**ENGINE**

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**Gaurav SharmaTABLE OF CONTENTS**

**CHAPTER NO. TITLE PAGE NO.**

1 **INTRODUCTION TO ENGINE 4**

[2  **TERMINOLOGY**](http://en.wikipedia.org/wiki/Hybrid_electric_vehicle#Terminology) **5**

[3  **HISTORY**](http://en.wikipedia.org/wiki/Hybrid_electric_vehicle#History) **7**

[4  **HEAT**](http://en.wikipedia.org/wiki/Hybrid_electric_vehicle#Sales_and_rankings) **ENGINE 14**

5  **ENVIROMENTAL EFFECTS 18**

[6**ELECTRIC**](http://en.wikipedia.org/wiki/Hybrid_electric_vehicle#Vehicle_types) **MOTOR 20**

[7  **ENGINE**](http://en.wikipedia.org/wiki/Hybrid_electric_vehicle#Raw_materials_shortage) **CONFIGRATION 24**

[8  **ENGINE**](http://en.wikipedia.org/wiki/Hybrid_electric_vehicle#Legislation_and_incentives) **CYCLE 33**

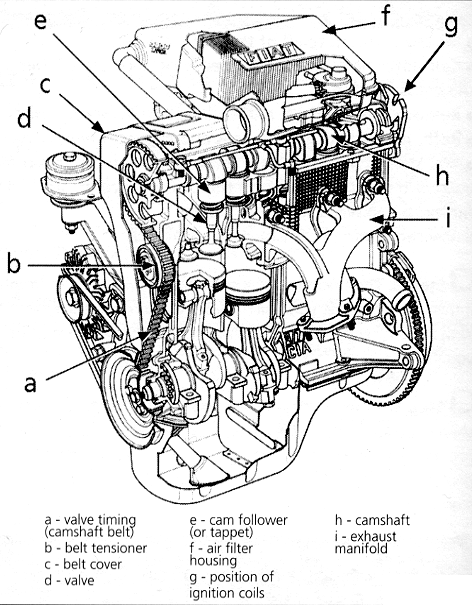
[9 **AIR**](http://en.wikipedia.org/wiki/Hybrid_electric_vehicle#References) **AND NOISE POLLUTION 44**

10 **SEASONAL ENGINE MAINTAINANCE 47**

11 **SEASONAL MAINTENANCE TIPS 57**

**INTRODUCTION TO ENGINE**

An engine or motor is a machine designed to convert energy into useful mechanical motion.

Motors converting heat energy into motion are usually referred to as engines, which come in many types. A common type is a heat engine such as an internal combustion engine which typically burns a fuel with air and uses the hot gases for generating power. External combustion engines such as steam engines use heat to generate motion via a separate working fluid.

Another common type of motor is the electric motor. This takes electrical energy and generates mechanical motion via varying electromagnetic fields.

Other motors including pneumatic motors that are driven by compressed air, and motors can be driven by elastic energy, such as springs. Some motors are driven by non combustive chemical reactions.

**TERMINOLOGY**

Originally an engine was a mechanical device that converted force into motion. Military devices such as catapults, trebuchets and battering rams are referred to as siege engines. The term "gin" as in cotton gin is recognised as a short form of the Old French word engin, in turn from the Latin ingenium, related to ingenious. Most devices used in the industrial revolution were referred to as engines, and this is where the steam engine gained its name.

In modern usage, the term is used to describe devices capable of performing mechanical work, as in the original steam engine. In most cases the work is produced by exerting a torque or linear force, which is used to operate other machinery which can generate electricity, pump water, or compress gas. In the context of propulsion systems, an air-breathing engine is one that uses atmospheric air to oxidise the fuel carried rather than supplying an independent oxidizer, as in a rocket.

In common usage, an engine burns or otherwise consumes fuel, and is differentiated from an electric machine (i.e., electric motor) that derives power without changing the composition of matter. A heat engine may also serve as a prime mover, a component that transforms the flow or changes in pressure of a fluid into mechanical energy. An automobile powered by an internal combustion engine may make use of various motors and pumps, but ultimately all such devices derive their power from the engine.

