AUTOMOTIVE INDUSTRY TRAINING
RETAIL, SERVICE AND REPAIR
AUR05

Learning & Assessment Resource

AURT201170A
Inspect & Service Engines

Automotive Training Board nsw

NEW SOUTH WALES DEPARTMENT OF EDUCATION AND TRAINING

State Training Services

Acknowledgment and Copyright

Disclaimer

Acknowledgement

This work has been produced by the Automotive Training Board NSW Ltd with funding provided by the NSW Department of Education and Training.

Contents

AURT201170A Inspect and Service Engines

Pre Requisite Units of Competence

Nil

Overview

This unit covers the competence required to carry out the inspection and service of two and four stroke spark ignition and two and four stroke compression ignition engines.

The unit includes identification and confirmation of work requirement, preparation for work, inspection and servicing of engines and completion of work finalisation processes, including clean-up and documentation.

All work and work practices must be undertaken to regulatory and legislative requirements. It is applicable in both a learning and assessment pathway and an assessment only pathway.

This competence is performed in the context that all materials and equipment needed to carry out this function have been provided, including learning materials, learning programs and learning resources.

Elements of Competence

To achieve competency in this unit you must demonstrate your ability to:

1. Prepare to undertake the inspection of engines;
2. Conduct engine system inspections and analyse results;
3. Prepare to service engines;
4. Carry out servicing; and
5. Prepare vehicle for use or storage.

1.0 The Internal Combustion Engine - Definition

The internal combustion engine is an engine in which the combustion of fuel and an oxidizer (typically air) occurs in a confined space called a combustion chamber. This exothermic reaction creates gases at high temperature and pressure, which are permitted to expand. The defining feature of an internal combustion engine is that useful work is performed by the expanding hot gases acting directly to cause movement of solid parts of the engine, by acting on pistons, rotors, or even by pressing on and moving the entire engine itself.

This contrasts with external combustion engines, such as steam engines, which use an external combustion chamber to heat a separate working fluid, which then in turn does work, for example by moving a piston or a turbine.

The term Internal Combustion Engine (ICE) is almost always used to refer specifically to reciprocating piston engines, Wankel engines and similar designs in which combustion is intermittent. However, continuous combustion engines, such as jet engines, most rockets and many gas turbines are also internal combustion engines.

1.1 Dates to Remember

1206 Al-Jazari described a double-acting reciprocating piston pump with a crankshaft-connecting rod mechanism.

1509 Leonardo da Vinci described a compression less engine.

1862 German inventor Nikolaus Otto designed an indirect-acting free-piston compression less engine whose greater efficiency won the support of Langen then most of the market, which at that time was mostly for small stationary engines fueled by lighting gas.

1876 Nikolaus Otto, working with Gottlieb Daimler and Wilhelm Maybach, developed a practical four-stroke cycle (Otto cycle) engine. The German courts, however, did not hold his patent to cover all in-cylinder compression engines or even the four-stroke cycle, and after this decision, in-cylinder compression became universal.

1879 Karl Benz, working independently, was granted a patent for his internal combustion engine, a reliable two-stroke gas engine, based on Nikolaus Otto's design of the four-stroke engine. Later, Benz designed and built his own four-stroke engine that was used in his automobiles, which became the first automobiles in production.

1882 James Atkinson invented the Atkinson cycle engine. Atkinson’s engine had one power phase per revolution together with different intake and expansion volumes, making it more efficient than the Otto cycle.

1892 Rudolf Diesel developed his Carnot heat engine type motor burning powdered coal dust.

1896 Karl Benz invented the boxer engine, also known as the horizontally opposed engine, in which the corresponding pistons reach top dead center at the same time, thus balancing each other in momentum.

1900 Rudolf Diesel demonstrated the diesel engine in the 1900 Exposition Universelle (World's Fair) using peanut oil (see biodiesel).

1900 Wilhelm Maybach designed an engine built at Daimler Motoren Gesellschaft—following the specifications of Emil Jellinek—who required the engine to be named Daimler-Mercedes after his daughter. In 1902 automobiles with that engine were put into production by DMG.

2.0 Petroleum Internal Combustion Engines

2.1 Petrol Ignition Process

Electrical/petrol-type ignition systems (that can also run on other fuels) generally rely on a combination of a lead-acid battery and an induction coil to provide a high-voltage electrical spark to ignite the air-fuel mix in the engine's cylinders. This battery can be recharged during operation using an electricity-generating device such as an alternator or generator driven by the engine. Petrol engines take in a mixture of air and petrol and compress to less than 1275kpa and use a spark plug to ignite the mixture when it is compressed by the piston head in each cylinder.

2.2 Diesel Ignition Process

Diesel engine ignition systems, such as the diesel engine and Homogeneous Charge Compression Ignition (HCCI) engines, rely solely on heat and pressure created by the engine in its compression process for ignition. The compression that occurs is usually more than three times higher than a petrol engine. Diesel engines will take in air only, and shortly before peak compression, a small quantity of diesel fuel is sprayed into the cylinder via a fuel injector that allows the fuel to instantly ignite. HCCI type engines will take in both air and fuel but continue to rely on an unaided auto-combustion process due to higher pressures and heat. This is also why diesel and HCCI engines are also more susceptible to cold starting issues, though they will run just as well in cold weather once started. Most diesels also have battery and charging systems; however, this system is secondary and is added by manufacturers as luxury for ease of starting, turning fuel on and off (which can also be done via a switch or mechanical apparatus), and for running auxiliary electrical components and accessories. Most new engines, however, rely on electrical systems that also control the combustion process to increase efficiency and reduce emissions.

2.3 Petrol Engine - History

The most commonly used source of power for motor vehicles was introduced by the German engineers Gottlieb Daimler and Karl Benz in 1885. The petrol engine is a complex piece of machinery made up of about 150 moving parts. It is a reciprocating piston engine, in which a number of pistons move up and down in cylinders. A mixture of petrol and air is introduced into the space above the pistons and ignited. The gases produced force the pistons down, generating power. The engine-operating cycle is repeated every four strokes (upward or downward movement) of the piston, this being known as the four-stroke cycle. The motion of the pistons rotates a crankshaft, at the end of which is a heavy flywheel. From the flywheel the power is transferred to the car's driving wheels via the transmission system of clutch, gearbox, and final drive.

The parts of the petrol engine can be subdivided into a number of systems.

- The **fuel system** pumps fuel from the petrol tank into the carburettor. There it mixes with air and is sucked into the engine cylinders. (With electronic fuel injection, it goes directly from the tank into the cylinders by way of an electronic monitor.)
- The **ignition system** supplies the sparks to ignite the fuel mixture in the cylinders. By means of an ignition coil and contact breaker, it boosts the 12-volt battery voltage to pulses of 18,000 volts or more. These go via a distributor to the spark plugs in the cylinders, where they create the sparks. (Electronic ignitions replace these parts.) Ignition of the fuel in the cylinders produces temperatures of 700°C/1,300°F or more, and the engine must be cooled to prevent overheating.
- Most engines have a **water-cooling system**, in which water circulates through channels in the cylinder block, thus extracting the heat. It flows through pipes in a radiator, which are cooled by fan-blown air. A few cars and most motorcycles are air-cooled, the cylinders being surrounded by many fins to present a large surface area to the air.
- The **lubrication system** also removes some heat, but its main job is to keep the moving parts coated with oil, which is pumped under pressure to the camshaft, crankshaft, and valve-operating gear.

3.0 Engine cycle

3.1 Two-stroke

Engines based on the two-stroke cycle use two strokes (one up, one down) for every power stroke. Since there are no dedicated intake or exhaust strokes, alternative methods must be used to scavenge the cylinders. The most common method in spark-ignition two-strokes is to use the downward motion of the piston to pressurize fresh charge in the crankcase, which is then blown through the cylinder through ports in the cylinder walls.

Spark-ignition two-strokes are small and light for their power output and mechanically very simple; however, they are also generally less efficient and more polluting than their four-stroke counterparts. However, in single-cylinder small motor applications, cc for cc,(cc meaning cubic centimeter), a two-stroke engine produces much more power than equivalent 4 strokes, due to the enormous advantage of having 1 power stroke for every 360 degrees of crankshaft rotation (compared to 720 degrees in a 4 stroke motor).

Small displacement, crankcase-scavenged two-stroke engines have been less fuel-efficient than other types of engines when the fuel is mixed with the air prior to scavenging, allowing some of it to escape out of the exhaust port. Modern designs (Sarich and Paggio) use air-assisted fuel injection, which avoids this loss, and are more efficient than comparably sized four-stroke engines. Fuel injection is essential for a modern two-stroke engine in order to meet ever more stringent emission standards.

Research continues into improving many aspects of two-stroke motors, including direct fuel injection, amongst other things. Initial results have produced motors that are much cleaner burning than their traditional counterparts.

Two-stroke engines are widely used in snowmobiles, lawnmowers, weed-whackers, chain saws, jet skis, mopeds, outboard motors, and many motorcycles.

The largest compression-ignition engines are two-strokes and are used in some locomotives and large ships. These engines use forced induction to scavenge the cylinders. An example of this type of motor is the Wartsila-Sulzer turbocharged 2 stroke diesel as used in large container ships. It is the most efficient and powerful engine in the world, with over 50% thermal efficiency. For comparison, the most efficient small 4-stroke motors are around 43% thermal efficiency (SAE 900648), and size is an advantage for efficiency due to the increase in the ratio of volume to area.

3.2 Four-stroke

Engines based on the four-stroke or Otto cycle have one power stroke for every four strokes (up-down-up-down) and are used in cars, larger boats, some motorcycles, and many light aircraft. They are generally quieter, more efficient, and larger than their two-stroke counterparts. There are a number of variations of these cycles, most notably the Atkinson and Miller cycles. Most truck and automotive diesel engines use a four-stroke cycle, but with a compression heating ignition system. This variation is called the diesel cycle. The steps involved here are:

1. Intake stroke: Air and vaporized fuel are drawn in;
2. Compression stroke: Fuel vapor and air are compressed and ignited;
3. Combustion stroke: Fuel combusts and piston is pushed downwards; and
4. Exhaust stroke: Exhaust is driven out. During the 1st, 2nd, and 4th, stroke the piston is relying on power and momentum generated by the other pistons. In that case a four cylinder engine would be less powerful than a six or eight cylinder engine.

3.3 Five-stroke

Engines based on the five-stroke cycle are a variant of the four-stroke cycle. Normally the four cycles are intake, compression, combustion, and exhaust. The fifth cycle added by Delautour is refrigeration. Engines running on a five-stroke cycle are claimed to be up to 30 percent more efficient than equivalent four-stroke engines.

3.4 Six-stroke

The six stroke engine captures the wasted heat from the 4-stroke Otto cycle and creates steam, which simultaneously cools the engine while providing a free power stroke. This removes the need for a cooling system, making the engine lighter while giving 40% increased efficiency over the Otto Cycle.

3.5 Bourke engine

In this engine, two opposed cylinders are linked to the crank by a Scotch yoke. The Scotch yoke mechanism prevents side thrust, preventing any piston slap, allowing operation as a detonation or "explosion" engine. This also greatly reduces friction between pistons and cylinder walls. The Bourke engine uses fewer moving parts and has to overcome less friction than conventional crank and slider engines with poppet valves. However no independent testing of this engine has ever borne out any of these claims.

3.6 Controlled Combustion Engine

These are also cylinder-based engines, which may be one or two-stroke but use, instead of a crankshaft and piston rods, two gear-connected, counter rotating concentric cams to convert reciprocating motion into rotary movement. These cams practically cancel out sideward forces that would otherwise be exerted on the cylinders by the pistons, greatly improving mechanical efficiency. The number of lobes of the cams (always an odd number not less than 3) determines the piston travel versus the torque delivered. In this engine, there are two cylinders that are 180 degrees apart for each pair of counter rotating cams. For single-stroke versions, there are as many cycles per cylinder pair as there are lobes on each cam, and twice as many for two-stroke engines.

3.7 Wankel

The Wankel engine (rotary engine) does not have piston strokes, so is more properly called a four-phase, rather than a four-stroke, engine. It operates with the same separation of phases as the four-stroke engine, with the phases taking place in separate locations in the engine. This engine provides three power 'strokes' per revolution per rotor (while it is true that 3 power strokes occur per ROTOR revolution, due to the 3/1 revolution ratio of the rotor to the eccentric shaft, only 1 power stroke per shaft revolution actually occurs), typically giving it a greater power-to-weight ratio than piston engines. This type of engine is most notably used in the current Mazda RX-8, the earlier RX-7, and other models.

3.8 Gas turbine

Gas turbines cycles (notably jet engines) do not use the same system to both compress and then expand the gases; instead, separate compression and expansion turbines are employed, giving continuous power. Essentially, the intake gas (normally air) is compressed and then combusted with a fuel, which greatly raises the temperature and volume. The larger volume of hot gas from the combustion chamber is then fed through the gas turbine, which is then able to power the compressor. The exhaust gas may be used to provide thrust, supplying only sufficient power to the turbine to compress incoming air (jet engine); or as much energy as possible can be supplied to the turbo shaft (gas turbine proper).

3.9 Disused methods

In some old noncompressing internal combustion engines: In the first part of the piston downstroke, a fuel/air mixture was sucked or blown in. In the rest of the piston downstroke, the inlet valve closed and the fuel/air mixture fired. In the piston upstroke, the exhaust valve was open. This was an attempt at imitating the way a piston steam engine works. Since the explosive mixture was not compressed, the heat and pressure generated by combustion was much less, causing lower overall efficiency.

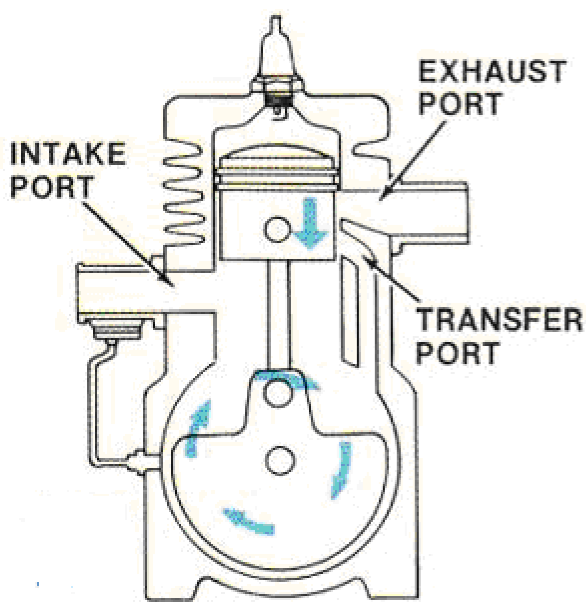
4.0 Two-stroke Cycle

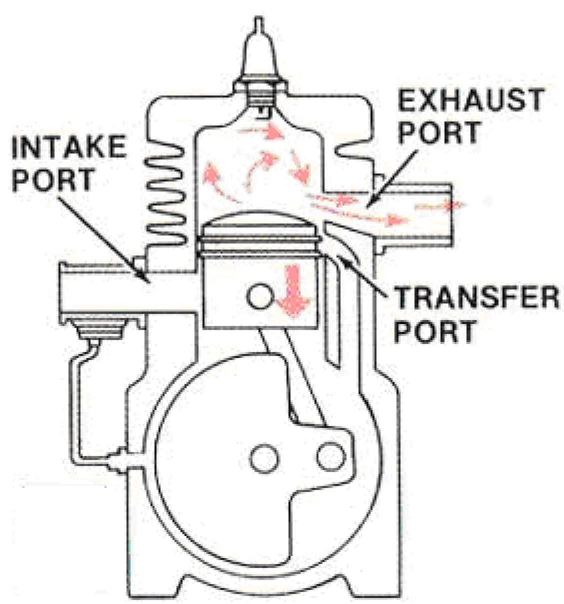
4.1 Operating cycle for internal combustion piston engines

The engine cycle is completed after just two strokes (up or down) of the piston, which distinguishes it from the more common four-stroke cycle. Some power mowers and lightweight motorcycles use two-stroke petrol engines, which are cheaper and simpler than four-strokes.

