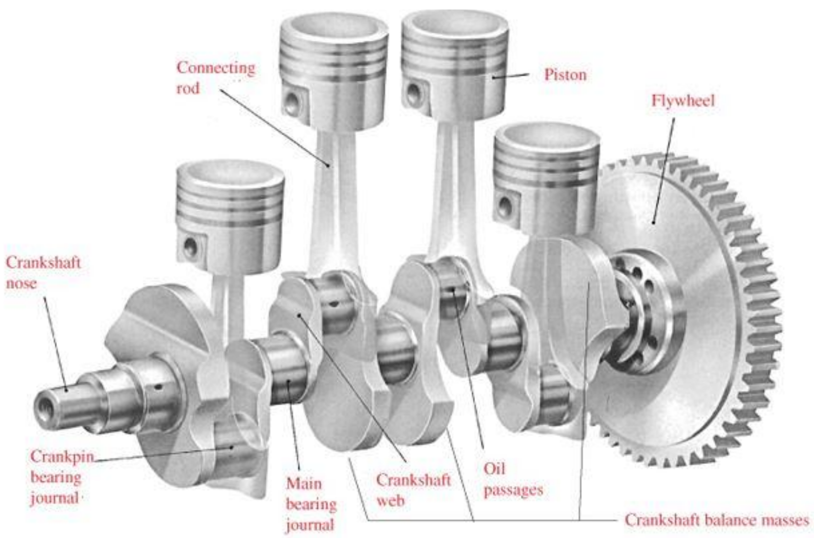
Now a days pistons typically are made of Aluminium. This is the material of choice as it is light, strong good in conducting heat. Lighter load gives better engine response, Good thermal conductivity gives better heat path.

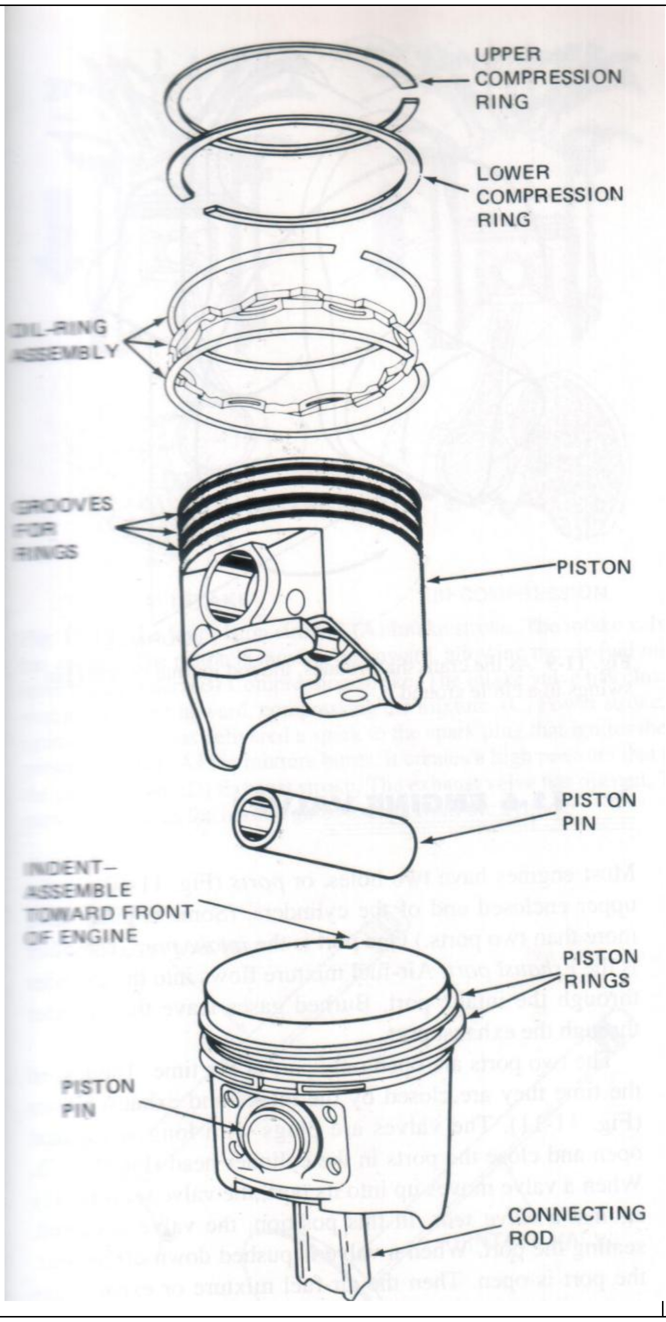
Pistons are made to slide fit in the cylinder liners. The gap between the cylinder liner and piston wall is called “Piston Clearance”. Typically this is about 1/1000 – 4/1000 th of an inch (0.025 – 0.1)mm, about 0.1-0.2% of bore diameter. In operation a lubricating oil film fills the piston clearance. This is a very critical dimension.

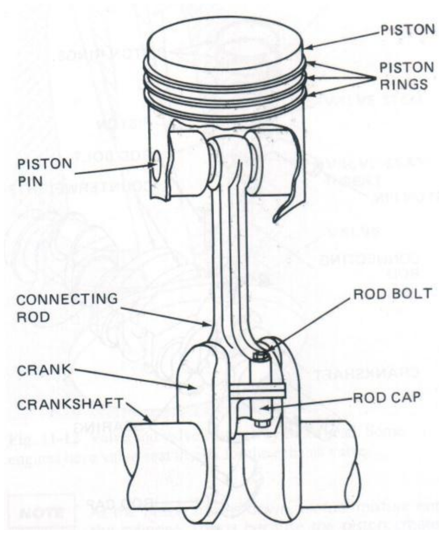
Too small a clearance – high friction, loss of power and heat generation.
Too high a clearance – Excess Blow-by, Piston slap, loss of power.