The term motor was originally used to distinguish the new internal combustion engine-powered vehicles from earlier vehicles powered by steam engines, such as the steam roller and motor roller, but may be used to refer to any engine.

**HISTORY OF ENGINES**

**ANTIQUITY**

Simple machines, such as the club and oar (examples of the lever), are prehistoric. More complex engines using human power, animal power, water power, wind power and even steam power date back to antiquity. Human power was focused by the use of simple engines, such as the capstan, windlass or treadmill, and with ropes, pulleys, and block and tackle arrangements; this power was transmitted usually with the forces multiplied and the speed reduced. These were used in cranes and aboard ships in Ancient Greece, as well as in mines, water pumps and siege engines in Ancient Rome. The writers of those times, including Vitruvius, Frontinus and Pliny the Elder, treat these engines as commonplace, so their invention may be far more ancient. By the 1st century AD, various breeds of cattle and horses were used in mills, driving machines similar to those powered by humans in earlier times.

According to Strabo, a water powered mill was built in Kaberia of the kingdom of Mithridates during the 1st century BC. Use of water wheels in mills spread throughout the Roman Empire over the next few centuries. Some were quite complex, with aqueducts, dams, and sluices to maintain and channel the water, along with systems of gears, or toothed-wheels made of wood and metal to regulate the speed of rotation. In a poem by Ausonius in the 4th century AD, he mentions a stone-cutting saw powered by water. Hero of Alexandria is credited with many such wind and steam powered machines in the 1st century AD, including the Aeolipile, but it is not known if any of these were put to practical use.

**MEDIEVAL**

During the Muslim Agricultural Revolution from the 9th to 13th centuries, Muslim engineers developed numerous innovative industrial uses of hydropower, early industrial uses of tidal power, wind power, and fossil fuels such as petroleum, together with the earliest large factory complexes (tiraz in Arabic). The industrial uses of watermills in the Islamic world date back to the 7th century, whereas horizontal-wheeled and vertical-wheeled water mills were both in widespread use since at least the 9th century. A variety of industrial mills were invented in the Islamic world, including fulling mills, hullers, steel mills, sugar refineries, and windmills. By the 11th century, every province throughout the Islamic world had these industrial mills in operation, from the Middle East and Central Asia to al-Andalus and North Africa.

Roman engineers invented water turbines in the 4th century AD, Muslim engineers employed gears in mills and water-raising machines, and pioneered the use of dams as a source of water power to provide additional power to watermills and water-raising machines. Such advances made it possible for many industrial tasks that were previously driven by manual labour to be mechanized and driven by machinery to some extent in the medieval Islamic world.

In 1206, al-Jazari employed a crank-connecting rod system for two of his water-raising machines. A similar steam turbine later appeared in Europe a century later, which eventually led to the steam engine and Industrial Revolution in 18th century Europe.

**INDUSTRIAL REVOLUTION**

English inventor Sir Samuel Morland allegedly used gunpowder to drive water pumps in the 17th century. For more conventional, reciprocating internal combustion engines, the fundamental theory for two-stroke engines was established by Sadi Carnot, France, 1824, whilst the American Samuel Morey received a patent on April 1, 1826. Sir Dugald Clark (1854–1932) designed the first two-stroke engine in 1878 and patented it in England in 1881. Automotive engines have used a range of energy-conversion systems. These include electric, steam, solar, turbine, rotary, piston-type internal combustion engine.

Karl Benz was one of the leaders in the development of new engines. In 1878 he began to work on new designs. He concentrated his efforts on creating a reliable gas two-stroke engine that was more powerful, based on Nikolaus Otto's design of the four-stroke engine. Karl Benz showed his real genius, however, through his successive inventions registered while designing what would become the production standard for his two-stroke engine. Benz was granted a patent for it in 1879.

The lightweight petrol internal combustion engine, operating on a four-stroke Otto cycle, has been the most successful for automobiles, while the more efficient diesel engine is used for trucks and buses.