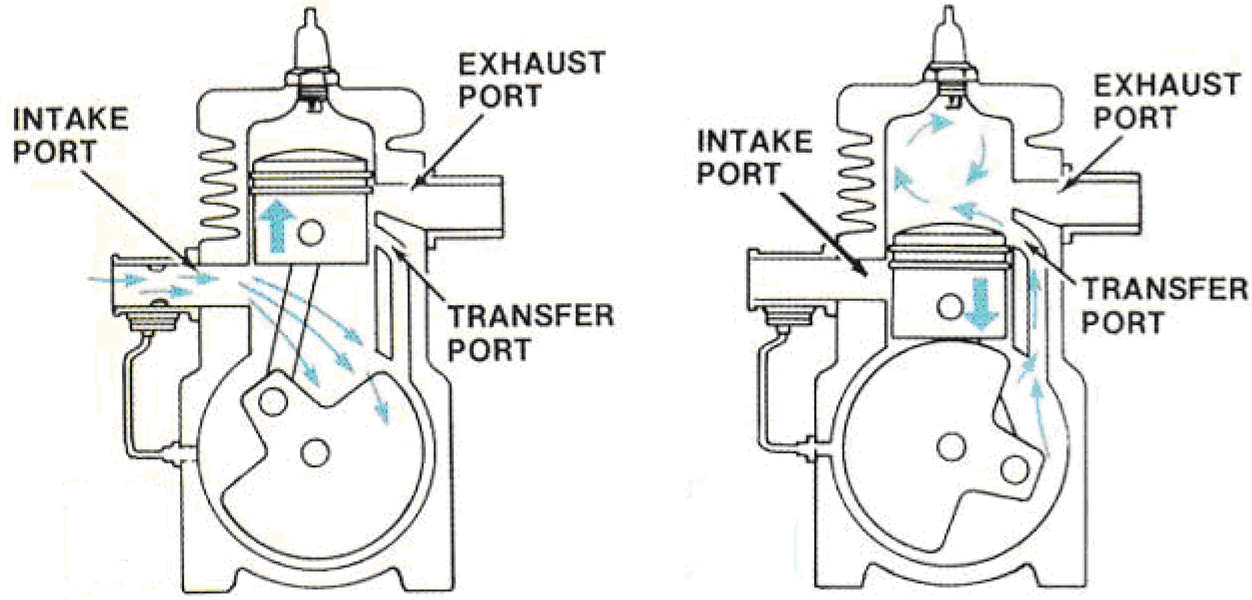
Most marine diesel engines are also two-stroke. In a typical two-stroke motorcycle engine, fuel mixture is drawn into the crankcase as the piston moves up on its first stroke to compress the mixture above it. Then the compressed mixture is ignited, and hot gases are produced, which drive the piston down on its second stroke. As it moves down, it uncovers an opening (port) that allows the fresh fuel mixture in the crankcase to flow into the combustion space above the piston. At the same time, the exhaust gases leave through another port.

4.1.1 Power/exhaust: This stroke occurs immediately after the ignition of the charge. The piston is forced down. After a certain point, the top of the piston passes the exhaust port, and most of the pressurized exhaust gases escape. As the piston continues down, it compresses the air/fuel/oil mixture in the crankcase. Once the top of the piston passes the transfer port, the compressed charge enters the cylinder from the crankcase and any remaining exhaust is forced out.





4.1.2 Intake/Compression: The air/fuel/oil mixture has entered the cylinder, and the piston begins to move up. This compresses the charge in the cylinder and draws a vacuum in the crankcase, pulling in more air, fuel, and oil from the carburetor. The compressed charge is ignited by the spark plug, and the cycle begins again.



4.2 Where are Two-Cycle Engines Used?

Two-cycle engines are inexpensive to build and operate when compared to four-cycle engines. They are lighter in weight and they can also produce a higher power-to-weight ratio. For these reasons, two-cycle engines are very useful in applications such as chainsaws, Weedeaters, outboards, lawnmowers and motorcycles, to name just a few. Two-cycle engines are also easier to start in cold temperatures. Part of this may be due to their design and the lack of an oil sump. This is a reason why these engines are also commonly used in snowmobiles and snow blowers.

4.3 Some Advantages and Disadvantages of Two-Cycle Engines

Because two-cycle engines can effectively double the number of power strokes per unit time when compared to four-cycle engines, power output is increased. However, it does not increase by a factor of two. The outputs of two-cycle engines range from only 20 to 60 percent above those of equivalent-size four-cycle units. This lower than expected increase is a result of the poorer than ideal charging efficiency, or in other words, incomplete filling of the cylinder volume with fresh fuel and air. There is also a major disadvantage in this power transfer scenario. The higher frequency of combustion events in the two-cycle engine results in higher average heat transfer rates from the hot burned gases to the motor's combustion chamber walls. Higher temperatures and higher thermal stresses in the cylinder head (especially on the piston crown) result. Traditional two-cycle engines are also not highly efficient because a scavenging effect allows up to 30 percent of the unburned fuel/oil mixture into the exhaust. In addition, a portion of the exhaust gas remains in the combustion chamber during the cycle. These

inefficiencies contribute to the power loss when compared to four-cycle engines and explains why two-cycle engines can achieve only up to 60 percent more power.

4.4 How Are Two-Cycle Engines Lubricated?

Two-cycle motors are considered total-loss type lubricating systems. Because the crankcase is part of the intake process, it cannot act as an oil sump as is found on four-cycle engines. Lubricating traditional two-cycle engines is done by mixing the oil with the fuel. The oil is burned upon combustion of the air/fuel mixture. Direct Injection engines are different because the fuel is directly injected into the combustion chamber while the oil is injected directly into the crankcase. This process is efficient because the fuel is injected after the exhaust port closes, and therefore more complete combustion of fuel occurs and more power is developed. Direct injection engines have a higher power density than traditional two-cycle engines. Because the oil is directly injected into the crankcase, less oil is necessary and lower oil consumption results (80:1 range). Direct Injection motors have higher combustion temperatures, often up to 48°C. They also require more lubricity than traditional two-cycle motors.

4.5 Different Two-Stroke Design Types

A Cox Babe Bee 0.8 cubic cm (0.049 cubic inch) reed valve engine disassembled. It uses glow plug ignition. The weight is 64 grams (2.25 ounces).

Although the principles remain the same, the mechanical details of various two-stroke engines may differ to a large extent and, in order to understand the operation, it is necessary to know which type of design is in question.

The design types of the two-stroke cycle engine vary according to the method of intake of fresh air/fuel mixture from the outside, the method of scavenging the cylinder (exchanging burnt exhaust for fresh mixture) and the method of exhausting the cylinder.

These are the main variations. They can be found alone or in various combinations.

4.5.1 Piston Controlled Inlet Port

Piston port is the simplest of the designs. All functions are controlled solely by the piston covering and uncovering the ports as it moves up and down in the cylinder. A fundamental difference from typical four-stroke engines is that the crankcase is sealed and forms part of the induction process.

4.5.2 Inlet Valve

This is similar to and almost as simple as the piston port but substitutes a reed type check valve in the intake tract for the piston controlled port. Reed valve engines deliver power over a wider RPM range than the piston port types, making them more useful in many applications, such as dirt bikes, ATVs,

and marine outboard engines. Reed valved engines do not lose fresh fuel charge out of the crankcase like piston port engines do.

In common with many two-strokes, reed valve engines can rotate in either direction. This has been used to back up microcars that lack reverse gearing, and it allows flexibility to pull or push model airplanes with either sense pitch propellers.

Many early two-stroke engines, particularly small marine types, employed a poppet type check valve for the same purpose, but the inertia of the valve made it suitable for low speed use only.

4.5.3 Rotary Inlet Valve

The intake tract is opened and closed by a rotating member. In the most commonly used type, it takes the form of a thin disk attached to the crankshaft and spins at crankshaft speed. The fuel/air path through the intake tract is arranged so that it passes through the disk. This disk has a section cut from it and when this cut passes the intake pipe it opens, otherwise it is closed.

Another form of rotary inlet valve used on two-stroke engines employs two cylindrical members with suitable cut-outs arranged to rotate one within the other - the inlet pipe being in communication with the crankcase only when the cut-outs coincide. The crankshaft itself may form one of the members such as was done with the twin cylinder Maytag washing machine engine of the 1930's and 40's and is still used on some model aircraft engines. In yet another embodiment, the crank disc is arranged to be a very close clearance fit in the crankcase and is provided with a cut-out which lines up with an inlet passage in the crankcase wall at the appropriate time. This type was used on the Vespa motor scooter.

The advantage of a rotary valve is that it enables the two-stroke engine's intake timing to be asymmetrical which is not possible with two-stroke piston port type engines. The two-stroke piston port type engine's intake timing opens and closes before and after top dead center at the same crank angle making it symmetrical whereas the rotary valve allows the opening to begin earlier and close earlier.

Rotary valve engines can be tailored to deliver power over a wider RPM range or higher horse power over a narrower RPM range than either piston port or reed valve engine though they are more mechanically complicated than either one of them.

4.5.4 Cross flow-Scavenged

In a cross flow engine the transfer ports and exhaust ports are on opposite sides of the cylinder and a deflector on the top of the piston directs the fresh intake charge into the upper part of the cylinder pushing the residual exhaust gas down the other side of the deflector and out the exhaust port. The deflector increases the weight of the piston and exposed surface area of the piston, also making it difficult to achieve an efficient combustion chamber shape. This type of two stroke has been largely superseded by loop scavenging method (below). With smaller size and lower piston speed the

deficiencies of the cross flow design become less apparent. The last of the OMC (Outboard Marine Corporation now Bombadier Recreational Products BRP) V4 and V6 two strokes produced up to 1995 in their mid range were still cross flows. These were produced in the 90-115 horsepower V4 configuration in a 1.6 litre as well as the 2.4 Litre 150-175-200 Horsepower V6's. These engines remained extremely competitive on fuel use compared to their loop charged competitors due to advanced exhaust tuning by the manufacturer. These Crossflow engines produced more torque and horsepower by burning less fuel than the Japanese loop charged competitors. Eventually OMC shifted to the Spitfire series Loop charged V4 and V6's in their mid range.

The 235 horsepower 2.6 Litre crossflow V6 (1976 - 1986) still remains today as a very high output low weight engine compared to its much heavier loop charged 2 stroke and 4 stroke replacements.

The Crossflow design produces far more low down engine torque than the slightly more fuel efficient Looper design. Many a boater replaced their Crossflow 2.6 Litre 235 (Flywheel rated) for larger (propshaft rated HP) 2.7 Litre and 3 Litre 225 horsepower V6's only to be disappointed with the lack of low down torque offered.

During the late 1970's 1980's OMC successfully raced the OMC CCC engine. This was a crossflow, carburetor V6 2.6 Litre that out ran many of the oppositions Loop scavenged, fuel injected larger displacement competitors.

It lived on with the XP 2.6 until 1986 in a much more civilised form.

Cross flows are still to be found in small engines because it is less expensive to manufacture and allows a more compact design for multiple cylinder configurations. BRP still offer the 9.9 and 15 HP twin cylinder two stroke available through their Johnson brand as there is still no alternative to this popular lightweight high output engine.

4.4.5 Loop-Scavenged

This method of scavenging uses carefully shaped and positioned transfer ports to direct the flow of fresh mixture as it enters the cylinder. Usually a piston deflector is not required conferring considerable advantage over the cross flow scheme (above). Often referred to as "Schnuerle" (or "Schnürl") scavenging after the German inventor of an early form in the mid 1920's, it became widely adopted in that country during the 1930's and spread further afield after World War II. Loop scavenging is by far the most common type used on modern engines.

4.4.6 Uniflow-Scavenged

In a uniflow engine the mixture, or air in the case of a diesel, enters at one end of the cylinder and the exhaust exits at the other end. The gas-flow is therefore in one direction only, hence the name uniflow. Inlet and/or exhaust may be controlled by mechanically operated valves or by ports. The valved arrangement is common in large Diesel locomotive and marine two strokes, e.g. those made by Electro-Motive Diesel. Ported types are represented by the "opposed piston" design in which there are

two pistons in each cylinder, working in opposite directions such as the Junkers Jumo and Napier Deltic. The unusual 'twingle' design also falls into this class being effectively a folded uniflow.

4.4.7 Power Valve Systems

Many modern two-stroke engines employ a power valve system. The valves are normally in or around the exhaust ports. They work in one of two ways, either they alter the exhaust port by closing off the top part of the port which alters port timing such as Ski-doo R.A.V.E Yamaha YPVS, Cagiva C.T.S., Suzuki AETC system or by altering the volume of the exhaust which changes the resonant frequency of the expansion chamber, such as Honda V-TACS system. The result is an engine with better low end power without losing high rpm power.

4.4.8 Stepped Piston Engine

A stepped piston engine uses piston movement to provide suction and then compression to feed fuel into the combustion chamber. A flange, or step, around the base of the piston creates a secondary chamber which draws the fuel air mixture in on the down stroke of the piston. On the upstroke, the fuel air mixture in this chamber is passed into the combustion chamber of an adjacent piston. The advantage of this system is that the piston is more easily lubricated and plain bearings can be used, as with a four stroke engine. The piston weight is increased by the step to about 20% heavier than a conventional looped scavenged two stroke piston. The patents on this design are held by Bernard Hooper Engineering Ltd (BHE).

4.4.9 Direct Injection

Modern two-strokes as those used for outboard engines no longer require the oil and fuel to be mixed. The oil tank is either part of the engine or for larger engines a tank on the boat. The oil is injected just after the reeds, lubricating the rotating assembly of the engine. The fuel is injected directly into the cylinder. In most cases the fuel is not injected until after the exhaust port has closed, eliminating short circuiting (fuel lost out the exhaust port without being combusted). Direct injection creates more power and uses less fuel than a carbureted engine would as well as having better emission ratings. In some cases the two-stroke engines have emission ratings as good or better than four-stroke engines.

5.0 Two-Stroke Diesel Engines

Unlike a petrol engine, which employs a spark plug to ignite the fuel/air charge in the cylinder, a Diesel engine relies solely on the heat of compression for ignition. Fuel is injected at high pressure into the superheated compressed air and instantly ignites. Therefore, scavenging is performed with air alone, combustion gases exiting through conventional poppet-type exhaust valves.

In order to allow the usage of a conventional oil-filled crankcase and pressure lubricated main and connecting rod bearings, modern two-stroke Diesels are scavenged by a mechanically driven blower (often a Roots positive displacement blower) or a hybrid turbo-supercharger, rather than by crankcase pumping. Generally speaking, the blower capacity is carefully matched to the engine displacement so

that a slight positive pressure is present in each cylinder during the scavenging phase (that is, before the exhaust valves are closed). This feature assures full expulsion of exhaust gases from the previous power stroke, and also prevents exhaust gases from backfeeding into the blower and possibly causing damage due to contamination by particulates.

Early two-stroke Diesels using the crosshead layout (where the cylinder is not integral with the crankcase) employed under-piston pressure to provide scavenge air to the combustion chamber via a by-pass port as used on a conventional petrol-fueled two-stroke engine. Although the cross-head layout is still used on some large engines, greater power and efficiency, as well as lowered exhaust emissions, can be obtained with a mechanical blower or turbocharger.

It should be noted that the scavenging blower is not a supercharger, as its purpose is to supply airflow to the cylinders in proportion to their displacement and engine speed. A two-stroke Diesel supplied with air from a blower alone is considered to be naturally aspirated. In some cases, turbocharging may be added to increase mass air flow at full throttle—with a corresponding increase in power output—by directing the discharge of the turbocharger into the inlet of the blower, an arrangement that was found on some Detroit Diesel two-stroke engines.

A conventional, exhaust-driven turbocharger cannot be used by itself to produce scavenging airflow, as it is incapable of operating unless the engine is already running. Hence it would be impossible to start the engine. The common solution to this problem is to drive the turbocharger's impeller through a gear train and overrunning clutch. In this arrangement, the impeller turns at sufficient speed during engine cranking to produce the required airflow, thus acting as a mechanical blower. At lower engine speeds, the turbocharger will continue to act as a mechanical blower. However, at higher power settings the exhaust gas pressure and volume will increase to a point where the turbine side of the turbocharger will drive the impeller and the overrunning clutch will disengage, resulting in true turbocharging.

5.1 Lubrication

Two-stroke engines often have a simple lubrication system in which a special two-stroke oil is mixed with the fuel, (then known as 'petroil' from "petrol" + "oil") and therefore reaches all moving parts of the engine. Handheld devices using this method of lubrication have the advantage of operating in any orientation since there is no oil reservoir which would be dependent upon gravity for proper function. Depending on the design of the engine system, the oil can be mixed with the fuel manually each time fuel is added, or an oil pump can automatically mix fuel and oil from separate tanks.