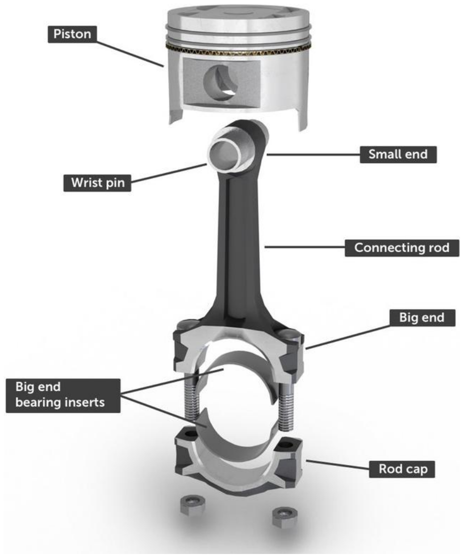
The top part of the piston may have a crown or recess, which forms a part of the combustion chamber shape. Aluminium has the ease of manufacturing. Pistons can be either Forged or Cast.







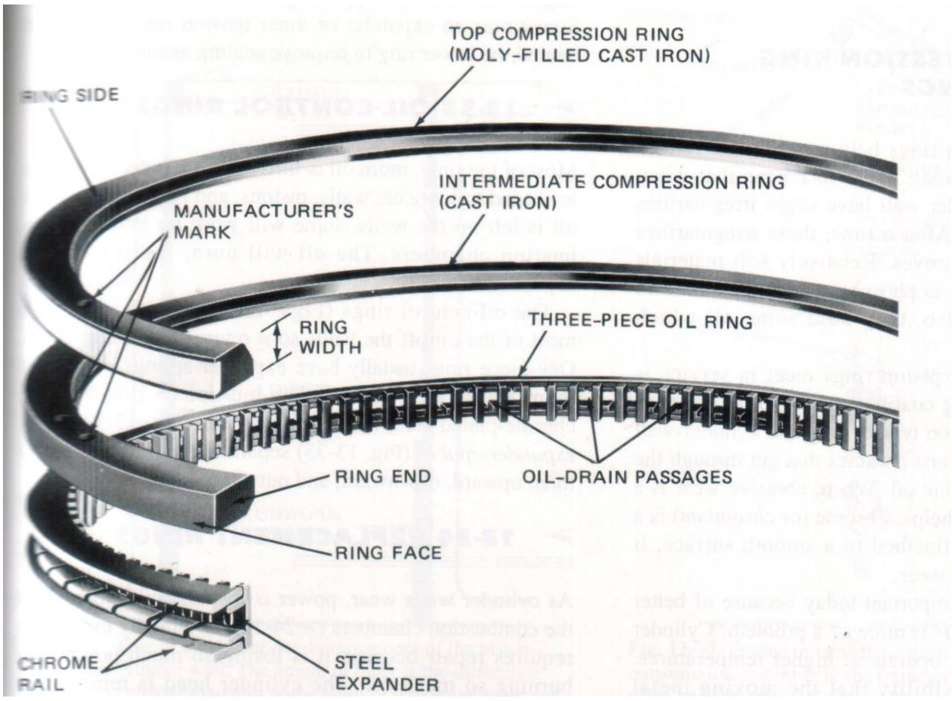




Piston Rings

Compression Ring : This forms a sliding seal between the piston and the cylinder to contain the compression and combustion pressure. Typically 2-3 compression rings are used.

Oil Ring : Scrape off excess oil so that it does not get up into the combustion chamber.



A radial cut is made in the rings so that it can be placed in the ring groove in the piston.

Subsequent cuts are placed ninety degree to each other to reduce blow-by losses.

Important properties of Ring materials are : Ware resistance, Elasticity, High Temperature Stability.

Ring Materials : Cast Iron with Chromium, Coated with Molybdenum.

Piston-Cylinder Assembly

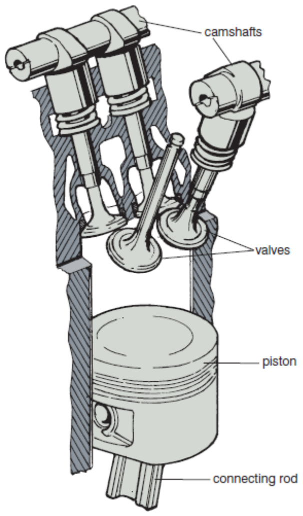
Piston - Connecting Rod – Crank Shaft Cam

It converts between reciprocal and rotational movement

Flywheel: At the end of the crankshaft a heavy disc is fitted called the flywheel. A flywheel is a rotating mechanical device that is used to store rotational energy. Flywheels have a significant moment of inertia and thus resist changes in rotational speed. The amount of energy stored in a flywheel is proportional to the square of its rotational speed. Flywheel provides continuous energy when the energy source is discontinuous. Flywheels are used in reciprocating engines because the energy source from the power is intermittent. As a result the power and speed of the engine is more uniform.

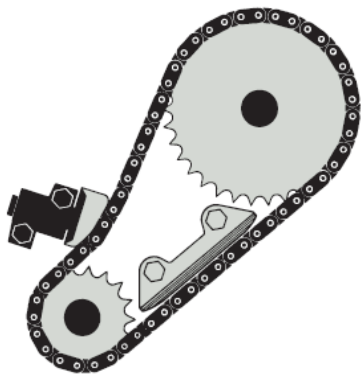
Cams and Cam Shaft

A cam is a rotating or sliding piece in a mechanical linkage used especially in transforming rotary motion into linear motion or vice-versa. A camshaft is a shaft to which a cam is fastened or of which a cam forms an integral part.