**HORIZONTALLY OPPOSED PISTONS**

In 1896, Karl Benz was granted a patent for his design of the first engine with horizontally opposed pistons. Many BMW motorcycles use this engine type. His design created an engine in which the corresponding pistons move in horizontal cylinders and reach top dead center simultaneously, thus automatically balancing each other with respect to their individual momentums. Engines of this design are often referred to as flat engines because of their shape and lower profile. They must have an even number of cylinders and six, four or two cylinder flat engines have all been common. The most well-known engine of this type is probably the Volkswagen Beetle engine. Engines of this type continue to be a common design principle for high performance aero engines (for propellor driven aircraft) and, engines used by automobile producers such as Porsche and Subaru.

**ADVANCEMENT**

Continuance of the use of the internal combustion engine for automobiles is partly due to the improvement of engine control systems (onboard computers providing engine management processes, and electronically controlled fuel injection). Forced air induction by turbocharging and supercharging have increased power outputs and engine efficiencies. Similar changes have been applied to smaller diesel engines giving them almost the same power characteristics as petrol engines. This is especially evident with the popularity of smaller diesel engine propelled cars in Europe. Larger diesel engines are still often used in trucks and heavy machinery. They do not burn as clean as gasoline engines, however they have far more torque. The internal combustion engine was originally selected for the automobile due to its flexibility over a wide range of speeds. Also, the power developed for a given weight engine was reasonable; it could be produced by economical mass-production methods; and it used a readily available, moderately priced fuel - petrol.

**INCREASING POWER**

The first half of the 20th century saw a trend to increasing engine power, particularly in the American models. Design changes incorporated all known methods of raising engine capacity, including increasing the pressure in the cylinders to improve efficiency, increasing the size of the engine, and increasing the speed at which power is generated. The higher forces and pressures created by these changes created engine vibration and size problems that led to stiffer, more compact engines with V and opposed cylinder layouts replacing longer straight-line arrangements.

**COMBUSTION EFFICIENCY**

The design principles favoured in Europe, because of economic and other restraints such as smaller and twistier roads, leant toward smaller cars and corresponding to the design principles that concentrated on increasing the combustion efficiency of smaller engines. This produced more economical engines with earlier four-cylinder designs rated at 40 horsepower (30 kW) and six-cylinder designs rated as low as 80 horsepower (60 kW), compared with the large volume V-8 American engines with power ratings in the range from 250 to 350 hp (190 to 260 kW).

**ENGINE CONFIGURATION**

Earlier automobile engine development produced a much larger range of engines than is in common use today. Engines have ranged from 1 to 16 cylinder designs with corresponding differences in overall size, weight, piston displacement, and cylinder bores. Four cylinders and power ratings from 19 to 120 hp (14 to 90 kW) were followed in a majority of the models. Several three-cylinder, two-stroke-cycle models were built while most engines had straight or in-line cylinders. There were several V-type models and horizontally opposed two- and four-cylinder makes too. Overhead camshafts were frequently employed. The smaller engines were commonly air-cooled and located at the rear of the vehicle; compression ratios were relatively low. The 1970s and '80s saw an increased interest in improved fuel economy which brought in a return to smaller V-6 and four-cylinder layouts, with as many as five valves per cylinder to improve efficiency. The Bugatti Veyron 16.4 operates with a W16 engine meaning that two V8 cylinder layouts are positioned next to each other to create the W shape.

The largest internal combustion engine ever built is the Wärtsilä-Sulzer RTA96-C, a 14-cylinder, 2-stroke turbocharged diesel engine that was designed to power the Emma Maersk, the largest container ship in the world. This engine weighs 2300 tons, and when running at 102 RPM produces 109,000 bhp (80,080 kW) consuming some 13.7 tons of fuel each hour.

**HEAT ENGINE**

**COMBUSTION ENGINE**

Combustion engines are heat engines driven by the heat of a combustion process.

**INTERNAL COMBUSTION ENGINE**

The internal combustion engine is an engine in which the combustion of a fuel (generally, fossil fuel) occurs with an oxidizer (usually air) in a combustion chamber. In an internal combustion engine the expansion of the high temperature and pressure gases, which are produced by the combustion, directly applies force to components of the engine, such as the pistons or turbine blades or a nozzle, and by moving it over a distance, generates useful mechanical energy.