The engine uses cylinder port valves which are incompatible with piston ring seals. This causes lubricant from the crank to work its way into the combustion chamber where it burns. Research has been conducted on designs that attempt to reduce the combustion of lubricant. This research could potentially produce an engine having very valuable properties of both high specific-power and low pollution.

5.2 Reversibility

With proper design, a two-stroke engine can be arranged to start and run in either direction, and many engines have been built to do so.

5.3 Applications

Throughout the 20th century, many small motorised devices such as chainsaws, and outboard motors were usually powered by two-stroke designs. They are popular due to their simple design (and therefore, low cost) and very high power-to-weight ratios. However, varying amounts of engine oil in traditional designs mixes with the air-fuel mixture, which significantly increases the emission of pollutants. For this reason, two-stroke engines have been replaced with four-stroke engines in many applications, though some newer two-stroke designs are as clean as four-strokes. Government mandates, rather than market forces, have driven manufacturers to abandoning the two-stroke in spite of its clear power and weight advantages.

6.0 Four-Stroke Cycle

6.1 Engine-Operating Cycle of Most Petrol and Diesel Engines

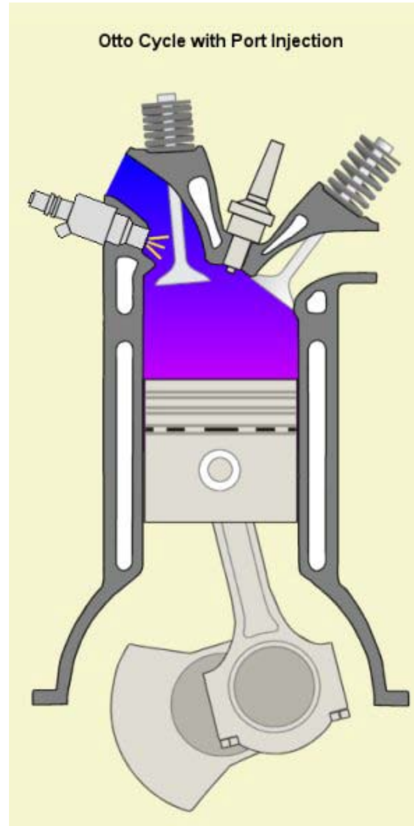
Each movement of the cylinder up or down the cylinder is one stroke of the four stroke combustion cycle or Otto cycle. Most modern internal combustion engines use the four stroke cycle. The four stroke cycle consists of an induction stroke where air and fuel are taken into the cylinder as the piston moves downwards, a compression stroke where the air and fuel are compressed by the upstroke of the cylinder, the ignition or power stroke where the compressed mixture is ignited and the expansion forces the cylinder downwards, and an exhaust stroke where the waste gases are forced out of the cylinder. The intake and outlet ports open and close to allow air to be drawn into the cylinder and exhaust gases to be expelled.

During the intake stroke the inlet valve opens at the top of the cylinder, as the piston moves down air and fuel are drawn into the cylinder. As the piston reaches its lowest position the inlet valve closes and the piston travels upwards compressing the air-fuel mixture. As the piston reaches its highest position at maximum compression a spark ignites the mixture causing a rapid expansion of gas raising the pressure in the cylinder and forcing the piston downwards. Once the cylinder has reached its lowest position the outlet port opens and as the piston rises up the cylinder the exhaust gases are forced out. The valves which open and close the port are sprung to make them naturally close. The valves are opened by a system of rotating cams and pushrods driven by a camshaft which in turn is timed and driven from the crankshaft. The valve timings vary between engines depending on the setup, generally there is some overlap to speed the flow of gases

6.2 Intake

The intake stroke of the combustion cycle is when the piston travels down the cylinder with the intake port/ports open. A mixture of air and explosive fuel are drawn into the cylinder, the proportions of which are called the air-fuel ratio. Both the air-fuel ratio and the quality of the mixture (dispersion,

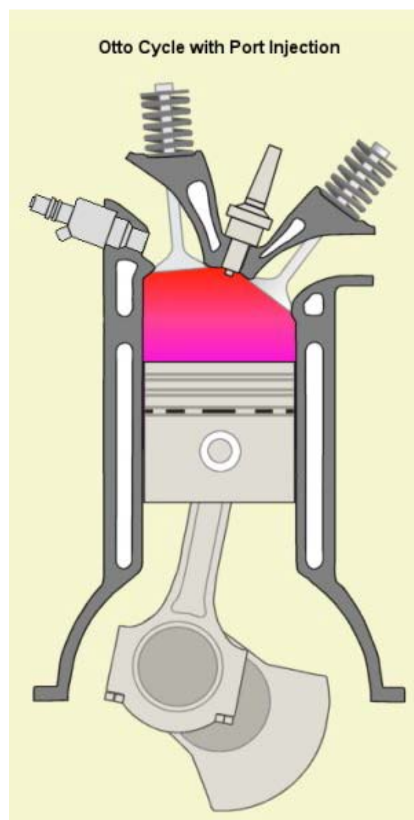
droplet size etc.) is important for an efficient combustion process. There are two methods of mixing air and fuel in a combustion engine, using a carburettor or fuel injection system.



In a carburetted engine, during the intake stroke of the piston a vacuum is created in the inlet manifold. With a multi cylinder engine the vacuum is almost constant. The carburettor is located at the top of the manifold and air is drawn through it by the vacuum created in the manifold. The carburettor has a small fuel chamber supplied from the fuel tank by a pump, fuel passes through the carburettor to small fuel jets positioned in the air flow. The flow of air past the jets creates a pressure difference causing the fuel to be drawn out. The fuel vaporises in the air flow and passes through the manifold and into cylinders on their intake stroke. The diagram below shows the basic operation of a fixed jet carburettor.

Electronic fuel injection systems spray fuel at high pressure either directly into the combustion chamber or into the intake port of the cylinder during the intake stroke. Using fuel injection enables improved control over the air-fuel mixture and reduces the power required to draw fuel from the jets. The diagram below shows a typical electronic fuel injection system.

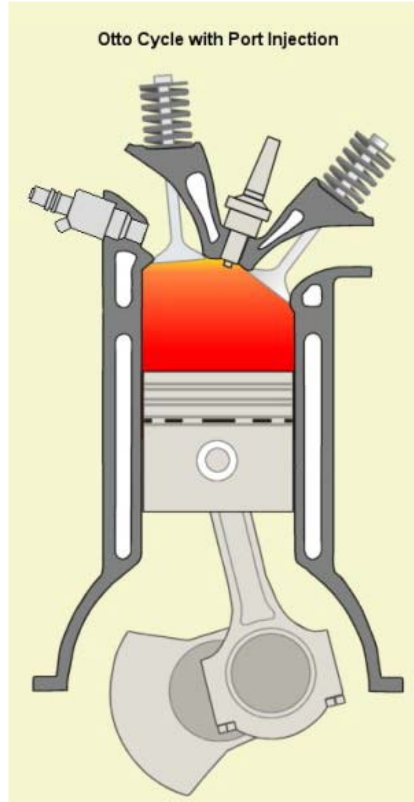
Diesel engines typically use direct injection which injects fuel directly into the combustion chamber during the compression stroke. The intake stroke on a diesel engine only draws air into the cylinder.



6.3 Compression

The compression stroke is the upwards movement of the piston in the cylinder with the valves closed following the intake stroke. This upwards motion compresses the fuel air mixture inside the combustion chamber raising the pressure. The difference between the initial volume of the cylinder and the final volume at the top of the compression stroke is known as the compression ratio. Typically this is approximately 9:1 in spark ignition engines and 15:1 for diesel engines. The compression ratio is particularly important in compression fired engines such as diesel engines. The fuel-air mix and compression ratio is critical to avoid pre-ignition which is the abnormal ignition of fuel in the combustion chamber before the combustion stroke. In diesel engines the fuel is injected under high pressure towards the top of the compression stroke. The distribution of fuel before combustion is also of interest because it affects the efficiency of combustion.

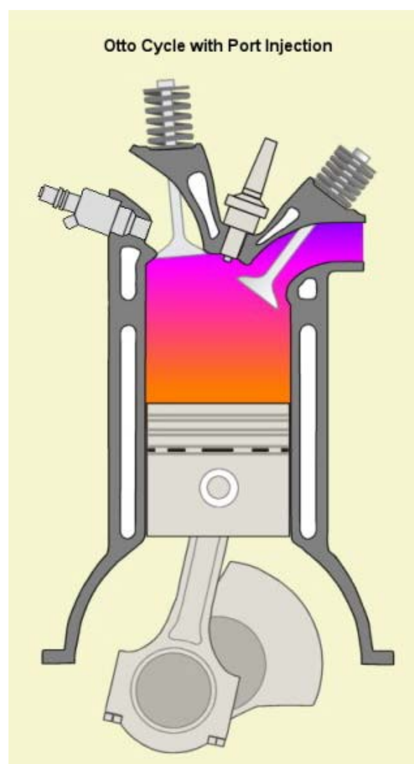
6.4 Combustion



Spark plugs are used to generate the spark which ignites the compressed fuel and air mixture in the spark ignition engine. To generate the spark a high voltage of around 20,000 Volts is applied. Low voltage current is fed through the primary winding of an inductor coil generating a magnetic field. The high voltage is generated when the low voltage supply is interrupted and the magnetic field breaks down generating a high voltage in the secondary winding which has a much larger number of coils. The low voltage supply to the coil is controlled by the distributor which also controls the spark plug that the high voltage surge is sent to. The distributor timing is critical and usually is timed mechanically from the engine. The diagram below shows the typical set-up of an ignition system for a spark ignition engine.

Compression ignition engines such as the diesel engine do not use spark plugs to ignite the fuel-air mix. When the piston reaches the top of the compression stroke the temperature and pressure in the combustion chamber is sufficient to ignite the mixture. Controlled ignition in both spark ignition and diesel engines is essential for efficient combustion and avoid uncontrolled combustion effects such as pre-ignition, auto-ignition and engine knock.

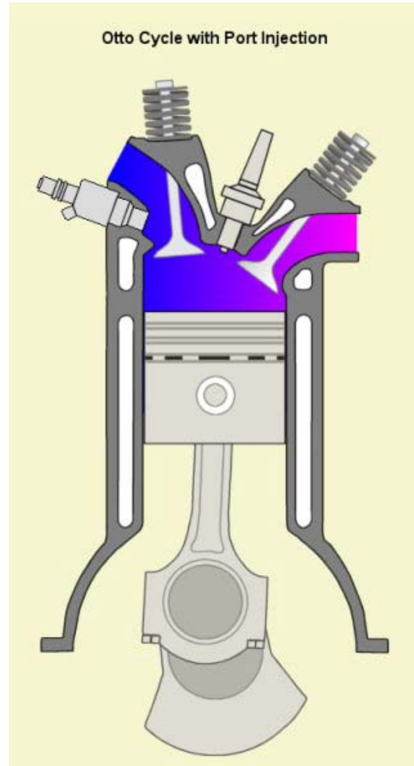
6.5 Exhaust



Exhaust gases are pushed out of the cylinder by the upwards motion of the piston following the ignition stroke. The exhaust gases are passed into the exhaust manifold and channelled into the exhaust pipe where they are released into the atmosphere. The exhaust system may contain a smoke box to trap the larger soot particles, it may also be fitted with a catalytic converter which removes some of the harmful components from the exhaust gases. On newer cars some of the exhaust gases are recycled back into the inlet system (typically at the manifold or air filter), this is known as exhaust gas re-circulation EGR.

The efficiency of the combustion process and the design of the engine determine the exhaust constituents. Typically exhaust gases contain oxygen, nitrogen, water vapour, carbon dioxide, carbon monoxide, hydrogen, nitrous oxides, particulates and unburned hydrocarbons.

6.6 Exhaust and Inlet Valve Overlap



Exhaust and inlet valve overlap is the transition between the exhaust and inlet strokes and is a practical necessity for the efficient running of any internal combustion engine. Given the constraints imposed by the operation of mechanical valves and the inertia of the air in the inlet manifold, it is necessary to begin opening the inlet valve before the piston reaches Top Dead Centre (TDC) on the exhaust stroke. Likewise, in order to effectively remove all of the combustion gases, the exhaust valve remains open until after TDC. Thus, there is a point in each full cycle when both exhaust and inlet valves are open. The number of degrees over which this occurs and the proportional split across TDC is very much dependent on the engine design and the speed at which it operates.

7.0 How the modern engine uses energy to make the wheels turn

Air enters the engine through the air cleaner and proceeds to the throttle plate. You control the amount of air that passes through the throttle plate and into the engine with the gas pedal. It is then distributed through a series of passages called the intake manifold, to each cylinder. At some point after the air cleaner, depending on the engine, fuel is added to the air-stream by either a fuel injection system or, in older vehicles, by the carburettor.

Once the fuel is vaporized into the air stream, the mixture is drawn into each cylinder as that cylinder begins its intake stroke. When the piston reaches the bottom of the cylinder, the intake valve closes and the piston begins moving up in the cylinder compressing the charge. When the piston reaches the top, the spark plug ignites the fuel-air mixture causing a powerful expansion of the gas, which pushes the piston back down with great force against the crankshaft, just like a bicycle rider pushing against the pedals to make the bike go.

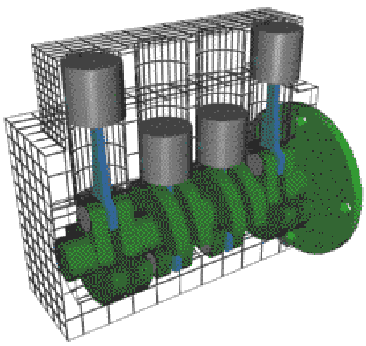
8.0 Engine Types

The majority of engines in motor vehicles today are four-stroke, spark-ignition internal combustion engines. The exceptions like the diesel and rotary engines will not be covered in this resource.

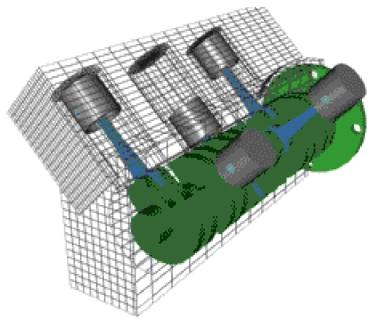
There are several engine types which are identified by the number of cylinders and the way the cylinders are laid out. Motor vehicles will have from 3 to 12 cylinders which are arranged in the engine block in several configurations. The most popular of them are shown on the left. In-line engines have their cylinders arranged in a row. 3, 4, 5 and 6 cylinder engines commonly use this arrangement. The "V" arrangement uses two banks of cylinders side-by-side and is commonly used in V-6, V-8, V-10 and V-12 configurations. Flat engines use two opposing banks of cylinders and are less common than the other two designs. They are used in engines from Subaru and Porsche in 4 and 6 cylinder

arrangements as well as in the old VW beetles with 4 cylinders. Flat engines are also used in some Ferraris with 12 cylinders

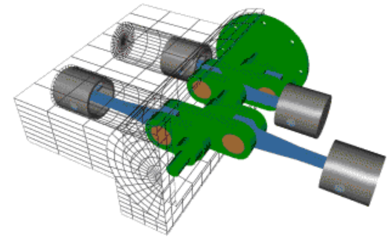
Typical Cylinder Arrangements



In line 4 cylinder



V- 6

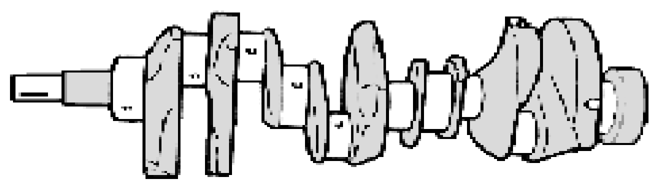


Flat 4

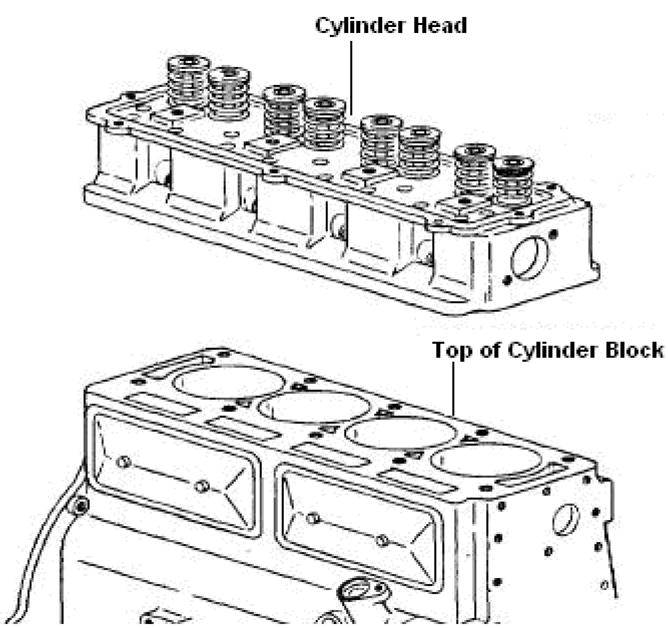
Most engine blocks are made of cast iron or cast aluminium.