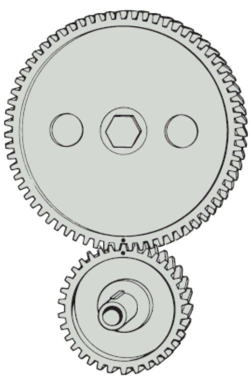


Crank-Cam Drive – Toothed belt/Chain-Sproket/Gear

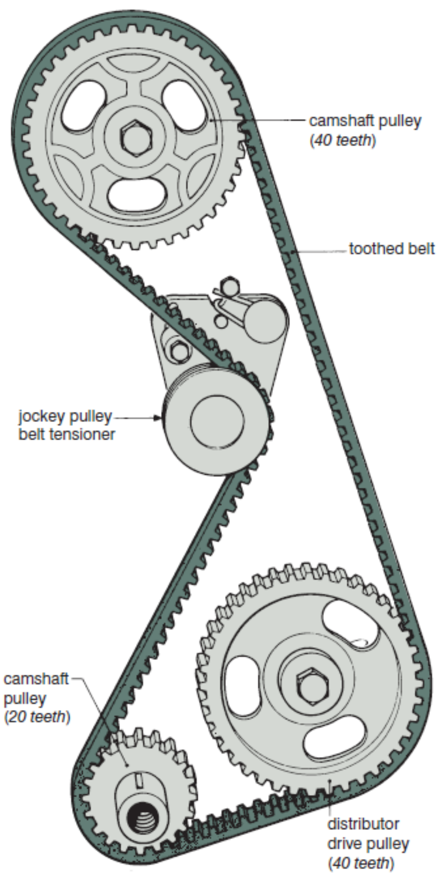
Camshaft rotates at half the speed of the Crankshaft.



Chain Drive



Gear Drive

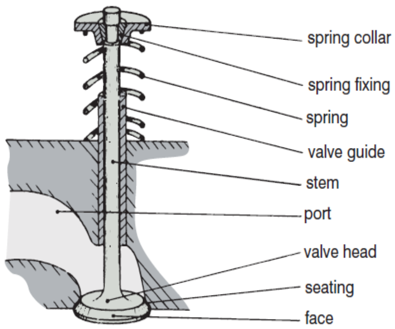


Toothed Belt Drive

Engine Valves: Valve Actuation Sequence

In-block Cam

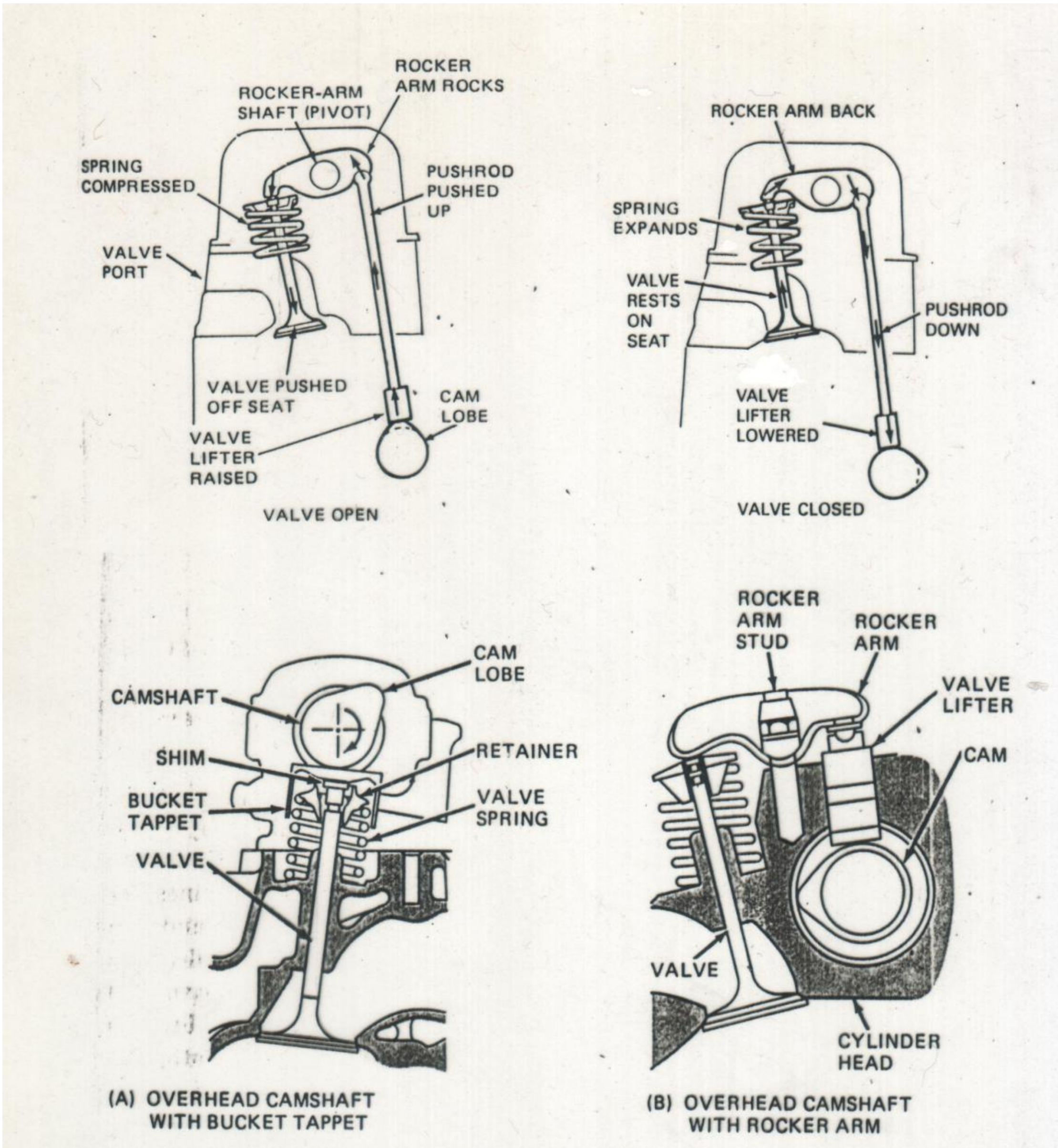
Crankshaft → Camshaft → Cam → Cam follower / Hydraulic Tappet → Push rod → Rocker → Valve body