**EXTERNAL COMBUSTION ENGINE**

An external combustion engine (EC engine) is a heat engine where an (internal) working fluid is heated by combustion of an external source, through the engine wall or a heat exchanger. The fluid then, by expanding and acting on the mechanism of the engine produces motion and usable work. The fluid is then cooled, compressed and reused (closed cycle), or (less commonly) dumped, and cool fluid pulled in (open cycle air engine).

"Combustion" refers to burning fuel with an oxidizer, to supply the heat. Engines of similar (or even identical) configuration and operation may use a supply of heat from other sources such as nuclear, solar, geothermal or exothermic reactions not involving combustion; but are not then strictly classed as external combustion engines, but as external thermal engines.

The working fluid can be a gas as in a Stirling engine, or steam as in a steam engine or an organic liquid such as n-pentane in an Organic Rankine Cycle. The fluid can be of any composition; gas is by far the most common, although even single-phase liquid is sometimes used. In the case of the steam engine, the fluid changes phases between liquid and gas.

**GAS TURBINE**

A gas turbine is internal combustion is the sense that the combustion takes place in the working fluid, but external combustion in the sense that the combustion is not fully closed in and is outside the actual moving turbine section. Traditionally, "internal combustion" usually excludes gas turbines, jets and rockets.

**AIR-BREATHING COMBUSTION ENGINES**

Air-breathing engines are combustion engines that use the oxygen in atmospheric air to oxidise ('burn') the fuel carried, rather than carrying an oxidiser, as in a rocket. Theoretically, this should result in a better specific impulse than for rocket engines.

A continuous stream of air flows through the Air-breathing engine. This air is compressed, mixed with fuel, ignited and expelled as the exhaust gas. Thrust produced by a typical air-breathing engine is about eight times greater than its weight. The maximum velocity of Air-breathing engines is limited to 1–3 km/s due to extreme temperature and dissociation of the exhaust gas; however, the maximum velocity of a hydrogen-breathing engine of the same design is about 4 times higher.

**EXAMPLES**

Typical air-breathing engines include:

* Reciprocating engine
* Steam engine
* Gas turbine
* duct jet engine
* Turbo-propeller engine
* IRIS engine
* Pulse detonation engine
* Pulse jet
* Ramjet
* Scramjet
* Liquid air cycle engine/Reaction Engines SABRE

**ENVIRONMENTAL EFFECTS**

Operation of engines typically has a negative impact upon air quality and ambient sound levels. There has been a growing emphasis on the pollution producing features of automotive power systems. This has created new interest in alternate power sources and internal-combustion engine refinements. Although a few limited-production battery-powered electric vehicles have appeared, they have not proved to be competitive owing to costs and operating characteristics. In the 21st century the diesel engine has been increasing in popularity with automobile owners. However, the gasoline engine, with its new emission-control devices to improve emission performance, has not yet been significantly challenged.

**AIR QUALITY**

Exhaust from a spark ignition engine consists of the following: nitrogen 70 to 75% (by volume), water vapor 10 to 12%, carbon dioxide 10 to 13.5%, hydrogen 0.5 to 2%, oxygen 0.2 to 2%, carbon monoxide: 0.1 to 6%, unburnt hydrocarbons and partial oxidation products (e.g. aldehydes) 0.5 to 1%, nitrogen monoxide 0.01 to 0.4%, nitrous oxide <100 ppm, sulfur dioxide 15 to 60 ppm, traces of other compounds such as fuel additives and lubricants, also halogen and metallic compounds, and other particles.[15] Carbon monoxide is highly toxic, and can cause carbon monoxide poisoning, so it is important to avoid any build-up of the gas in a confined space. Catalytic converters can reduce toxic emissions, but not completely eliminate them. Also, resulting greenhouse gas emissions, chiefly carbon dioxide, from the widespread use of engines in the modern industrialized world is contributing to the global greenhouse effect – a primary concern regarding global warming.