Each cylinder contains a piston that travels up and down inside the cylinder bore. All the pistons in the engine are connected through individual connecting rods to a common crankshaft.

The crankshaft is located below the cylinders on an in-line engine, at the base of the V on a V-type engine and between the cylinder banks on a flat engine. As the pistons move up and down, they turn the crankshaft just like your legs pump up and down to turn the crank that is connected to the pedals of a bicycle.

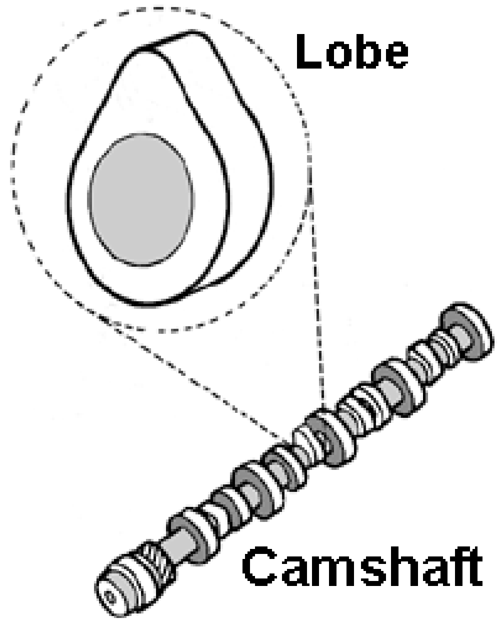


CRANKSHAFT



A cylinder head is bolted to the top of each bank of cylinders to seal the individual cylinders and contain the combustion process that takes place inside the cylinder. Most cylinder heads are made of cast aluminium or cast iron. The cylinder head contains at least one intake valve and one exhaust valve for each cylinder. This allows the air-fuel mixture to enter the cylinder and the burned exhaust gas to exit the cylinder. Engines have at least two valves per cylinder, one intake valve and one exhaust valve. Many newer engines are using multiple intake and exhaust valves per

cylinder for increased engine power and efficiency. 1000 These engines are sometimes named for the number of valves that they have such as "24 Valve V6" which indicates a V-6 engine with four valves per cylinder. Modern engine designs can use anywhere from 2 to 5 valves per cylinder.



The valves are opened and closed by means of a camshaft. A camshaft is a rotating shaft that has individual lobes for each valve.

The lobe is a "bump" on one side of the shaft that pushes against a valve lifter moving it up and down. When the lobe pushes against the lifter, the lifter in turn pushes the valve open. When the lobe rotates away from the lifter, the valve is closed by a spring that is attached to the valve. A common configuration is to have one camshaft located in the engine block with the lifters connecting to the valves through a series of linkages. The camshaft must be synchronized with the crankshaft so that the camshaft makes one revolution for every two revolutions of the crankshaft. In most engines, this is done by a "Timing Chain" (similar to a bicycle chain) that connects the camshaft with the crankshaft. Newer engines have the camshaft located in the cylinder head directly over the valves. This design is more efficient but it is more costly to manufacture and requires multiple camshafts on Flat and V-type engines. It also requires much longer timing chains or timing belts which are prone to wear. Some engines have two camshafts on each head, one for the intake valves and one for the exhaust valves. These engines are called Double Overhead Camshaft (D.O.H.C.) Engines while the other type is called Single Overhead Camshaft (S.O.H.C.) Engines. Engines with the camshaft in the block are called Overhead Valve (O.H.V) Engines.

9.0 How an Engine Works

Since the same process occurs in each cylinder, we will take a look at one cylinder to see how the four stroke process works.

The four strokes are **Intake, Compression, Power** and **Exhaust**. The piston travels down on the Intake stroke, up on the Compression stroke, down on the Power stroke and up on the Exhaust stroke.

9.1 Oiling System

Oil is the life-blood of the engine. An engine running without oil will last about as long as a human without blood. Oil is pumped under pressure to all the moving parts of the engine by an oil pump. The oil pump is mounted at the bottom of the engine in the oil pan and is connected by a gear to either the crankshaft or the camshaft. This way, when the engine is turning, the oil pump is pumping. There is an oil pressure sensor near the oil pump that monitors pressure and sends this information to a warning light or a gauge on the dashboard. When you turn the ignition key on, but before you start the car, the oil light should light, indicating that there is no oil pressure yet, but also letting you know that

the warning system is working. As soon as you start cranking the engine to start it, the light should go out indicating that there is oil pressure.

9.2 Engine Cooling

Internal combustion engines must maintain a stable operating temperature, not too hot and not too cold. With the massive amounts of heat that is generated from the combustion process, if the engine did not have a method for cooling itself, it would quickly self-destruct. Major engine parts can warp causing oil and water leaks and the oil will boil and become useless.

While some engines are air-cooled, the vast majority of engines are liquid cooled.   The water pump circulates coolant throughout the engine, hitting the hot areas around the cylinders and heads and then sends the hot coolant to the radiator to be cooled off.

9.3 Flywheel

A 4 cylinder engine produces a power stroke every half crankshaft revolution, an 8 cylinder, every quarter revolution. This means that a V8 will be smoother running than a 4. To keep the combustion pulses from generating a vibration, a flywheel is attached to the back of the crankshaft. The flywheel is a disk that is about 30 to 40 cms in diameter. On a standard transmission car, the flywheel is a heavy iron disk that doubles as part of the clutch system. On automatic equipped vehicles, the flywheel is a stamped steel plate that mounts the heavy torque converter. The flywheel uses inertia to smooth out the normal engine pulses.

9.4 Balance Shaft

Some engines have an inherent rocking motion that produces an annoying vibration while running. To combat this, engineers employ one or more balance shafts. A balance shaft is a heavy shaft that runs through the engine parallel to the crankshaft. This shaft has large weights that, while spinning, offset the rocking motion of the engine by creating an opposite rocking motion of their own.

9.5 Distributor

A device in the ignition system of a piston engine that distributes pulses of high-voltage electricity to the spark plugs in the cylinders. The electricity is passed to the plug leads by the tip of a rotor arm, driven by the engine camshaft, and current is fed to the rotor arm from the ignition coil. The distributor also houses the contact point or breaker, which opens and closes to interrupt the battery current to the coil, thus triggering the high-voltage pulses. With electronic ignition the distributor is absent.

9.6 Spark Plug

A spark plug produces an electric spark in the cylinder of a petrol engine to ignite the fuel mixture. It consists essentially of two electrodes insulated from one another. High-voltage (18,000 V) electricity is fed to a central electrode via the distributor. At the base of the electrode, inside the cylinder, the

electricity jumps to another electrode earthed to the engine body, creating a spark. See also ignition coil.

9.7 Ignition Coil

The ignition coil is a transformer that is an essential part of a petrol engine's ignition system. It consists of two wire coils wound around an iron core. The primary coil, which is connected to the car battery, has only a few turns. The secondary coil, connected via the distributor to the spark plugs, has many turns. The coil takes in a low voltage (usually 12 volts) from the battery and transforms it to a high voltage (about 15,000–20,000 volts) to ignite the fuel.

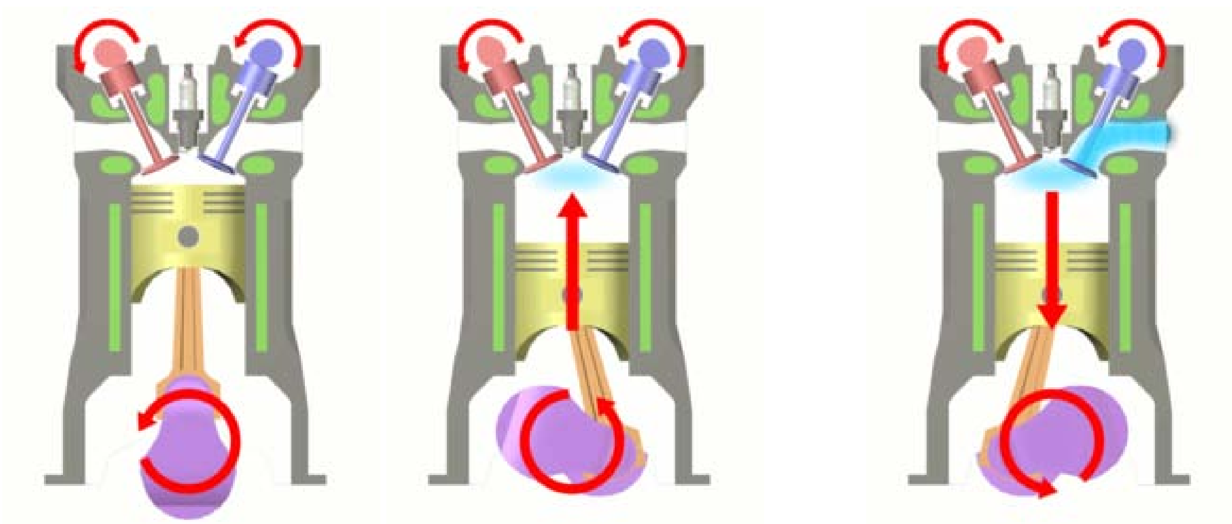
When the engine is running, the battery current is periodically interrupted by means of the contact breaker in the distributor. The collapsing current in the primary coil induces a current in the secondary coil, a phenomenon known as electromagnetic induction. The induced current in the secondary coil is at very high voltage. This passes to the spark plugs to create sparks.

9.8 Compression ratio

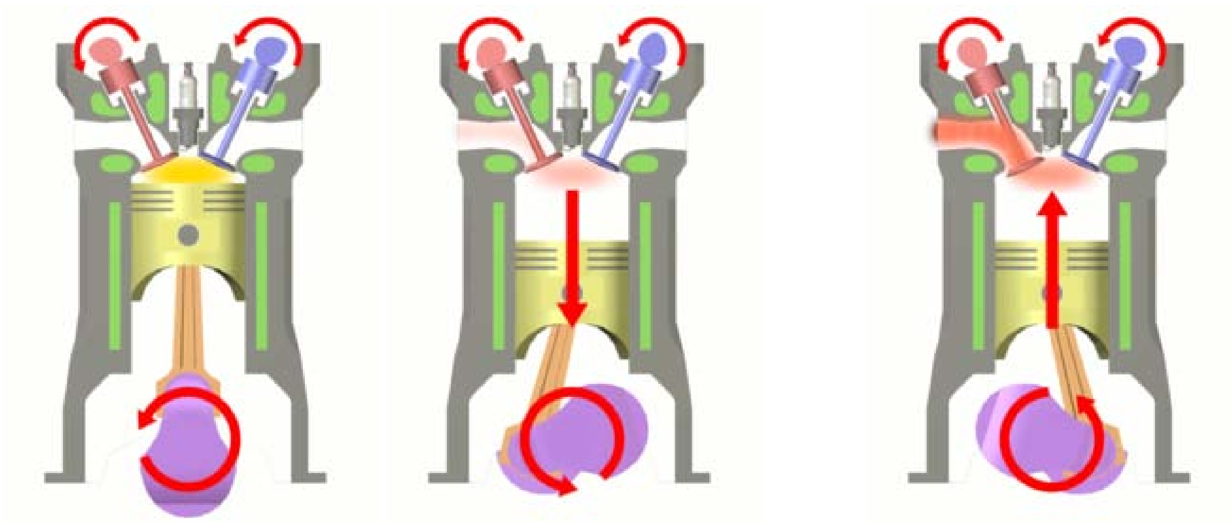
The compression ratio is the ratio between the cylinder volumes at the beginning and end of the compression stroke. Broadly speaking, the higher the compression ratio, the higher the efficiency of the engine. However, compression ratio has to be limited to avoid pre-ignition of the fuel-air mixture which would cause engine knocking and damage to the engine. Modern motor-car engines generally have compression ratios of between 9:1 and 10:1, but this can go up to 11 or 12:1 for high-performance engines that run on, say, 98 Octane petrol. In the 1950s, with low-octane fuel and less well-designed cylinder heads, compression ratios were between 6.5:1 and 7:1. Old tractor engines running on tractor vaporising oil might have compression ratios as low as 4.5:1 but modern tractors have diesel engines.

9.9 Valve train

The valves are typically operated by a camshaft, with a series of *cams* along its length, each designed to open a valve appropriately for the execution of intake or exhaust strokes while rotating at half crankshaft speed. A tappet between valve and cam furnishes a contact surface on which the cam slides to open the valve. The location of the camshaft varies, as does the quantity. Most engines use overhead cams, or even dual overhead cams, as in the illustration, in which cams directly actuate valves through a flat tappet. This design is typically capable of higher engine speeds because it gives the most direct and shortest inelastic path between cam and valve. In other engine designs, the cam shaft is placed in the crankcase and its motion transmitted by a push rod, rocker arms, and valve stems.



Starting position, *intake stroke,* *compression stroke.*



Ignition of fuel, *power stroke,* *exhaust stroke.*

9.10 Valve Clearance Adjustment

Valve clearance refers to the small gap between valve lifter and valve stem (or rocker arm and valve stem) that ensures that the valve completely closes, an expansion joint in the valve train. On engines that require valve adjustment, excessive clearance will cause excessive noise from the valve train "hammering" during operation. In either case, an improperly adjusted valve clearance will cause reduced engine performance, reduced engine life and excessive noise.

Most engines have the valve clearance set by grinding the end of the valve stem during engine assembly, overhead cams not needing subsequent adjustment. All engines with poppet type valves make some sort of allowance for maintaining this "expansion joint", while less sophisticated engines use solid, "non-adjustable" components which are simply ground-off at the contact points to provide the correct clearance (though the low efficiency of this design may not be practical when the cost of labor is very high). Another method is to provide some method of manually changing the clearance with adjustable screws or shims, the implementation of which depends on and varies widely with the

design of the engine. Manual valve lash adjustment is used in almost all very high-performance engines because the hydraulic adjusters used in "automatic" systems are often affected by the extreme valve train accelerations of ultra high-speed engines.

Most modern and advanced production engines use some form of automatic valve adjustment (usually hydraulic) to maintain a state known as "zero lash". In pushrod and some OHC engines this adjuster is incorporated into the tappet, lash adjuster or tip of the rocker. Many DOHC engines now employ tiny hydraulic lash adjusters in the top of the cam followers to maintain "zero lash". "Zero lash" is a desirable condition, since this allows for very quiet engine operation. Hydraulic lifters or lash adjusters also reduce required maintenance, reduce noise, help engines to perform at peak efficiency and minimize exhaust emissions by compensating for wear and expansion of various engine components. Earlier engines, mostly those with push rods and rocker arms, used adjustable tappets or hydraulic lifters to automatically compensate for valve train component and camshaft wear. Lack of valve clearance will prevent valve closure causing leakage and valve damage.

Valve clearance adjustment must be performed to manufacturer's specifications. It is normal that the exhaust valve will have a larger clearance. Adjustment is performed by either adjusting the rocker arm or by placing shims between cam follower and valve stem. Most modern engines have Hydraulic lifters and require infrequent adjustment.

9.11 Valve Clearance Measurement

Valve clearance is measured with the valve closed, typically at Top dead center of the compression stroke. The tappet will be resting on the heel of the cam lobe. A feeler gauge must pass through the clearance space. The feeler gauge should fit in and out with a slight drag. If the feeler gauge will not fit in, then the clearance is too small. If the blade of the feeler gauge fits in too loose then the clearance is too big.

9.12 Valve Clearance Too Wide

A too wide valve clearance will cause excessive wear to the camshaft and valve lifter contact areas, the pushrods can also bend and the engine will be noisy. Should the clearance become wide enough, valve timing will change resulting in poor performance.