Overhead Cam

Crankshaft → Over head Camshaft → Cam → Hydraulic Tappet → Rocker → Valve body

Materials : Special Steel-Alloys with Cr, Si, Ni, Mn
Must withstand high temperature(750°C)



Engine Sub-Systems

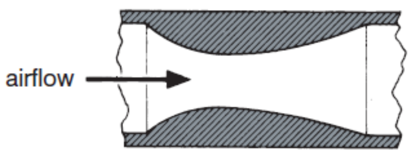
- Air Intake & Exhaust System
- Fuel Supply System
- Ignition System
- Lubrication System
- Cooling System
- Starting System

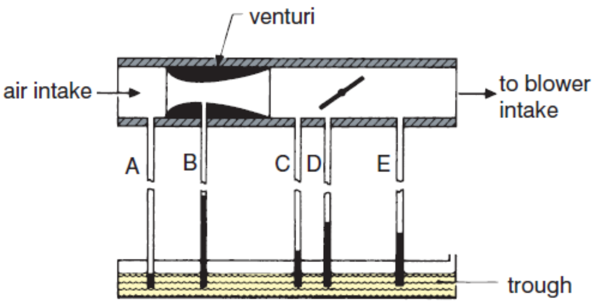
Fuel and Ignition System (SI)

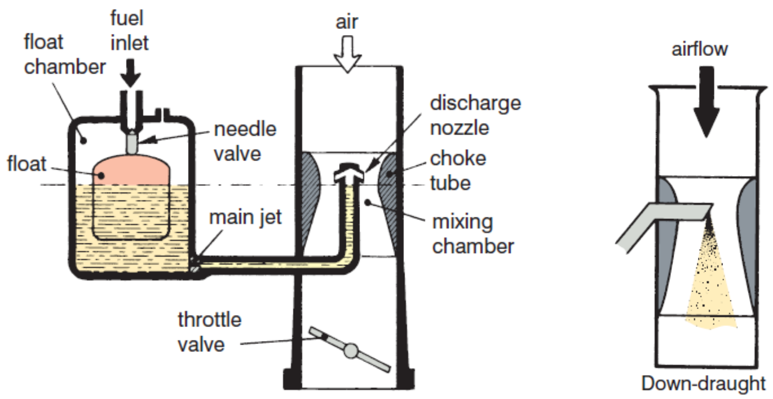
Followings are main features of a SI engine

1. The Charge (incoming fluid) in to the engine is a mixture of air and fuel which is mixed prior to entering the engine cylinder.
2. Carburetion is process of mixing fuel with incoming air according to the engine requirement. The processes involve atomization and vaporization of liquid fuel and its mixing with air. The fuel needs to have high volatility.
3. A rightly times electric spark is used to ignite the air-fuel mixture to initiate combustion. An ignition system is needed to generate the spark.

SI Engine Fuel System - Carburettor

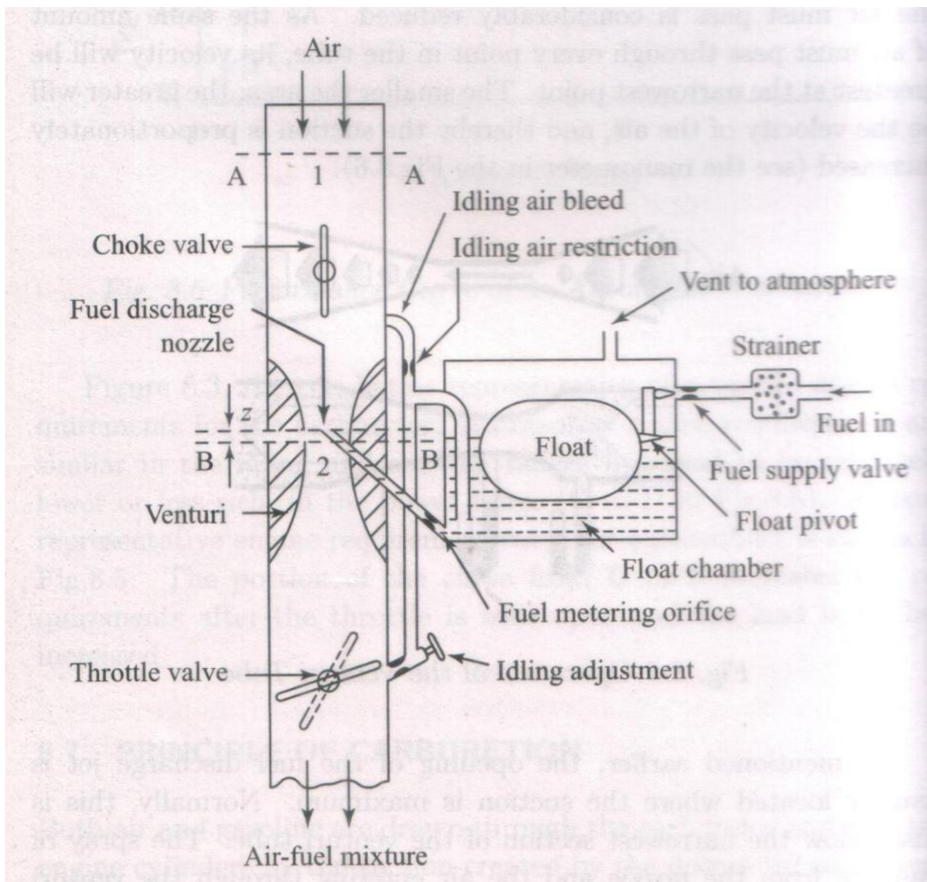






Simple Carburettor Construction

The main part of the carburettor is a venture (converging diverging section). It operates on the basis of Bernoulli's Equation – the summation of pressure and velocity head is constant. The venture is placed in the air inlet line between the air filter and the intake manifold. During suction stroke as air rushes through the venture, the velocity increases and a pressure depression (low pressure) is created at the venture throat. This low pressure sucks the fuel into the air stream. The fuel jet is disintegrated in to tiny droplets (atomization) and gradually evaporates (vaporization) in to the in going air steam stream to the cylinder. This process of mixing air and fuel is called 'Carburetion'. The throttle valve is used to control the quantity and quality of the air-fuel mixture entering the cylinders.