**NON COMBUSTIVE HEAT ENGINES**

Some engines convert heat from non combustive processes into mechanical work, for example a nuclear power plant uses the heat from the nuclear reaction to produce steam and drive a steam engine, or a gas turbine in a rocket engine may be driven by decomposing hydrogen peroxide. Apart from the different energy source, the engine is often engineered much the same as an internal or external combustion engine.

**NON THERMAL CHEMICALLY POWERED MOTOR**

Non thermal motors usually are powered by a chemical reaction, but are not heat engines. Examples include:

* Molecular motor - motors found in living things
* Synthetic molecular motor

**ELECTRIC MOTOR**

An electric motor uses electrical energy to produce mechanical energy, usually through the interaction of magnetic fields and current-carrying conductors. The reverse process, producing electrical energy from mechanical energy, is accomplished by a generator or dynamo. Traction motors used on vehicles often perform both tasks. Electric motors can be run as generators and vice versa, although this is not always practical. Electric motors are ubiquitous, being found in applications as diverse as industrial fans, blowers and pumps, machine tools, household appliances, power tools, and disk drives. They may be powered by direct current (for example a battery powered portable device or motor vehicle), or by alternating current from a central electrical distribution grid. The smallest motors may be found in electric wristwatches. Medium-size motors of highly standardized dimensions and characteristics provide convenient mechanical power for industrial uses. The very largest electric motors are used for propulsion of large ships, and for such purposes as pipeline compressors, with ratings in the thousands of kilowatts. Electric motors may be classified by the source of electric power, by their internal construction, and by their application.

The physical principle of production of mechanical force by the interactions of an electric current and a magnetic field was known as early as 1821. Electric motors of increasing efficiency were constructed throughout the 19th century, but commercial exploitation of electric motors on a large scale required efficient electrical generators and electrical distribution networks.

By convention, electric engine refers to a railroad electric locomotive, rather than an electric motor.

**PHYSICALLY POWERED ENGINE**

Some engines are powered by potential energy, for example some clocks have a weight that falls under gravity. Other forms of potential energy include compressed gases (such as pneumatic motors), springs and elastic bands.

Historic military siege engines included large catapults, trebuchets, and (to some extent) battering rams were powered by potential energy.

**PNEUMATIC MOTOR**

A pneumatic motor is a machine which converts potential energy in the form of compressed air into mechanical work. Pneumatic motors generally convert the compressed air to mechanical work though either linear or rotary motion. Linear motion can come from either a diaphragm or piston actuator, while rotary motion is supplied by either a vane type air motor or piston air motor. Pneumatic motors have found widespread success in the hand-held tool industry and continual attempts are being made to expand their use to the transportation industry. However, pneumatic motors must overcome efficiency deficiencies before being seen as a viable option in the transportation industry.

**SOUND LEVELS**

In the case of sound levels, engine operation is of greatest impact with respect to mobile sources such as automobiles and trucks. Engine noise is a particularly large component of mobile source noise for vehicles operating at lower speeds, where aerodynamic and tyre noise is less significant. Petrol and diesel engines are fitted with mufflers (silencers) to reduce noise.

**ENGINE CONFIGURATIONS**

Internal combustion engines can be classified by their configuration.

**FOUR STROKE CONFIGURATION**

**OPERATION**

As their name implies, operation of four stroke internal combustion engines have four basic steps that repeat with every two revolutions of the engine:

1. Intake

Combustible mixtures are emplaced in the combustion chamber

1. Compression

The mixtures are placed under pressure

1. Combustion (Power)

The mixture is burnt, almost invariably a deflagration, although a few systems involve detonation. The hot mixture is expanded, pressing on and moving parts of the engine and performing useful work.

1. Exhaust

The cooled combustion products are exhausted into the atmosphere

Many engines overlap these steps in time; jet engines do all steps simultaneously at different parts of the engine

**COMBUSTION**

All internal combustion engines depend on the exothermic chemical process of combustion: the reaction of a fuel, typically with oxygen from the air (though it is possible to inject nitrous oxide in order to do more of the same thing and gain a power boost). The combustion process typically results in the production of a great quantity of heat, as well as the production of steam and carbon dioxide and other chemicals at very high temperature; the temperature reached is determined by the chemical make up of the fuel and oxidisers (see stoichiometry), as well as by the compression and other factors.