9.13 Valve Clearance Too Narrow

A narrow valve clearance will not allow for heat expansion and will result in the failure of the valve to close on its seat. The combustion chamber will not seal properly, producing poor compression and power. It is also possible that the valve becomes so hot that it melts.

9.14 Port Flow

The power output of the motor is dependent on the ability of the engine to allow a volume flow of both air-fuel mixture and exhaust gas through the respective valve ports, typically located in the cylinder head. Therefore time is spent designing this part of an engine. Factory flow specifications are

generally lower than what the engine is capable of, but due to the time and expensive nature of smoothing the entire intake and exhaust track, compromises in flow for reductions in costs is often made. In order to gain power, irregularities such as casting flaws are removed and with the aid of a flow bench, the radii of valve port turns and valve seat configuration can be modified to promote high flow. This process is called porting, and can be done by hand, or via CNC machine.

There are many common design and porting strategies to increase flow. Increasing the diameter of the valves to take up as much the cylinder diameter as possible to increase the flow through the intake and exhaust ports is one method. However, increased valve size can decrease valve shrouding (the impedance of flow created by the cylinder floor.) To counter this, valves are commonly designed to open into the middle of the cylinder (such as the Chrysler Hemi or the Ford Cleveland engines with canted valves). Also, increasing valve lift, or the distance valves are opened into the cylinder or using multiple smaller valves can increase flow. With the advent of computer technology, in modern engines valves events can be controlled directly by the engine's computer, minimizing engine operation at any speed or load.

9.15 Output Limit

The amount of power generated by a four-stroke engine is proportional to its speed. The speed is ultimately limited due to material strength. Since valves, pistons and connecting rods are accelerated and decelerated very quickly, the materials used must be strong enough to withstand these forces. Both physical breakage and piston ring flutter can occur, resulting in power loss or even engine destruction. Piston ring flutter occurs when the piston rings change direction so quickly that they are forced from their seat on the ring land and the cylinder walls, resulting in a loss of cylinder sealing and power as well as possible breakage of the ring. Worst is overreving (overspeed), when valves lose their forced contact with the valve train. This would occur if the valve closing force (normally provided by the valve spring) is inadequate to overcome the inertia of the drivetrain, and can potentially result in valve contact with the piston and causing major damage. Various countermeasures are reducing the valve train mass; for instance, using OHC instead of OHV, four instead of two valves (even more air/gas flow)

One important factor in engine design is the rod/stroke ratio. Rod/stroke ratio is the ratio of the length of the connecting rod to the length of the crankshaft's stroke. An increase in the rod/stroke ratio (a longer rod, shorter stroke, or both,) results in a decrease in piston speed. However, again due to strength and size concerns, there is a limit to how long a rod can be in relation to the stroke. A longer rod (and consequently, higher rod/stroke ratio,) can potentially create more power, due to the fact that with a longer connecting rod, more force from the piston is delivered tangentially to the crankshafts rotation, delivering more torque. A shorter rod/stroke ratio creates higher piston speeds, but this can be beneficial depending on other engine characteristics. Increased piston speeds can create *tumble* or *swirl* within the cylinder and reduce detonation. Increased piston speeds can also draw fuel/air mix into the cylinder more quickly through a larger intake runner, promoting good cylinder filling.

Rod length and stroke length are independent variables. Rod length is expressed as Center-to-Center (c/c) length. An engine with a particular stroke can be fitted with rods of several c/c lengths by changing the piston pin location or block deck height. A rod that is longer in relation to stroke causes

the piston to dwell a longer time at top dead center and causes the piston to move toward and away from TDC more slowly. Long rod engines with a particular stroke also build suction above the piston with less force, since the piston moves away from TDC more slowly. Consequently, long rod engines tend to produce a lower port air velocity, which also reduces low speed torque. Long rods place less thrust load on the cylinder walls, thus generate less parasitic drag and result in less frictional losses as engine revolutions rise. A "short rod" engine has the opposite characteristics. “The short rod exerts more force to the crank pin at any crank angle that counts i.e.--20° ATDC to 70° ATDC”. Short rod engines tend develop more torque at lower engine speeds with torque and horsepower falling off quickly as engine RPM rises to high levels. Long rod engines generally produce more power due to reduced engine drag, especially as engine RPM increases. Regardless of rod length for a given stroke, the average piston speed (usually expressed in M/sec or Ft/sec) remains the same. What changes as the rod length becomes shorter or longer in relation to the stroke, is the RATE of motion as the piston rises and falls in relation to the crankshaft. A long rod fitted to a given stroke generates less stress on the component parts due to the lower rate of acceleration away from and toward TDC.

The average piston speed is the same; however, the peak piston speed is lower with long rods.

There is no "Ideal" rod to stroke ratio, however a ratio of about 2 to 1 seems to be the upper practical limit and 1.5 to 1 the lower limit in general practice. The Chevrolet 350 engine with a 3.48" stroke and a 5.7-inch (140 mm) c/c rod has a rod/stroke ratio of 1.638 to 1. The durability and longevity of this engine seems to prove that this is a “acceptable” figure for a rod/stroke ratio number. The "small block 400" used a 3.75" stroke and a rod c/c of 5.565" for a ratio of 1.484. The SB 400 was known for torque and "running out of breath" at high engine speeds. Even with large port heads and high lift camshaft, the S/B 400 ran into a "wall" of friction when engine speeds climbed above 5000 rpm. S/B 400s we also know for wearing piston skirts and cylinder walls at a faster rate than their smaller brothers. Many people that race the S/B 400 convert the engine to 5.7 or 6.0 rods to reduce the effects of the long stroke crankshaft and lower friction within the engine. The 1967-1969 Z-28 302 engine was fitted with a 3.0" stroke crank and in some racing applications used up to a 6.0" rod, resulting in a 2 to 1 rod/stroke The 302 Chevrolet V-8 was famous for phenomenal power in the upper RPM range while it sacrificed low speed torque to gain the high RPM power and reliability.

Honda's B16A/B16B is considered ideal in high revolution and high durability applications and it is, not coincidentally, right in between the 1.5:1 and 2:1 ratios, with a 1.75:1 ratio. Although this gives it relative low power at lower engine speeds, it also gives it a rev-happy nature that is durable beyond it's factory rev limit. Some sport bikes surpass the 1.75:1 ratio, but the lower torque at less engine speed becomes evident for practical applications such as cars(where power/weight ratio is important).

A "square engine" is an engine with a bore equal to its stroke. An engine where the bore dimension is larger than the stroke is commonly known as an oversquare engine; such engines have the ability to attain higher rotational speed since the pistons do not travel as far. Conversely, an engine with a bore that is smaller than its stroke is known as an undersquare engine; such engines cannot rotate as quickly, but are able to generate more torque at lower rotational speeds.

10.0 Wankel Engine

The Wankel engine is a type of internal combustion engine which uses a rotary design to convert pressure into a rotating motion instead of using reciprocating pistons. Its four-stroke cycle is generally generated in a space between the inside of an oval-like epitrochoid - shaped housing and a roughly triangular rotor. This design delivers smooth high-rpm power from a compact, lightweight engine.

The engine was invented by German engineer Felix Wankel. He began its development in the early 1950s at NSU Motorenwerke AG (NSU) before completing a working, running prototype in 1957. NSU then subsequently licenced the concept to other companies across the globe, who added more efforts and improvements in the 1950s and 1960s.

Because of their compact, lightweight design, Wankel rotary engines have been installed in a variety of vehicles and devices such as automobiles and racing cars, aircraft, go-karts, personal water crafts, and auxiliary power units.

10.1 History

In 1951, Wankel began development of the engine at NSU, where he first conceived his rotary engine in 1954 (DKM 54) and later the KKM 57 (the Wankel rotary engine) in 1957. The first working prototype DKM 54 was running on February 1, 1957 at the NSU research and development department.

Considerable effort went into designing rotary engines in the 1950s and 1960s. They were of particular interest because they were smooth and quiet running, and because of the reliability resulting from their simplicity.

In the United States, in 1959 under license from NSU, Curtiss-Wright pioneered minor improvements in the basic engine design. In Britain, in the 1960s, Rolls Royce Motor Car Division at Crewe, Cheshire, pioneered a two-stage diesel version of the Wankel engine.

Also in Britain, Norton Motorcycles developed a Wankel rotary engine for motorcycles, which was included in their Commander and F1; Suzuki also made a production motorcycle with a Wankel engine, the RE-5. In 1971 and 1972 Arctic Cat produced snowmobiles powered by 303 cc Wankel rotary engines manufactured by Sachs in Germany. John Deere Inc, in the U.S., designed a version that was capable of using a variety of fuels. The design was proposed as the power source for several U.S. Marine combat vehicles in the late 1980s.

After occasional use in automobiles, for instance by NSU with their Ro 80 model, Citroën with the M35, and GS Birotor using engines produced by Comotor, as well as abortive attempts by General Motors and Mercedes-Benz to design Wankel-engine automobiles, the most extensive automotive use of the Wankel engine has been by the Japanese company Mazda.

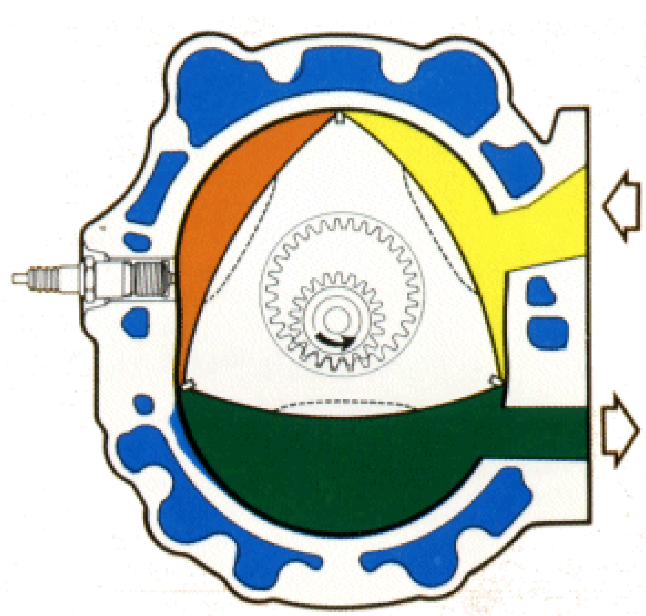
After years of development, Mazda's first Wankel engined car was the 1967 Cosmo. The company followed with a number of Wankel ("rotary" in the company's terminology) vehicles, including a bus

and a pickup truck. Customers often cited the cars' smoothness of operation. However, Mazda chose a method to comply with hydrocarbon emission standards that, while less expensive to produce, increased fuel consumption, just before a sharp rise in fuel prices. Mazda later abandoned the Wankel in most of their automotive designs, but continued using it in their RX-7 sports car until August 2002 (RX-7 importation for North America ceased with the 1995 model year). The company normally used two-rotor designs, but received considerable attention with their 1991 Eunos Cosmo, which used a twin-turbo three-rotor engine. In 2003, Mazda introduced the RENESIS engine with the new RX-8. The RENESIS engine relocated the ports for exhaust and intake from the periphery of the rotary housing to the sides, allowing for larger overall ports, better airflow, and further power gains. The RENESIS is capable of delivering 238 hp (177 kW) from its 1.3 L displacement with better fuel economy, reliability, and environmental friendliness than any other Mazda rotary engine in history.

Soviet automobile manufacturer VAZ also experimented with the design of Wankel-engine cars. In 1978, they designed an engine with two-rotors and, in the 1980s, started delivering Wankel-powered VAZ-2106s, mostly to security services; about 200 were made. Aviadvigatel, the Soviet aircraft engine design bureau, is known to have produced Wankel engines for aircraft and helicopters, though little specific information has surfaced.

The People's Republic of China is also known to have experimented with Wankel engines, but even less is known in the West about the work done there, other than one paper delivered to the SAE in 1988 by Chen Teluan of the South China Institute of Technology at Guangzhou.

Although many manufacturers licensed the design, and Mercedes-Benz used it for their C111 concept car, only Mazda has produced Wankel engines in large numbers. American Motors (AMC) was so convinced "...that the rotary engine will play an important role as a powerplant for cars and trucks of the future...", according to Chairman Roy D. Chapin Jr., the smallest U.S. automaker signed an agreement in 1973 to build Wankels for both passenger cars and Jeeps, as well as the right to sell any rotary engines it produces to other companies. It even designed the unique Pacer around the engine, even though by then, AMC had decided to buy the Wankel engines from GM instead of building them itself. However, the engines had not reached production when the Pacer was to hit the showrooms. Part of the demise of this feature was the rising fuel prices and concerns about proposed emission legislation in the United States. General Motors' Wankel did not comply with emission standards, so in 1974 the company canceled its development. This meant the Pacer had to be reconfigured to house AMC's venerable straight-sixs with rear-wheel drive.



10.2 Naming

Since its introduction in the NSU Motorenwerke AG (NSU) and Mazda cars of the 1960s, the engine has been commonly referred to as the *rotary engine*, a name which has also been applied to several completely different engine designs.

10.3 Design

The Wankel cycle. The shaft turns three times for each rotation of the rotor around the lobe and once for each orbital revolution around the eccentric shaft.

In the Wankel engine, the four strokes of a typical Otto cycle occur in the space between a three-sided symmetric rotor and the inside of a housing. In the basic single-rotor Wankel engine, the oval-like epitrochoid-shaped housing surrounds a rotor which is similar to a Reuleaux triangle, a three-pointed curve of constant width, but with the bulge in the middle of each side a bit more flattened. From a theoretical perspective, the chosen shape of the rotor between the fixed apexes is basically the result of a minimization of the volume of the geometric combustion chamber and a maximization of the compression ratio, respectively. Thus, the symmetric curve connecting two arbitrary apexes of the rotor is maximized in the direction of the inner housing shape with the constraint not to touch the housing at any angle of rotation (an arc is not a solution of this optimization problem).

The central drive shaft, also called an eccentric shaft or E-shaft, passes through the center of the rotor and is supported by bearings. The rotor both rotates around an offset lobe (crank) on the E-shaft and makes orbital revolutions around the central shaft. Seals at the corners of the rotor seal against the periphery of the housing, dividing it into three moving combustion chambers. Fixed gears mounted on each side of the housing engage with ring gears attached to the rotor to ensure the proper orientation as the rotor moves.

The best way to visualize the action of the engine in the animation at left is to look not at the rotor itself, but the cavity created between it and the housing. The Wankel engine is actually a variable-volume progressing-cavity system. Thus there are 3 cavities per housing, all repeating the same cycle. As the rotor rotates and orbitally revolves, each side of the rotor gets closer and farther from the wall of the housing, compressing and expanding the combustion chamber similarly to the strokes of a piston in a reciprocating engine. The power vector of the combustion stage goes through the center of the offset lobe.

While a four-stroke piston engine makes one combustion stroke per cylinder for every two rotations of the crankshaft (that is, one half power stroke per crankshaft rotation per cylinder), each combustion chamber in the Wankel generates one combustion stroke per each driveshaft rotation, i.e. one power stroke per rotor orbital revolution and three power strokes per rotor rotation. Thus, power output of a Wankel engine is generally higher than that of a four-stroke piston engine of similar engine displacement in a similar state of tune and higher than that of a four-stroke piston engine of similar physical dimensions and weight. Wankel engines also generally have a much higher redline than a reciprocating engine of similar size since the strokes are completed with a rotary motion as opposed to

a reciprocating engine which must use connecting rods and a crankshaft to convert reciprocating motion into rotary motion.

National agencies that tax automobiles according to displacement and regulatory bodies in automobile racing variously consider the Wankel engine to be equivalent to a four-stroke engine of 1.5 to 2 times the displacement; some racing sanctioning bodies ban it altogether.

10.4 Advantages with Wankels

Wankel engines have several major advantages over reciprocating piston designs, in addition to having higher output for similar displacement and physical size.

Wankel engines are considerably simpler and contain far fewer moving parts. For instance, because valving is accomplished by simple ports cut into the walls of the rotor housing, they have no valves or complex valve trains; in addition, since the rotor is geared directly to the output shaft, there is no need for connecting rods, a conventional crankshaft, crankshaft balance weights, etc. The elimination of these parts not only makes a Wankel engine much lighter (typically half that of a conventional engine of equivalent power), but it also completely eliminates the reciprocating mass of a piston engine with its internal strain and inherent vibration due to repeated acceleration and deceleration, producing not only a smoother flow of power but also the ability to produce more power by running at higher rpm.