Components of a typical Carburettor

CARBURETTOR SUB-SYSTEMS

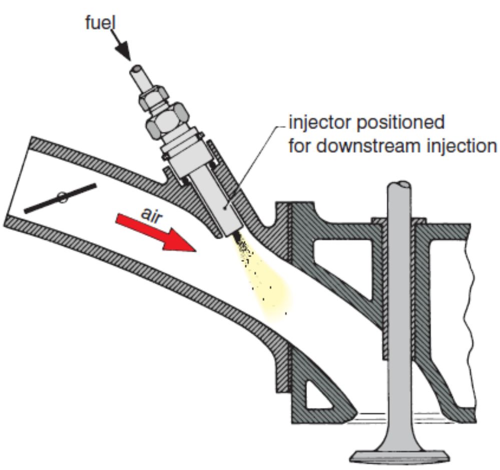
- Float System : Maintains the supply fuel head
- Choke System : Used for cold start of engine
- Idle System : When engine running at low speed
- Main metering system : Main nozzle in operation
- Power System : Additional supply of fuel enriches mixture at high loads
- Accelerator-pump System : Compensates fuel lag with rapid acceleration

Electronic Fuel Injection (EFI)- Single Point Injection (SPI)

Multipoint Fuel Injection (MPFI)

Gasoline Direct Injection (GDI)

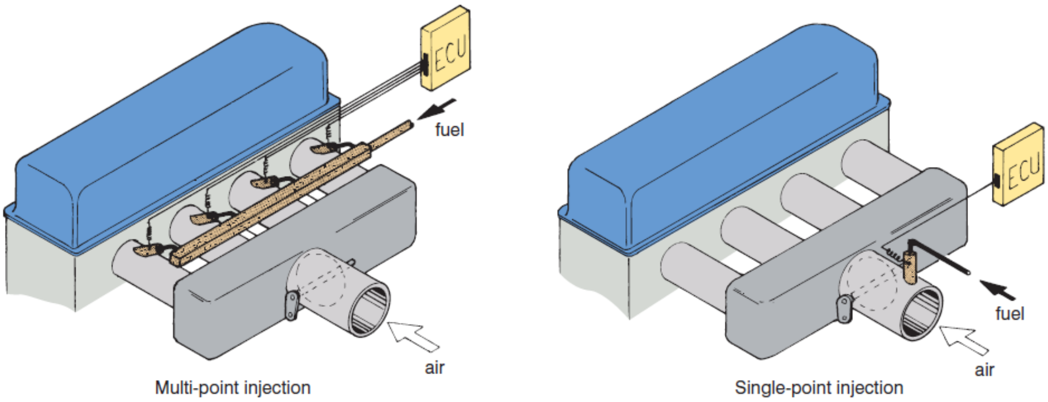
Modern engines use electronically controlled fuel injection to mix fuel into the incoming air. A micro-controller or on-board computer takes information from a number of transducers. Based on these the computer decides regarding the rate of fuel injection in the air. A pump supplies the fuel at 2-5 bar pressure to the fuel injector, which opens its port and creates a spray of fuel – typically outside the engine cylinder, as per the controller requirement. The controller generally uses pulse width modulation (PWM) to control the injector solenoid to activate the spray. This allows very precise control of a fuel flow in to the air stream, according to the engine requirement. However the fuel injection pressure level is far less compared diesel fuel which injected inside the engine cylinder. The throttle valve is used to control the air flow, indirectly controlling the fuel spray.



- Lower exhaust pollution
- Lower fuel consumption
- Higher power output
- Smoother engine operation due to an even power output from each cylinder

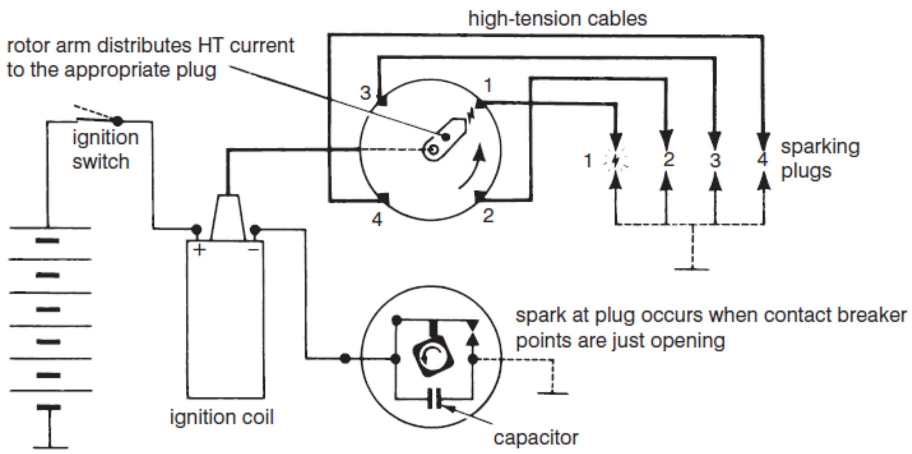
1 *Multi-point injection* - separate injectors for each cylinder, each injector positioned close to the inlet valve of the engine

2 *Single-point injection* - one injector only that discharges fuel into the air stream at the point used by a carburettor.



Ignition System

The ignition system provides a high voltage spark (25000-35000 volts) in individual cylinders towards the end of the compression stroke, in order to ignite the compressed air-fuel mixture. The exact timing of spark requirement depends on a number of engine operating conditions like – speed, load, air-fuel ratio, temperature etc.