The most common modern fuels are made up of hydrocarbons and are derived mostly from fossil fuels (petroleum). Fossil fuels include diesel fuel, gasoline and petroleum gas, and the rarer use of propane. Except for the fuel delivery components, most internal combustion engines that are designed for gasoline use can run on natural gas or liquefied petroleum gases without major modifications. Large diesels can run with air mixed with gases and a pilot diesel fuel ignition injection. Liquid and gaseous biofuels, such as ethanol and biodiesel (a form of diesel fuel that is produced from crops that yield triglycerides such as soybean oil), can also be used. Engines with appropriate modifications can also run on hydrogen gas, wood gas, or charcoal gas, as well as from so-called producer gas made from other convenient biomass.

Internal combustion engines require ignition of the mixture, either by spark ignition (SI) or compression ignition (CI). Before the invention of reliable electrical methods, hot tube and flame methods were used.

**GASOLINE IGNITION PROCESS**

Gasoline engine ignition systems 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 is recharged during operation using an electricity-generating device such as an alternator or generator driven by the engine. Gasoline engines take in a mixture of air and gasoline and compress it to not more than 12.8 bar (1.28 MPa), then use a spark plug to ignite the mixture when it is compressed by the piston head in each cylinder.

**DIESEL IGNITION PROCESS**

Diesel engines and HCCI (Homogeneous charge compression ignition) engines, rely solely on heat and pressure created by the engine in its compression process for ignition. The compression level that occurs is usually twice or more than a gasoline 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 more susceptible to cold-starting issues, although they will run just as well in cold weather once started. Light duty diesel engines with indirect injection in automobiles and light trucks employ glowplugs that pre-heat the combustion chamber just before starting to reduce no-start conditions in cold weather. Most diesels also have a battery and charging system; nevertheless, this system is secondary and is added by manufacturers as a luxury for the 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 rely on electrical and electronic control system that also control the combustion process to increase efficiency and reduce emissions.

**TWO STROKE CONFIGURATION**

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. In terms of power per cm³, a two-stroke engine produces comparable power to an equivalent four-stroke engine. The advantage of having one power stroke for every 360° of crankshaft rotation (compared to 720° in a 4 stroke motor) is balanced by the less complete intake and exhaust and the shorter effective compression and power strokes. It may be possible for a two stroke to produce more power than an equivalent four stroke, over a narrow range of engine speeds, at the expense of less power at other speeds.

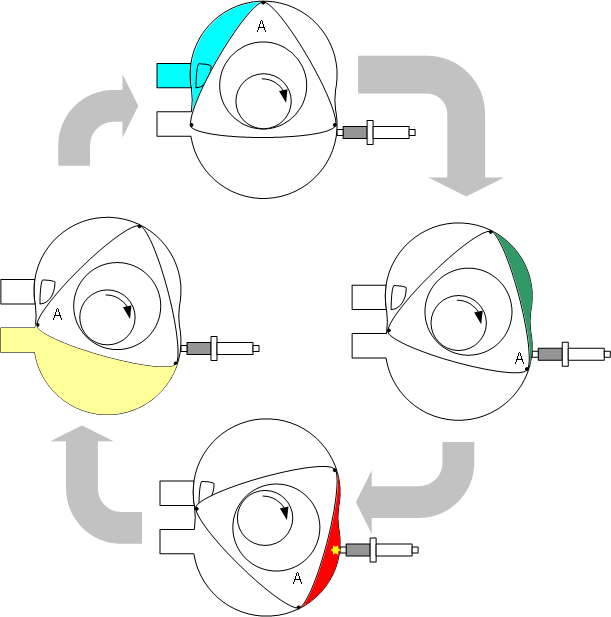
Small displacement, crankcase-scavenged two-stroke engines have been less fuel-efficient than other types of engines when the fuel is mixed with the air prior to scavenging allowing some of it to escape out of the exhaust port. Modern designs (Sarich and Paggio) use air-assisted fuel injection which 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. The initial results have produced motors that are much cleaner burning than their traditional counterparts. Two-stroke engines are widely used in snowmobiles, lawnmowers, string trimmers, chain saws, jet skis, mopeds, outboard motors, and many motorcycles. Two-stroke engines have the advantage of an increased specific power ratio (i.e. power to volume ratio), typically around 1.5 times that of a typical four-stroke engine.