In addition to the enhanced reliability by virtue of the complete removal of this reciprocating stress on internal parts, the engine is constructed with an iron rotor within a housing made of aluminium, which has greater thermal expansion. This ensures that even a severely overheated Wankel engine cannot seize, as would likely occur in an overheated piston engine. This is a substantial safety benefit in aircraft use since no valves can burn out.

A further advantage of the Wankel engine for use in aircraft is the fact that a Wankel engine can have a smaller frontal area than a piston engine of equivalent power. The simplicity of design and smaller size of the Wankel engine also allows for savings in construction costs, compared to piston engines of comparable power output.

Of perhaps the most importance is that Wankel engines are almost immune to catastrophic failure. A Wankel that loses compression, cooling or oil pressure will lose a large amount of power, and will die over a short period of time; however, it will usually continue to produce some power during that time. Piston engines under the same circumstances are prone to seizing or breaking parts that almost certainly results in complete internal destruction of the engine and instant loss of power. For this reason Wankel engines are very well suited to aircraft.

Due to a 50% longer stroke duration compared to a four stroke engine, there is more time to complete the combustion. This leads to greater suitability for direct injection. A Wankel rotary engine has stronger flows of air-fuel mixture and a longer operating cycle than a reciprocating engine, so it realizes concomitantly thorough mixing of hydrogen and air. The result is a homogeneous mixture, which is crucial for hydrogen combustion.

10.5 Disadvantages

Rolls Royce R6 two stage Wankel Diesel engine

Compared to four stroke piston engines, the time available for fuel to be port injected into a Wankel engine is significantly shorter, due to the way the three chambers rotate. The fuel-air mixture cannot be pre-stored as there is no intake valve.

The surface/volume-ratio problem is so complex that one cannot make a direct comparison between a reciprocating piston engine and a Wankel engine in relation to the surface/volume-ratio. The flow velocity and the heat losses behave quite differently. Surface temperatures behave absolutely differently; the film of oil in the Wankel engine acts as isolator. Engines with higher compression ratio have a worse surface/volume-ratio. The surface/volume-ratio of a Diesel engine is much worse than a petrol engine, but Diesel engines are well known for a higher efficiency factor than petrol engines. Thus we should compare engines with equal power: a naturally aspirated 1.3 litre Wankel engine with a naturally aspirated 1.3 litre four stroke reciprocating piston engine with equal power. But such a four stroke engine is not possible and needs twice the displacement for the same power as a wankel engine. The extra or "empty" stroke(s) we should not ignore, as a 4-stroke cylinder produces a power stroke only every other rotation of the crankshaft. In actuality, this doubles the real surface/volume-ratio for the four stroke reciprocating piston engine.

The trailing side of the rotary engine’s combustion chamber develops a squeeze stream which pushes back the flamefront. With the conventional two-spark-plug or one-spark-plug system, this squeeze stream prevents the flame from propagating to the combustion chamber's trailing side in the mid and high engine speed ranges. This is why there can be more carbon monoxide and unburnt hydrocarbons in a Wankel's exhaust stream. A side port exhaust, as is used in the Mazda Renesis, avoids this because the unburned mixture cannot escape. The Mazda 26B avoided this issue through a 3-spark plug ignition system. (As a result, at the Le Mans 24 hour endurance race in 1991, the 26B had significantly lower fuel consumption than the competing reciprocating piston engines. All competitors had only the same amount of fuel available, because of the Le Mans 24h limited fuel quantity rule).

All Mazda-made Wankel rotaries, including the new Renesis found in the RX8, burn a small quantity of oil by design; it is metered into the combustion chamber in order to preserve the apex seals. Owners must periodically add small amounts of oil, slightly increasing running costs--though it is still reasonable when compared to many reciprocating piston engines.

Engineering left Mazda old L10A Camber axial cooling, middle Audi NSU EA871 axial water cooling only hot bow, right Diamond Engines Wankel radial cooling only in the hot bow.

Felix Wankel managed to overcome most of the problems that made previous rotary engines fail by developing a configuration with vane seals that could be made of more durable materials than piston ring metal that led to the failure of previous rotary designs.

Rotary engines have a thermodynamic problem not found in reciprocating four-stroke engines in that their "cylinder block" operates at steady state, with intake, compression, combustion, and exhaust

occurring at fixed housing locations for all "cylinders". In contrast, reciprocating engines perform these four strokes in one chamber, so that extremes of freezing intake and flaming exhaust are averaged and shielded by a boundary layer from overheating working parts.

The boundary layer shields and the oil film act as thermal insulation, leading to a low temperature of the lubricating film (max 200°C/400°F) on a water-cooled Wankel engine. This gives a more constant surface temperature. The temperature around the spark plug is about the same as the temperature in the combustion chamber of a reciprocating engine. With circumferential or axial flow cooling, the temperature difference remains tolerable.

Four-stroke reciprocating engines are less suitable for hydrogen. The hydrogen can misfire on hot parts like the exhaust valve and spark plugs. Another problem concerns the hydrogenate attack on the lubricating film in reciprocating engines. In a Wankel engine this problem is circumvented by using a ceramic apex seal against a ceramic surface: there is no oil film to suffer hydrogenate attack. Since ceramic piston rings are not available as of 2008, the problem remains with the reciprocating engine. The piston shell must be lubricated and cooled with oil. This substantially increases the lubricating oil consumption in a four-stroke hydrogen engine.

10.6 Materials

Unlike a piston engine, where the cylinder is cooled by the incoming charge after being heated by combustion, Wankel rotor housings are constantly heated on one side and cooled on the other, leading to high local temperatures and unequal thermal expansion. While this places high demands on the materials used, the simplicity of the Wankel makes it easier to use alternative materials like exotic alloys and ceramics. With water cooling in a radial or axial flow direction, with the hot water from the hot bow heating the cold bow, the thermal expansion remains tolerable.

10.7 Sealing

Early engine designs had a high incidence of sealing loss, both between the rotor and the housing and also between the various pieces making up the housing. Also, in earlier model Wankel engines carbon particles could become trapped between the seal and the casing, jamming the engine and requiring a partial rebuild. (This can be prevented in older Mazda engines by always allowing the engine to reach operating temperature.) It was common for very early Mazda engines to require rebuilding after 50,000 miles (80,000 km). Modern Wankel engines have not had these problems for many years. Further sealing problems arise from the uneven thermal distribution within the housings causing distortion and loss of sealing and compression. This thermal distortion also causes uneven wear between the apex seal and the rotor housing, quite evident on higher mileage engines. Attempts have been made to normalize the temperature of the housings, minimizing the distortion, with different coolant circulation patterns and housing wall thicknesses.

10.8 Fuel Consumption and Emissions

Just as the shape of the Wankel combustion chamber prevents preignition, it also leads to incomplete combustion of the air-fuel charge, with the remaining unburned hydrocarbons released into the

exhaust. While manufacturers of piston-engine cars were turning to expensive catalytic converters to completely oxidize the unburned hydrocarbons, Mazda was able to avoid this cost by enriching the air/fuel mixture and increasing the amount of unburned hydrocarbons in the exhaust to actually support complete combustion in a 'thermal reactor' (an enlarged open chamber in the exhaust manifold) without the need for a catalytic converter, thereby producing a clean exhaust at the cost of some extra fuel consumption. World petrol prices rose sharply at the time Mazda introduced their Wankel engine, making the cleaner exhaust/increased fuel consumption tradeoff an unwelcome one for consumers.

In Mazda's RX-8 with the Renesis engine, fuel consumption is now within normal limits while passing California State emissions requirements. The exhaust ports, which in earlier Mazda rotaries were located in the rotor housings, were moved to the sides of the combustion chamber. This approach allowed Mazda to eliminate overlap between intake and exhaust port openings, while simultaneously increasing exhaust port area

11.0 Back To Basics

For an engine to run, you need three things:

- Air (Vacuum, compression);
- Fuel; and
- Spark (Electrical).

Without any one of these things the engine will not run. The easiest method of ensuring that repairs can be avoided is to inspect and service your equipment regularly. Some suggested issues that can happen because of the lack of servicing can be attributed to the following topics.

11.1 Air

If you hold it up to the light and you can't see through it, throw it away and put in a new one. Another thing to check is the tube that connects the air filter housing to the intake manifold. It is designed to flex and over time they dry up, get brittle and crack. Look for small cracks at the bottom of the bellow folds. Cracks there will allow un-metered air (air the computer doesn't know about) into the engine, causing a lean condition.

Further up the line is the throttle body. A lot of air gets worked and routed in here. It is also a great place for gum, dirt and varnish to collect and clog up small air passages.

11.2 Fuel

In the fuel system the fuel filter is the weak link in the chain. Fuel filters will cause all kinds of driveability problems that you may not relate to at first thought. If you have a driveability problem such as loss of power or stalling, one of the first things to do is replace the fuel filter. It's a simple thing to do and could very well fix the problem.

If the car doesn't start, check the battery. The battery has to be good and fully charged. More often the question is "Does it crank?" but "Does the battery voltage stay above 9 to 9.5 volts while it is cranking?" Most fuel pumps will not run on less than 9 or 10 volts. Check the fuel pump fuse. Is it blown? If it is, that's an excellent reason for not starting.

11.3 Spark

Distributor caps have to work under very severe conditions. Heat and high voltage take its toll on the distributor cap. They start to crack at the towers or inside the distributor cap itself. Distributor rotors burn out their tips or the centre electrode burns out the centre of the distributor rotor and the spark grounds to the distributor shaft.

Spark plug wires are another place that can cause a variety of driveability problems. They work hard also. They have to carry very high voltage in conditions that are less than ideal. When they get old they can start to crack. If there is a ground close enough, the spark will take the shortcut and ignore the spark plug. Remember, electricity is lazy and will always take the short and easy path. And it's a lot of hard work the jump across that spark plug gap.

An easy and simple way to check spark plug wires for cracks is to use a spray bottle to spray the wires with water. If there are cracks in the wires you will see and hear the sparks jumping to ground. Doing this at night makes seeing the spark much easier.

Spark plugs can go bad internally as well. Inside most spark plug wires is a carbon core. After a while this core can crack and small gaps develop in the core. This makes the resistance in the spark plug wire increase to the point where the spark won't travel to the spark plug, or get to the spark plug greatly weakened.

Another thing is spark plug wire routing. Some cars, are sensitive to spark plug wire routing. If they are too close to each other, they will develop cross fire and lead to all kinds of driveability problems. So when you replace spark plug wires, make sure you route them in the same way and that any protective shields or wraps are put back on.

If it's been a while the best thing to do is replace the spark plug wires so there is no question of their quality.

Now we go to the spark plugs. Here we have to check for the proper spark plug type and gap. Also "reading" the spark plugs will tell a story of the general engine condition. The brand of spark plugs you use can make a big difference. It is suggested to use Motorcraft in Ford products, AC Delco in GM products and so forth. Japanese cars do not, for some reason, like American spark plugs so you could use NGK brand spark plugs in them and Bosch spark plugs in German cars. So if you have any doubts about the spark plugs, replace them.

12.0 The Basic Engine Service

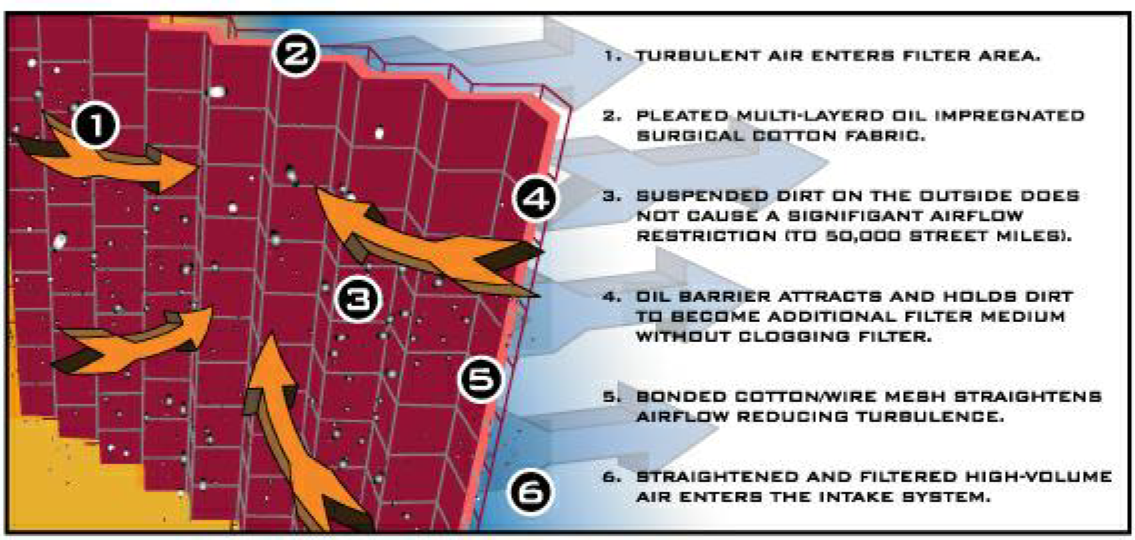
12.1 The Air Filter

The primary function of an air filter is to deliver both high airflow and superior dirt protection therefore air filters should provide minimum restriction allowing high airflow into an engine. In the vast majority of cases increased airflow will increase engine performance measured by kilowatts and throttle response (torque).

Air filters are designed to provide superior filtration of the contaminants that can harm your engine while maximizing the airflow characteristics of the filter in question. The ability of an air filter to protect your engine is generally measured in accordance with testing procedures. Some filter designs are tested for particles ranging in size from less than 5.5 microns to 176 microns. As a point of reference, a human hair is approximately 50 microns in diameter. The result of the test procedure is a specific air filtration efficiency number. This efficiency number represents the percentage of test dust retained by the filter and thereby kept out of an engine. A goal is to design our air filters to achieve maximum airflow while targeting overall filtration efficiency at 98%. Because no two air filters are alike, the specific airflow and overall filtration efficiency will vary depending on the filter in question.

12.2 What's the Big Deal About Air Flow?

Simply put, Everything! At its most basic level, an engine is an air pump. More air entering the engine increases the efficiency of the combustion process creating more kilowatts and torque. Kilowatts is a measure of the engine's maximum power while torque measures how quickly you can accelerate. Maintaining optimal, unrestricted air flow becomes a problem when it must pass through a filtering medium. The level of air resistance varies depending on the size, surface area and physical attributes of the filtering medium.



12.3 How to Change Your Air Filter

Locate and open the filter housing. With your hood open and safely propped, locate the air filter housing. On any car made in the last 20 years or so, it'll be in a black plastic case with metal clips on the sides. You'll also see a black tube going into the plastic case on most cars. Flip the little metal clips downward. If they are tight, slide a flat-head screwdriver in between the clip and the case from the top, and pop it off. Some housings will also have a nut holding them from the top. If you removed nuts from the top of your filter housing, be sure to put them in a safe secure location. You don't want to lose these! You can even stick them in your pocket. Whatever you do, put them someplace safe.

12.4 Remove the Old Filter

Your filter (round or rectangular) will be made of lots of folded paper surrounded by rubber. Before you remove the dirty filter, take a moment to note how it sits in the housing so you can be sure to put the new one in correctly. Carefully pull it out, being sure that nothing falls into the bottom of the box. I've seen sticks, trash and some *really* big bugs caught in the filter. If it looks anything like the filter in the above photo, you know you're doing the right thing.

12.5 Put the New Filter in Place

Put the new, clean filter in place, being sure to put it in the same configuration as the one you removed (as in which side is up, etc.). Don't worry about making a mistake here; if you have the filter in upside down you won't be able to get the top closed. Also be sure to press the rubber gasket of the filter all the way into its groove in the housing. If you find the cover hard to get back on, re-check this as it's often the culprit.

12.6 The Fuel Filter

A fuel filter is one of those engine components that is inexpensive, but can protect your engine from thousands of dollars in damage. Fuel filters protect some of the very delicate parts of your engine. Carburettors and fuel injection systems can be clogged up by the tiniest of particles, so a properly functioning fuel filter is very

important. If your fuel filter starts to get clogged up, the fuel trying to flow through the filter to your engine gets stuck.