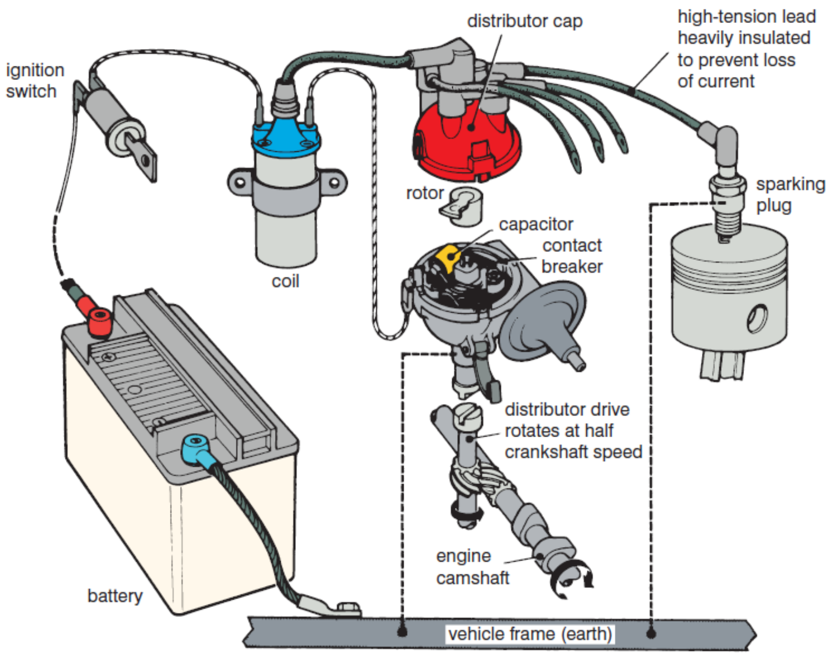


FIRING ORDER

For multi-cylinder engines it is desired that the power strokes in different cylinders occur is a sequence, not at a time. ‘Firing Order’ is the sequence in which sparks are sent to different cylinders in a multi-cylinder engine. The most common firing orders are given below-

4-Cylinder : 1-3-4-2

6-Cylinder : 1-4-2-6-3-5 or 1-5-3-6-2-4

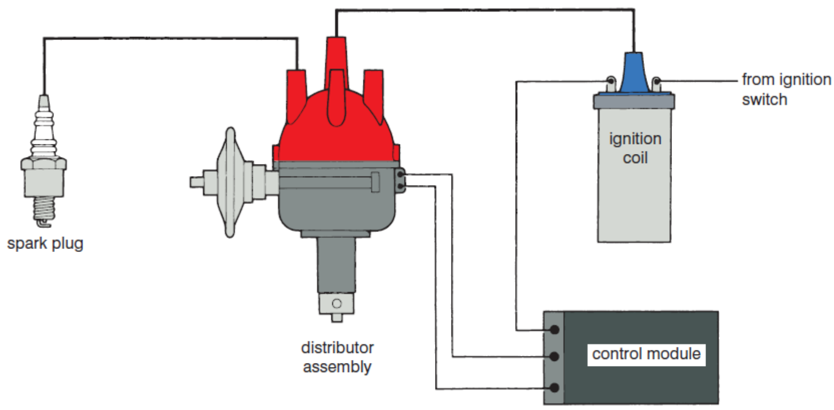


Electronic Ignition / Breaker less Ignition / Solid State Ignition

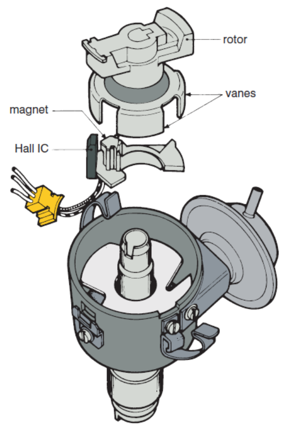
Here the mechanical contact breaking switch is replaced by much more efficient and reliable electronic sensors like:

- Inductive Pulse Generator
- Optical Pulse Generator
- Hull Effect IC

In addition an Electronic Control Module (ECM) is used to precisely control the timing of the 'Spark' according to the engine requirements under all operating conditions.



Electronic Ignition System



Hall IC Switching

Diesel Ignition System

A diesel engine (also known as a compression-ignition engine) is an internal combustion engine that uses the heat of compression to initiate ignition to burn the fuel, which is injected into the combustion chamber. Here the property of self ignition temperature (SIT, about 316°C for Diesel) is used to initiate the combustion. Here the quantity of diesel injection is used for controlling engine power. There is no throttle valve for controlling air flow in a Diesel engine.

Typical Components

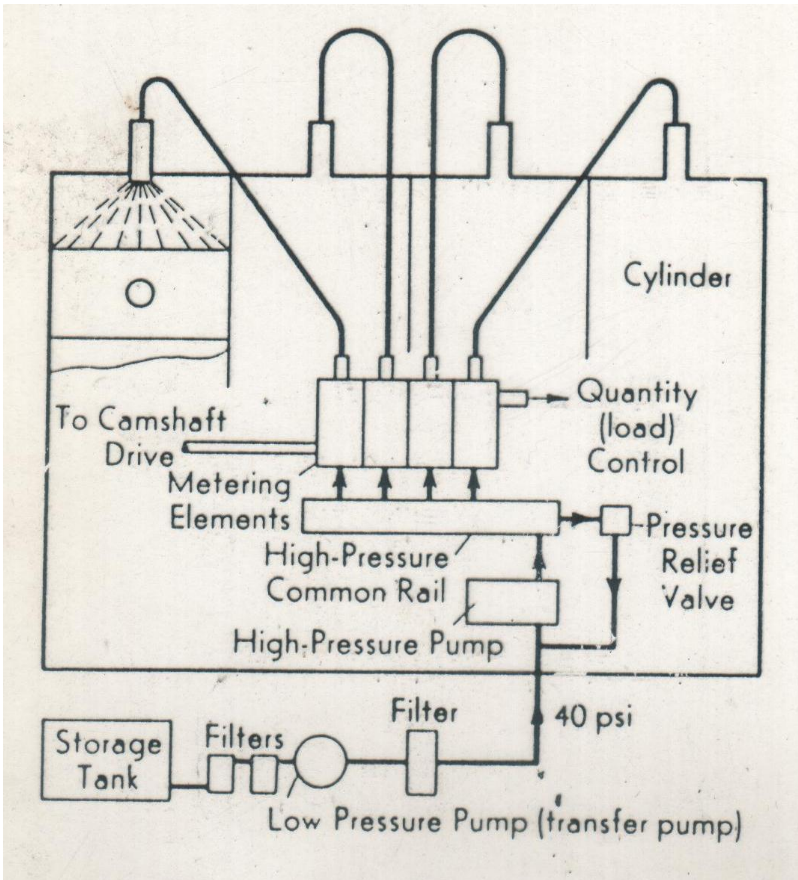
- Fuel Tank
- Fuel filters
- Injection pump :