The largest internal combustion engines in the world are two-stroke diesels, used in some locomotives and large ships. They use forced induction (similar to super-charging, or turbocharging) to scavenge the cylinders; an example of this type of motor is the Wartsila-Sulzer turbocharged two-stroke diesel as used in large container ships. It is the most efficient and powerful internal combustion engine in the world with over 50% thermal efficiency.[5][6][7][8][9] For comparison, the most efficient small four-stroke motors are around 43% thermal efficiency (SAE 900648); size is an advantage for efficiency due to the increase in the ratio of volume to surface area.

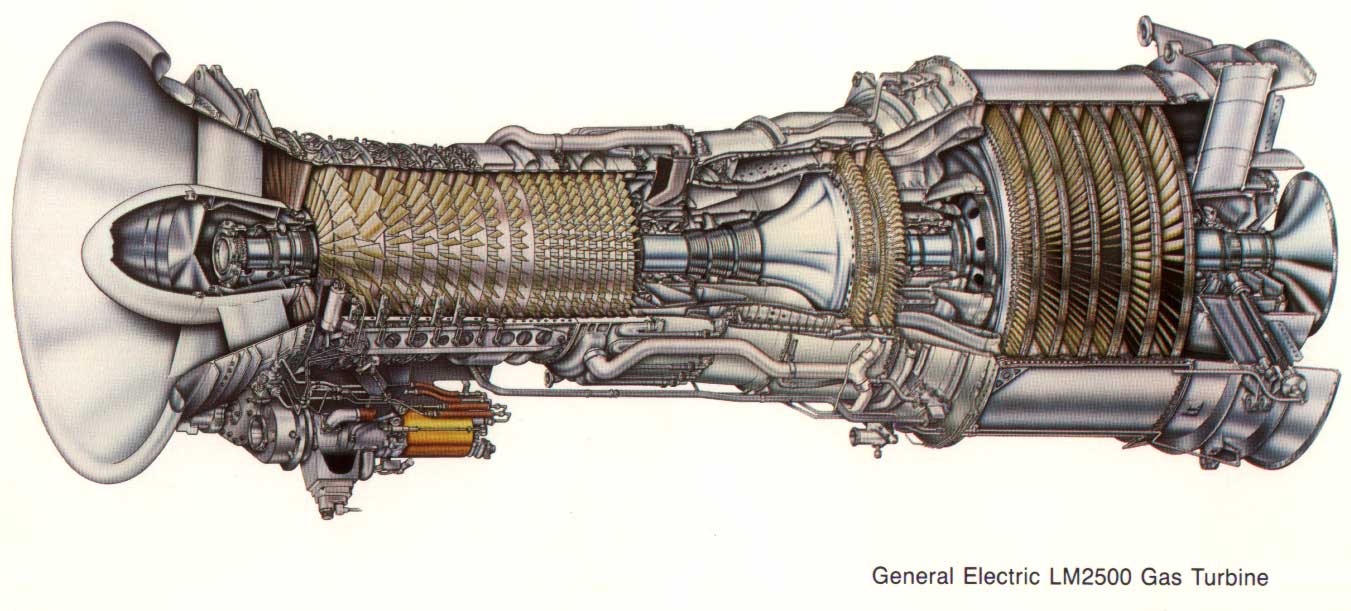
Common cylinder configurations include the straight or inline configuration, the more compact V configuration, and the wider but smoother flat or boxer configuration. Aircraft engines can also adopt a radial configuration which allows more effective cooling. More unusual configurations such as the H, U, X, and W have also been used.