Safety Step! Relieving Fuel System Pressure

- allow engine to cool
- relieve fuel system pressure
- put on your eye protection

Before you begin the job of replacing your fuel filter, you *must* relieve the pressure in your fuel system. A fuel injection system operates under very high pressure. If you don't release this pressure before you start unscrewing fuel lines the result can be explosive.

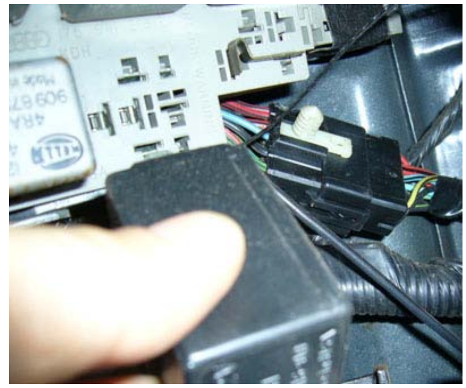
To release the pressure in your fuel lines (and fuel filter) you'll need to locate the fuel pump fuse in the fuse box. If you don't have a fuel pump fuse, find the relay that operates the fuel pump. Once you've found the fuel pump fuse or relay, start the car. With the engine running, pull the fuse or relay out. If you pulled the right one, the engine will quickly die. Since it's using all of the pressurized fuel in the system, the fuel lines won't be pressurized when you crack the fittings on your fuel filter.

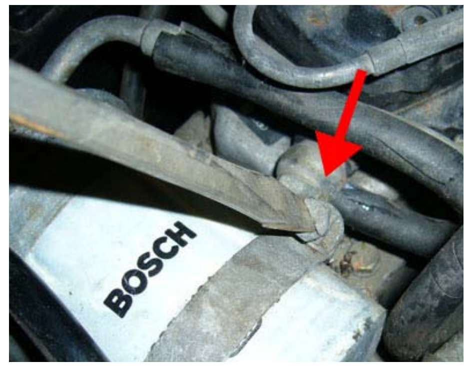
Now that you've relieved the fuel pressure you can remove the old fuel filter. If you didn't do this yet, you must go to the previous step and do it. Very dangerous!

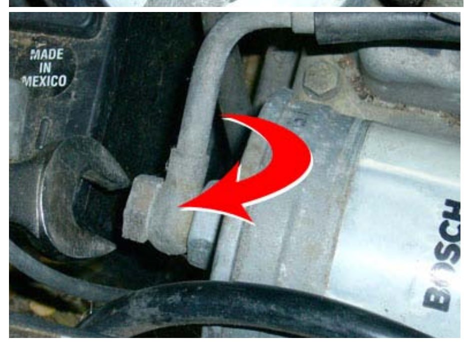
If your car has fuel injection (most do these days) find two open end wrenches* that are the right size for the fuel filter fittings. They will be two different sizes in most cases. With the wrenches in place, put a rag over the fitting to separate your head from the fuel lines. This will further protect your eyes in case there is some pressure in the lines.

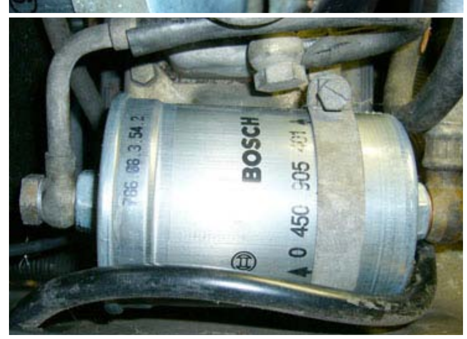
Hold the wrench that fits on the actual filter, and turn the other wrench counter clockwise until the special bolt (part of what's called a "banjo fitting") comes out. Slide the fuel line off the bolt and set the bolt aside. Now do the same for the other side of the fuel filter.

**Some vehicles require a special fuel line wrench to disconnect the lines, check yours out before you start this job.*









With the fuel lines disconnected from the fuel filter, you can remove the old fuel filter from the car. Most will be held in by a clamp that can be released using a flat head screwdriver.

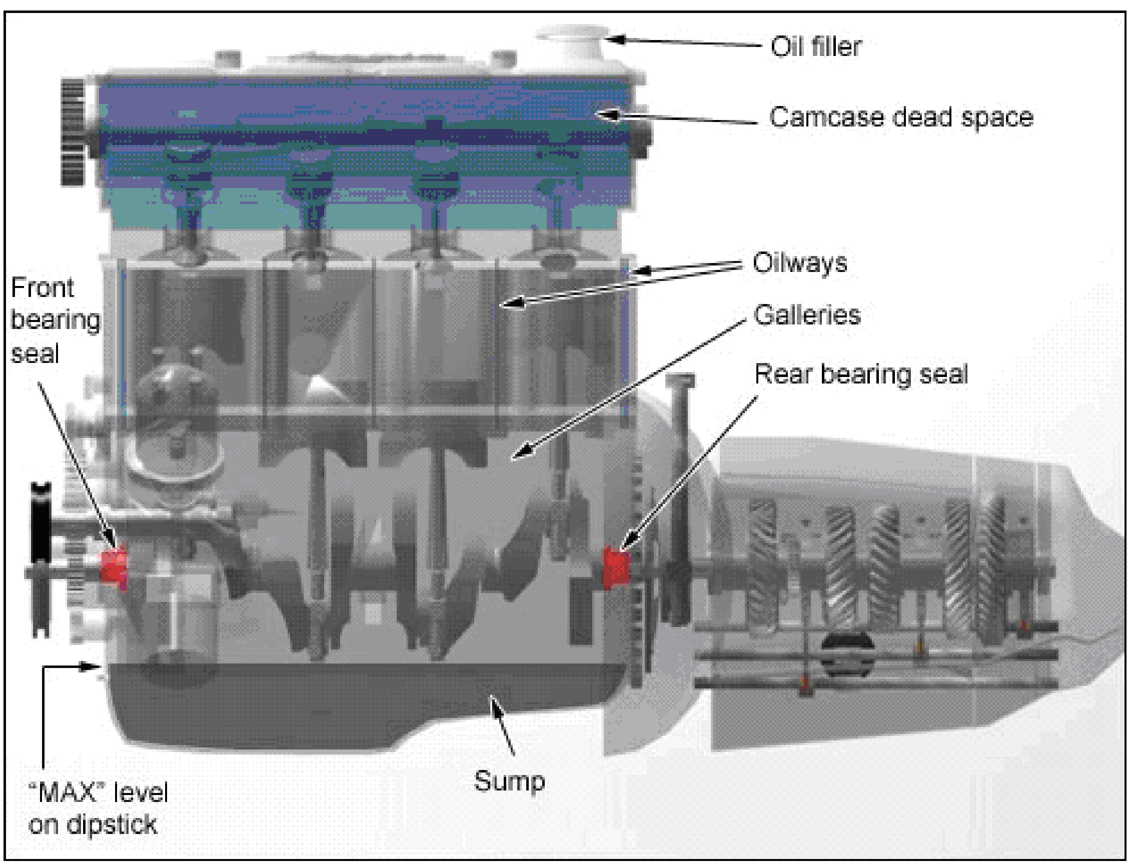
***Important:** Try to remove the old fuel filter carefully; it will probably still be full of gas!

Remember those special fuel line bolts you carefully set aside? Sitting on those will be a special pressure washer. They are usually either copper or aluminium. Remove the old washers and replace them with the new washers that match. The washers are usually different from one side of the fuel filter to the other. You'll place one washer on the bolt before you slide the fuel line on, and one after. Installation of the new filter is the opposite of removal. Don't forget to put the fuel pump fuse or relay back before you try to start the car. Now you can enjoy peace of mind and better gas mileage.

13.0 Engine Oils

13.1 What does my oil actually do?

An engine oil's job is primarily to stop all the metal surfaces in your engine from grinding together and tearing themselves apart from friction whilst transferring heat away from the combustion cycle. Engine oil must also be able to hold all the nasty by-products of combustion, such as silica (silicon oxide) and acids in suspension; it cleans the engine of these chemicals and build-ups, and keeps the moving parts coated in oil. Finally, engine oil minimises the exposure to oxygen and thus oxidation at higher temperatures and it does all of these things under tremendous heat and pressure,



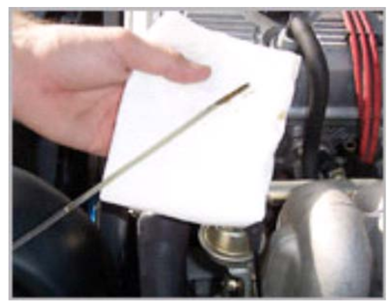
13.2 Mineral or synthetic?

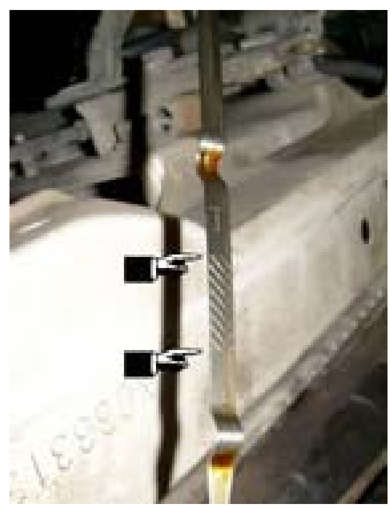
Mineral oils are based on oil that comes from the Earth which has been refined, synthetic oils are entirely concocted by chemists in oil company laboratories. The only other type is semi-synthetic, sometimes called premium, which is a blend of the two. It is safe to mix the different types, but it's wiser to switch completely to a new type rather than mixing.

13.3 Synthetics

Despite their name, most synthetic derived motor oils (i.e. Mobil 1, Castrol Formula RS etc.) are actually derived from mineral oils - they are mostly Poly-alpha-olefins (PAO) and these come from the purest part of the mineral oil refraction process, the gas. PAO oils will mix with normal mineral oils which means you can add synthetic to mineral, or mineral to synthetic without an engine seizing up. (In truth, Mobil 1 is actually made by reformulating ethanol).

The most stable bases are polyol-ester (not polyester). 'Stable' in this case means 'less likely to react adversely with other compounds.' Synthetic oil bases tend not to contain reactive carbon atoms for this reason. Reactive carbon has a tendency to combine with oxygen creating an acid. As you can imagine, in an oil, this would be a bad thing. So think of synthetic oils as custom-built oils. They're designed to do the job efficiently but without any of the excess baggage that can accompany mineral based oils.





13.4 Check an Engine's Oil

Checking a car engine's oil level is the single most important thing you can do to extend the life of a car's engine. Oil is the engine's life blood and without good and fresh oil it wouldn't last very long at all. With the hood safely propped, pull the dipstick out and wipe the end clean with a towel or rag. Re-insert the dipstick into the engine, making sure it goes all the way in. Now pull it out, but don't turn it upside down to look at it, this makes the oil run upward and ruins your reading. The dipstick will have two marks at the bottom. They are usually either lines or holes in the stick. The oil level can be read by looking to see where the oily part ends and the dry part begins. If it's between the two marks, you're good. If it's below the bottom mark, you would need to add a litre of oil. Never add more than a litre at once without driving and taking a new reading of the oil level. Overfilling the engine can be messy.

13.5 To Change an Engine's Oil

Follow the steps below to successfully service an engine's oil, system and filter.

- Warm Up the Engine;

- Raise & Secure Vehicle;
- Drain Old Oil;
- Remove Oil Filter;
- Install New Oil Filter;
- Refill Oil;
- Check Oil Level;
- Dispose Of Old Oil Correctly; and
- Re-Check Oil Level.

13.5.1 Warm Up the Engine

Run the engine until normal operating temperature is reached and switch off, as warm oil will drain more effectively than cold oil and help to drain out any built up sludge. **Never change oil while the engine is hot!**

To perform an Oil Change

The first step in an oil change is to get the old stuff out of there. The oil drains out of the oil pan at the very bottom of your engine. The oil is held in by a drain plug that looks like a big bolt at the bottom of the pan.

13.5.2 Catching the Oil for Recycling

Before you remove the oil drain plug, be sure that your recycling container is positioned underneath the oil drain.

An oil change can be no fun if most of your time is spent cleaning up oil.

When you remove the drain plug, let it drop into the top of the recycling container. Place a screen on top that will keep it from dropping into the muck.
Let all of the oil drain out, and then replace the drain plug, tightening it to the engine's torque specifications (or "snug but not too hard").

Transfer the used oil to the recycling storage for your scheduled pick up.

13.5.3 Remove the Old Oil Filter

Next you need to remove your old oil filter. Move your oil catch pan under the oil filter. Using an oil filter wrench to get it started, remove the oil filter. Using an oil filter wrench, turn the filter counter clockwise until it's free. Be careful with it, it's still full of old oil that can spill and make a mess. A strap type oil filter wrench is the best kind to use. A socket type oil filter tool is used with a ratchet just like a regular socket. The problem with the socket type is that it tends to get stuck on the filter. Use the socket type tool if you don't have enough clearance around the oil filter to use the strap type.

Some oil filters can be reached from the top, but for most you'll have to be under the car.

13.5.4 The New Oil Filter

With the old oil out and the old filter out of the way, it's time to put the *change* in oil change. But before you install the new oil filter, you have to prep it. Before you screw the new oil filter into place, lubricate the rubber gasket on the end of the filter with some new oil; screw the filter on until its 'hand tight'. Then use the oil filter wrench to snug it up another 1/8 to 1/4 turn. This is critical!

When the vehicle is running, the oil pump puts the oil under pressure. If you don't install the oil filter tight enough, the oil will come gushing out. If that happens shut down the engine immediately! Without oil, an engine will lock up within seconds.

Warning! Don't over-tighten the filter. Follow the instructions above carefully!

13.5.5 Oil Characteristics

		Characteristics
Fully Synthetic	0W - 30 0W - 40 5W - 40	Fuel economy savings Enhances engine performance and power Ensures engine is protected from wear and deposit buildup Ensures good cold starting and quick circulation in freezing temperatures Gets to moving parts of the engine quickly
Semi Synthetic	5W - 30 10W - 40 15W - 40	Better protection Good protection within the first 10 minutes after starting out Roughly three times better at reducing engine wear Increased oil change intervals- don’t need to change oil quite so often
Mineral	10W - 40 15W - 40	Basic protection for a variety of engines Oil needs to be changed more often

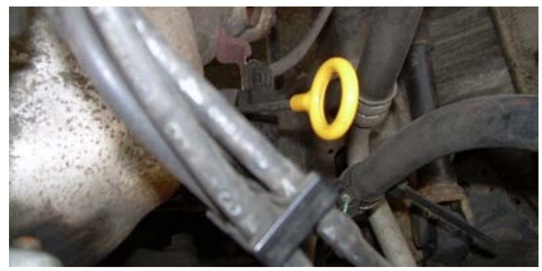
13.5.6 Add the new oil

Ensure that you know the quantity of oil the engine takes before you add any oil. Never fill the exact the specified quantity of oil immediately. It is good practice to initially fill 80% of the specified capacity. (e.g. if your car takes 5 litres put 4 litres in to begin with). There are different types of motor oil, so check the car's owner's manual to see what they recommend. If the correct oil cannot be determined it is suggested that you use 10W-30 or 10W-40 safely. It is suggested that you should use a funnel to add oil to an engine.

With the hood safely propped open, look for a big screw cap right in the middle of the engine. It'll have a picture of what looks like a watering can on it, and some even say OIL. Again, you can consult the owner's manual on this. Don't forget the cap!

Unscrew the cap, and put it someplace safe, where you won't forget it! Leaving the cap off can be messy and even dangerous. A suggestion is to place the cap over the hole in the hood latch so that you can't close the hood without putting the cap back on. Place a medium sized funnel in the hole and carefully pour in the new oil SLOWLY. Some engines have a habit of developing airlocks which result in the oil spilling back out the filler hole. Periodically, stop pouring and allow the oil to settle down into the engine sump.

Check the dipstick until you have the correct level. Note: the dipstick will often indicate an overfill when the correct quantity of oil is added. The level will drop once the oil has circulated to the new filter. Start the engine and make sure the dashboard OIL light goes out or the gauge indicates pressure. If not, stop the engine immediately.



13.5.7 Checking the Oil Level

Be sure to put your oil cap back on! Oil spray can cause a fire.

Once you are satisfied with your oil level, run your engine for around 1 minute and then shut it off. Check the engine for oil leaks- particularly around the oil filter and sump plug. Re-check oil level.