  Low pressure pump (3 bar) for transferring fuel from tank to engine.

  High pressure injection pump (100-200 bar) for fuel injection.
- Governor system to ensure the metering of fuel
- Distribution system to ensure every cylinder gets its share
- Injector/Nozzle - to deliver the fuel spray inside the cylinder.

Objectives that need to be fulfilled - consistently and precisely.

1. Meter the quantity of fuel demanded by the engine operation
2. Distribute the metered fuel equally among the cylinders
3. Inject the fuel at the correct time in the cycle.
4. Inject the fuel at the correct rate.
5. Inject the fuel with the spray pattern and atomization demanded by the design of combustion chamber.
6. Begin and end the fuel injection sharply.



common-rail system

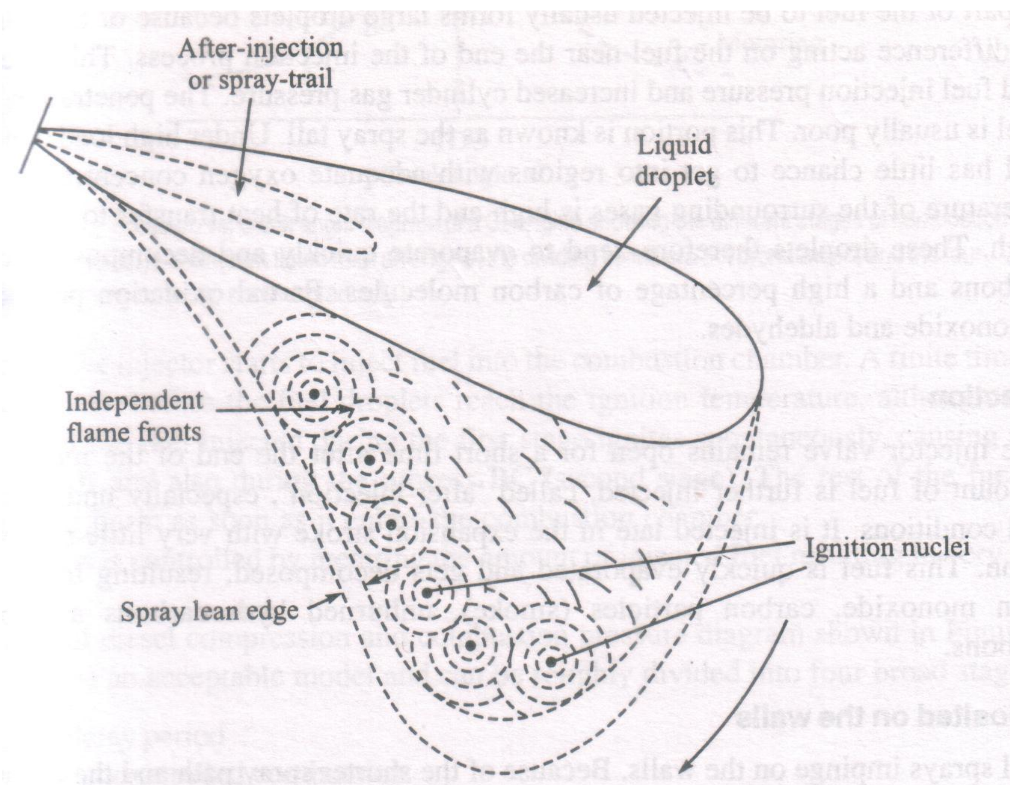


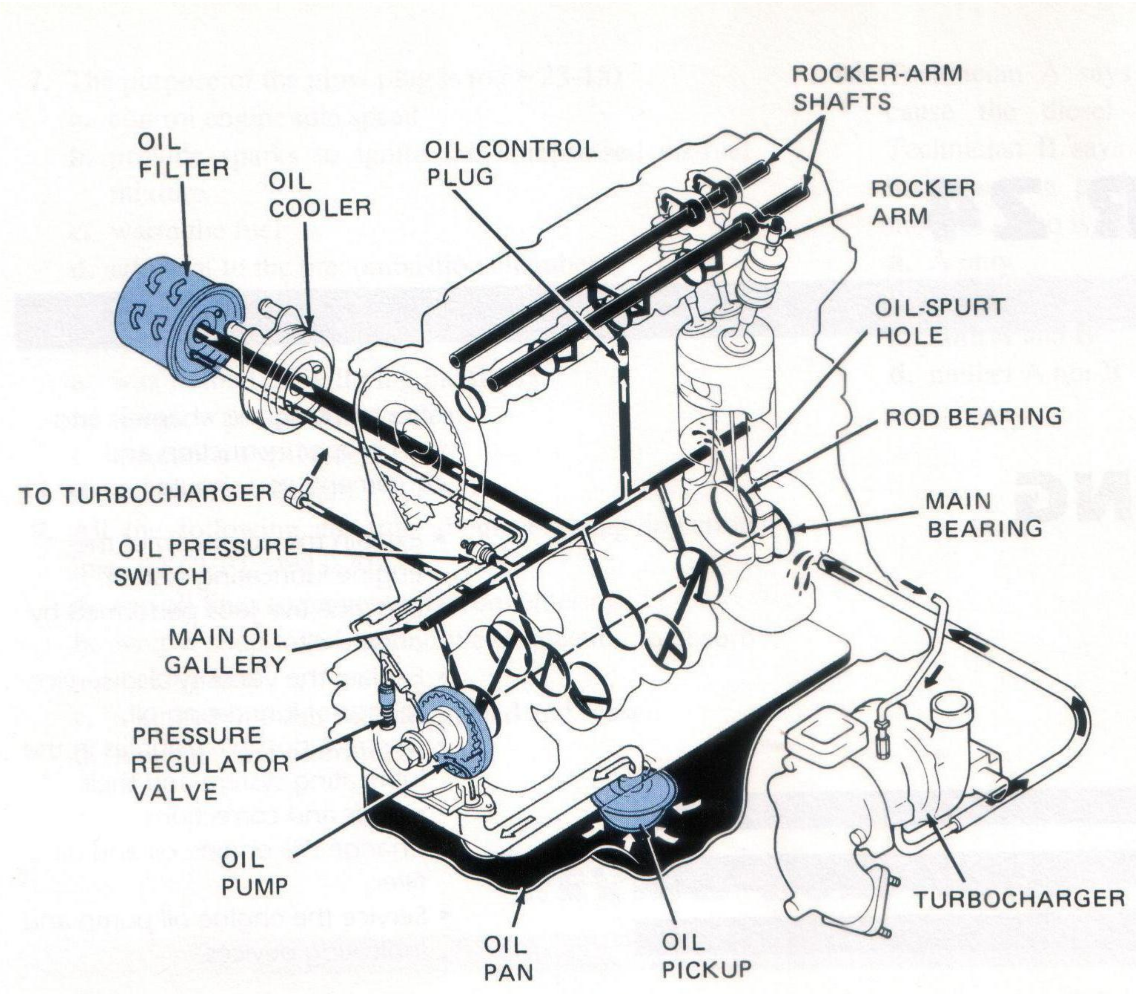
Figure 7.4 Mechanisms of combustion of a fuel spray injected in swirling air.

Lubrication System

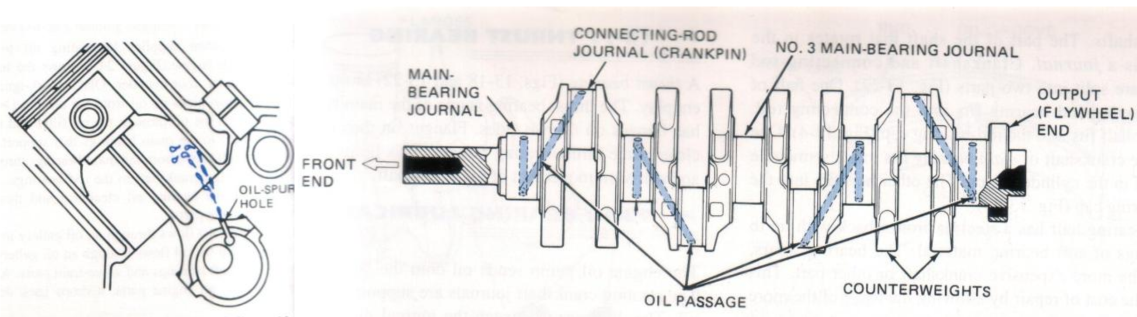
Lub Oil Sump
(Chamber)
↓
Strainer
↓
Pump
(Cam operated gear/vane
fitted with relief valve)
↓
Filter
(Replaceable cartidge)
↓
Main Oil Gallery
↓
Holes/Passages/Channels
(to valves, cam, crank-piston)
⇩
Return to sump
(gravity feed)

Oil Filter

Cap for Oil Refill



Flow of Lubricating Oil in an engine



Lubrication of Cylinder Wall

Functions of Lubrication System

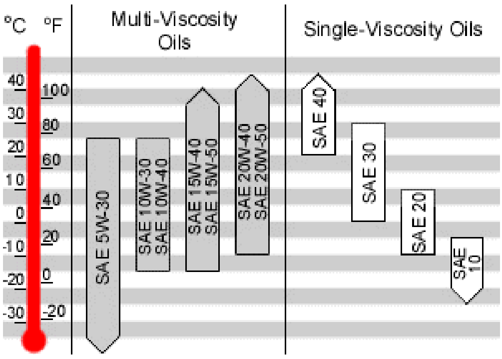
- Reduce wear of mating components