13.5.8 Dispose of Old Oil Correctly

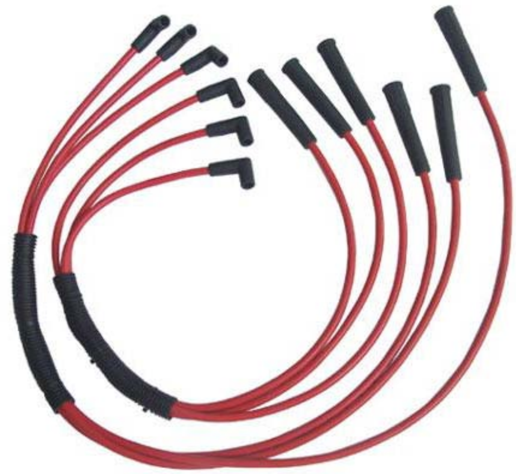
Check with local authorities about disposing of used oil. Many communities have collection centres which will see that oil is disposed of safely. Never dump used oil on the ground, into drains or in the rubbish bin.

13.5.9 Re-Check Oil Level

After short periods of use following an oil change it is good practice to check the engine oil level on the dipstick and also check for any oil leaks.

14.0 Spark Plugs

14.1 Leads



Spark plug wires are pretty durable. They aren't a moving part so they don't wear out too often. A careful inspection of your plug wires can avoid any problems.

The only thing that can really go wrong with a plug wire is a break in the insulation. The insulation (the rubber on the outside of the wire) keeps the electricity where it needs to be so it sparks on the inside of your engine, not someplace else before it gets there. If the insulation is cracked, the spark will jump off the wire, or arc, onto something metal.

An arcing plug wire can cause a weak spark or no spark at all in the cylinder with the bad wire. This makes an engine run rough and can affect economy and performance and it can also cause unburned fuel to pass into the exhaust system.

A simple check can be completed by:

- With the engine off, start at the distributor end of the plug wire and work your way toward the plug end. You're looking for anything that is not smooth, pliable rubber;
- Bend the wires slightly to be sure no cracks appear;
- Check the boots at the distributor end of the wires to be sure they are not torn or cracked; and
- Finally, check the wires at the spark plug end one at a time by pulling it off the plug and inspecting the end for any tears or cracks. Also look to be sure there is no burning or darkening of the end.

If you find any damage, it's appropriate to replace the entire set although this is not necessary.

14.2 Why Do You Need to Change Your Spark Plugs?

With a lot of improvements in engine ignition systems in recent decades there is one constant. Most engines still have a spark plug someplace, and even today's technology hasn't stopped them from wearing out. It's an easy maintenance procedure that can make an engine run more smoothly and increase economy and performance.

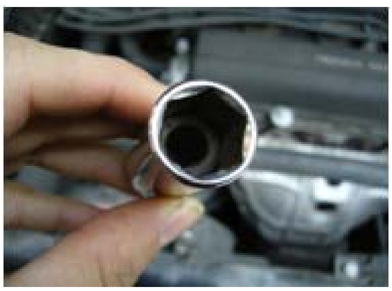
What is a spark plug? Basically it's a high voltage bridge for electricity. When the electricity crosses the "bridge" (which is actually a gap between two contact points) inside an engine, the spark it makes ignites the gas vapours, which makes the engine go putt putt. How long they can do this without being replaced depends on lots of things. The condition of the engine, the purity of the fuel, and the performance loads can affect the life of the plugs.

14.3 Removing the Spark Plug

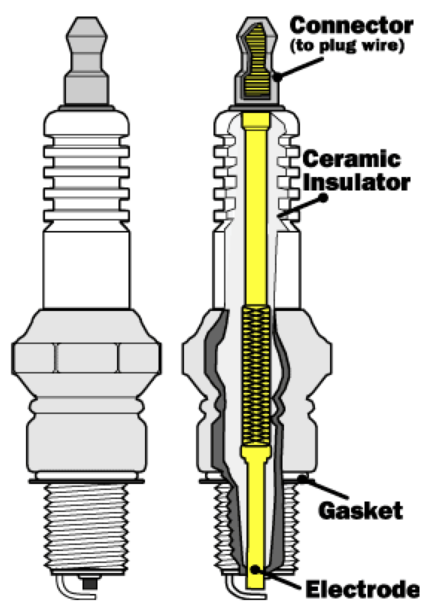
Now that you have *one* plug wire off, put your spark plug socket and the extension on your ratchet. If you look inside the spark plug socket, you should see some black foam or rubber on the inside end. This is important, because it holds onto the spark plug while you manoeuvre it in and out of the engine.

If for some reason your socket doesn't have the gripper in there, you can improvise. Cut off a half inch or less of electrical or masking tape and stick it onto the inside of the clean socket. This will make the socket grip a little more tightly on the spark plug so you can hold onto it.

With your ratchet wrench set to loosen (that's counter-clockwise) slide it over the end of the plug, being sure to push it on as far as it will go. Now remove the old plug.



14.4 How Does the Spark Plug Look?



While you have your old plug in your hand, take a look at it. It should be a little dirty on the end, a little black with a little soot, the key phrase being "a little." If it's white or oily, this could indicate other problems so make a note of how they're looking. Also check to see if the porcelain insulator is cracked.

Finally, take a look at how the end you pulled the plug wire off is set up. Some will just be threaded like a screw, and others will have a large metal cap on the end. Be sure your new plugs are set up like the old ones were.

14.5 In With the New Plug

With the wire end of your plug set up like the old one, you're ready to put it in the car.

But don't; have you set the gap with a feeler gauge. Well, you do not have too. These days you order plugs specifically for your car, and they come already gapped.

Put the plug-wire end of the plug in the socket and, holding just the extension, push it all the way in. Now carefully guide the spark plug into the hole. Try not to ram it in or bang it on anything because this can screw up the gap or damage the plug. With it sitting in the hole, begin to screw the new plug in by hand. Starting them off by hand instead of using the wrench will keep you from accidentally cross-threading one of the plugs. Screw it in by hand until it stops, then put the wrench on the end and tighten it snugly. If you have a torque wrench, you can torque it to specification, but if you don't, just make it tight without overdoing it. The metal in there is soft and can be damaged by overtightening. If you are pulling hard enough to make a sound come out of your mouth, like a grunt, you're overdoing it.

Now put the plug wire back on.

14.6 Finishing Up & Testing it Out

Repeat all the steps one plug at a time until you've done 'em all. Now start her up and listen to the purr!

If you decided not to use this process and pulled all the wires off at once, you might have mixed up the plug wires. This will be easy to determine because the engine either won't start, will run really rough, or perhaps there will be a deafening backfire. To rectify this, the engine's firing order is required to correspond that to the points on the distributor cap after you set the engine to Top Dead Centre and put them all back on. It is certainly easier to replace them one at a time?

15.0 Summary

Automotive engine servicing is a specialist task. The opening statement of this learning resource tells us "The internal combustion engine is an engine in which the combustion of fuel and an oxidizer (typically air) occurs in a confined space called a combustion chamber. This exothermic reaction creates gases at high temperature and pressure, which are permitted to expand. The defining feature of an internal combustion engine is that useful work is performed by the expanding hot gases acting directly to cause movement of solid parts of the engine, by acting on pistons, rotors, or even by pressing on and moving the entire engine itself." We as operators don't really need to need to know as we can rely of the technicians'.

15.1 Servicing Documentation

Documentation provides valuable descriptions of an organisation’s development, acquisition, and operating environments and significantly enhances an organisation’s ability to administer, operate, and maintain technology systems. Primary advantages for technicians’ involves having access to operation manuals and on-line application help features. Documentation enhances administrators’ and technicians’ ability to maintain and update systems efficiently and to identify and correct programming defects.

Developing and maintaining current, accurate documentation can be complicated, time consuming, and expensive. However, standardised documentation procedures and the use of automated documentation software can facilitate an organisation’s ability to maintain accurate documentation.

15.2 Final Inspection

Consumers expectations are that they will receive their vehicle back in a serviceable condition and in a better operational condition than when it was delivered to the workshop. This expectation requires two (2) critical components:

- A final inspection must be completed by the service technician to ensure that all of the protective features for the braking system have been refitted is replaced to the required specifications; and
- A final inspection must be completed by the service technician to ensure that all of the work that was commenced on the system was completed to workplace, customer and manufacturers expectations.

15.3 For the Technician

There are some tasks that a technician will not carry out frequently. It would be unrealistic for a technician to have a detailed knowledge of seldom-performed procedures. In these circumstances, job cards or checklists are very useful as they give a step-by-step guide to follow whenever the rarely-used procedure needs to be performed. The required knowledge is often kept in manuals which may not be easily accessible. However, going through a large manual, possibly in front of a customer, does nothing for time effectiveness or professional image.

A job card is also used as the basis of a recording process for the organisation. In addition to refreshing the process for the technician it will be a list of the workplace expectations as well. It is suggested that the final task on a job card will be to ensure that the equipment is cleaned for use or storage.

End

16.0 Competency Based Training and Assessment Tools

• Are you ready for assessment?	Yes	☐	No	☐
• Do you understand the assessment process?	Yes	☐	No	☐
• Have you considered the Recognition of Prior Learning (RPL) process?	Yes	☐	No	☐
• Do you understand the term evidence and how it is to be collected?	Yes	☐	No	☐

If you have answered YES to these four questions you are ready to proceed to the assessment phase of this unit of competence. If you have answered NO you need to discuss your progress with a qualified assessor.

Introduction

Competency Based Training is always concerned with what a participant will be able to do at the end of training. What the inputs are or how the participant got there will vary, however it is critical that the participant achieves the listed competencies and that a quality assessment be undertaken by a competent trainer/assessor.

Assessment Coversheet

Participant Name			
Participant Email		**Telephone Number**	

Receipt of Assessment

Receiver's Signature		**Date**	
Signature of assessor		**Result**	

I certify that this assessment is my own work based on my personal study and /or research and that I have acknowledged all materials and resources used in the preparation of this assessment whether they are books, articles, reports, lecture notes and any other kind of document, electronic or personal communications. I also certify that the assessment has not previously been submitted for assessment in any award or course and that I have not copied in part or whole or otherwise plagarised the work of other students and/or persons. I can produce another hard/soft copy of this assessment within 24 hours if requested.

Participant Signature		**Date**	

This assignment/assessment will not be marked unless the the above declaration is signed

Please copy this page and attach it to each submission for assessment

Observation Report/Third Party Assessment

To be administered by an Assessor and/or a Workplace Supervisor

Purpose of the task

The purpose of the observations is to assess your competency in inspection and servicing of engines.

Instructions for the observation component

You will be required to participate in servicing sessions whilst being observed by an assessor who is qualified in this unit of competency. You may use an assessor from your preferred registered training organisation, or alternatively, you may source your own assessor (this person must use the observation checklist and provided a certified copy of their qualifications).

You will need to be observed in a **minimum of three (3)** service sessions:

- These sessions can be conducted by a workplace supervisor but must be completed by an suitably qualified assessor from a Registered Training Organisation on at least one occasion if you are submitting this assessment for recognition towards a nationally recognised qualification.

You will be assessed on the following required skills and attributes:

- Customer service
- Oral communication and interpersonal skills
- OHS skills
- Workshop practice skills

Please refer to the observation checklist for specific observation requirements under the above skills groups. Competency will need to be demonstrated over a period of time reflecting the scope of the role, as reflected by all components of this unit.

Where assessment is part of a structured learning experience, the evidence collected must relate to a number of performances assessed at different points in time and separated by further learning and practice with a decision of competence only taken at the point when the assessor has complete confidence in the ability of the person.

Where assessment is for the purpose of recognition (RCC/RPL), the evidence provided will need to show that it represents competency demonstrated over a period of time and is current.

Evidence must show the ability to transfer skills to different environments.

Observation Report/Third Party Assessment

To be administered by an Assessor or a Workplace Supervisor

Candidate Name:	
RTO Assessor Name:	
Unit/s of Competency:	
Name of Workplace:	
Date of Assessment:	

During the Observation Assessment, did the candidate:	**PC**	**S**	**NS**
Identify and confirm the nature and scope of work requirements	1.1	☐	☐
Observe throughout the work OH&S requirements, including individual State/Territory regulatory requirements and personal protection needs	1.2	☐	☐
Source procedures and information such as workshop manuals and specifications and tooling required	1.3	☐	☐
Prepare in accordance with standard operating procedures methods appropriate to the circumstances	1.4	☐	☐
Identify, source and prepare resources and support equipment required for inspection of engine systems	1.5	☐	☐
Observe warnings in relation to working with engine systems	1.6	☐	☐
Implement in accordance with workplace procedures and manufacturer/component supplier specifications for engine servicing for engine systems inspections	2.1	☐	☐
Engines are started and run up to operating temperature and inspected for leaks, abnormal noises and pressures	2.2	☐	☐
Indication of compliance or non-compliance for analysis results are compared with manufacturer/component supplier specifications	2.3	☐	☐
Results are documented with evidence and supporting information and recommendation(s) are made	2.4	☐	☐
The reports are processed in accordance with workplace procedures	2.5	☐	☐
Observe throughout the work OH&S requirements, including individual State/Territory regulatory requirements and personal protection needs	3.1	☐	☐
Identify and source procedures and information required	3.2	☐	☐
Identify and prepare resources required for servicing and support equipment	3.3	☐	☐

Implement the service in accordance with workplace procedures and manufacturer/component supplier specifications	4.1	☐	☐
Adjustments made during the service are in accordance with manufacturer/component supplier specifications	4.2	☐	☐
Documentation for the servicing schedule is completed	5.1	☐	☐
Ensure protective features are in place by completing a final inspection	5.2	☐	☐
Ensure work is to workplace expectations by completing a final inspection	5.3	☐	☐
Ensure that equipment is cleaned for use or storage to workplace expectations	5.4	☐	☐
Process the job card in accordance with workplace procedures	5.5	☐	☐

Legend

S	NS	
		NS = Not Satisfactory. The participant requires more training, instruction and/or experience prior to re assessment
		S = Satisfactory
		NOTE : Always indicate an outcome

Feedback comments:

Result for Assessment:	☐ **Satisfactory (S)** ☐ **Not Satisfactory (NS)**

Candidate Signature:		**Date:**	
RTO Assessor Signature:		**Date:**	

Portfolio of Evidence

To be completed by the candidate and submitted to the RTO Assessor

Candidate Name:	
RTO Assessor Name:	
Unit/s of Competency:	
Name of Workplace:	
Date of Assessment:	

This assessment covers components of the elements required for competency in

Element 1 Prepare to undertake the inspection of engines

Element 2 Conduct engine system inspections and analyse results

Element 3 Prepare to service engines

Element 4 Carry out servicing

Element 5 Prepare vehicles for use or storage

Purpose of the task

As you work through the steps in assessing competence, you must collect documentation or work samples that “prove” what you do.

Indicative examples of the type of evidence you should collect at different stages of your program are listed below. There may be other pieces of evidence that you could collect. You are encouraged to discuss any other options with your assessor.

Instructions

You are required to provide evidence of

- Gather information about the OH&S and environmental regulations/requirements, equipment, material and personal safety requirements;
- Make a list of some of the dangers of working with engines;
- Detail, in writing, the operating principles of three (3) different engine systems/cycles;
- Make a list of the different types and layout of service/repair manuals (hard copy and electronic);
- Provide a written description about how to conduct of a systematic approach to inspection;
- List a complete servicing procedure;
- Provide your enterprise quality procedures; and
- Detail your work organisation and planning processes.

S	NS

NS = Not Satisfactory. The participant requires more training, instruction and/or

		experience prior to re assessment
		S = Satisfactory
		NOTE : Always indicate an outcome

Feedback Comments:

Result for Assessment:	☐ **Satisfactory (S)** ☐ **Not Satisfactory (NS)**		
Candidate Signature:		**Date:**	
RTO Assessor Signature:		**Date:**	

Sources of Acknowledgement

Boyce Automotive Data @ www.boyce.com.au

Gregory's *ACL Engine Manual* Gregory's 7th edition Gregory's Automotive Publications 2006

Gregory's *Automotive Mechanics Fundamentals* 6th edition Gregory's Automotive Publications 2005

Owen, Clifton E *Today's Technician* 4th edition Delmar Publishing 2007

J.Y. Wong *Theory of Ground Vehicles* 3rd edition John Wiley & Sons Inc 2001

www.yourautoadvisor.com/resources/servicemanual/manuals.html

www.repairmanual.com

www.wheelsdirectory.com/repair/repair.htm