- Reduce frictional power losses
- Serve as a cooling agent
- Serve as a cleaning agent
- Better sealing
- Better cushion at bearings

Lubricating Oil

Correct viscosity – less change in operating temp range

Designation of Lub Oil SAE 30, SAE 40 (higher number more viscous)

SAE 10W-30, SAE 20W-50 (Multiple viscosity)



The SAE designation for multi-grade oils includes two viscosity grades; for example, 20W-50 designates a common multi-grade oil. The W or winter number is important for low temperature performance. The first number '20W' is the viscosity rating at cold temperature (-15°C) and the second number '50' is the grade of the equivalent single-grade oil viscosity at 100 °C. Additives called 'viscosity improvers' are added to oil for this.

Cooling System

Water Cooled System – Very Common

Air Cooled System – Less Common, small engines

Components :

- Radiator – Water-Air Heat Exchanger, Large surface area, Cross flow from fan
- Pressure Cap – Maintains pressure, two-way valves
- Expansion Tank – Keeps radiator filled with water hot and cold controlling volume
- Hoses – Fabric reinforced Rubber
- Thermostatic Valve – Maintains water temperature in the water-jacket in certain desired level - by controlling flow
- Water Jacket – Water filled space around cylinders
- Fan – Electrical/Mechanical Drive – Motor/Fan belt.
- Pump – Centrifugal type – low head

Engine Coolant includes - water, antifreeze and corrosion inhibitors.