Multiple crankshaft configurations do not necessarily need a cylinder head at all because they can instead have a piston at each end of the cylinder called an opposed piston design. Because here gas in- and outlets are positioned at opposed ends of the cylinder, one can achieve uniflow scavenging, which is, like in the four stroke engine, efficient over a wide range of revolution numbers. Also the thermal efficiency is improved because of lack of cylinder heads. This design was used in the Junkers Jumo 205 diesel aircraft engine, using at either end of a single bank of cylinders with two crankshafts, and most remarkably in the Napier Deltic diesel engines. These used three crankshafts to serve three banks of double-ended cylinders arranged in an equilateral triangle with the crankshafts at the corners. It was also used in single-bank locomotive engines, and continues to be used for marine engines, both for propulsion and for auxiliary generators.

**WANKEL**

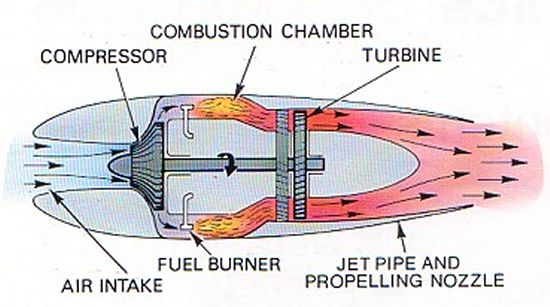
The Wankel engine (rotary engine) does not have piston strokes. It operates with the same separation of phases as the four-stroke engine with the phases taking place in separate locations in the engine. In thermodynamic terms it follows the Otto engine cycle, so may be thought of as a "four-phase" engine. While it is true that three power strokes typically occur per rotor revolution due to the 3:1 revolution ratio of the rotor to the eccentric shaft, only one power stroke per shaft revolution actually occurs; this engine provides three power 'strokes' per revolution per rotor 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.

**GAS TURBINES**

A gas turbine is a rotary machine similar in principle to a steam turbine and it consists of three main components: a compress or, a combustion chamber, and a turbine. The air after being compressed in the compressor is heated by burning fuel in it. About ⅔ of the heated air combined with the products of combustion is expanded in a turbine resulting in work output which is used to drive the compressor. The rest (about ⅓) is available as useful work output.

**JET ENGINE**

Jet engines take a large volume of hot gas from a combustion process (typically a gas turbine, but rocket forms of jet propulsion often use solid or liquid propellants, and ramjet forms also lack the gas turbine) and feed it through a nozzle which accelerates the jet to high speed. As the jet accelerates through the nozzle, this creates thrust and in turn does useful work.



**ENGINE CYCLE**

**TWO-STROKE**

This system manages to pack one power stroke into every two strokes of the piston (up-down). This is achieved by exhausting and re-charging the cylinder simultaneously.

The steps involved here are:

1. Intake and exhaust occur at bottom dead center. Some form of pressure is needed, either crankcase compression or super-charging.
2. Compression stroke: Fuel-air mix compressed and ignited. In case of Diesel: Air compressed, fuel injected and self ignited
3. Power stroke: piston is pushed downwards by the hot exhaust gases.

Two Stroke Spark Ignition (SI) engine:

In a two strokes SI engine a cycle is completed in two stroke of a piston or one complete revolution (360º) of a crankshaft. In this engine the suction stroke and exhaust strokes are eliminated and ports are used instead of valves. Petrol is used in this type of engine.

The major components of a two stroke spark Ignition engine are: Cylinder: It is a cylindrical vessel in which a piston makes an up and down motion. Piston: It is a cylindrical component making an up and down movement in the cylinder. Combustion Chamber: It is the portion above the cylinder in which the combustion of the fuel-air mixture takes place. Inlet and exhaust ports: The inlet port allows the fresh fuel-air mixture to enter the combustion chamber and the exhaust port discharges the products of combustion. Crank shaft: a shaft which converts the reciprocating motion of piston into the rotary motion. Connecting rod: connects the piston with the crankshaft. Cam shaft: The cam shaft controls the opening and closing of inlet and Exhaust valves. Spark plug: located at the cylinder head. It is used to initiate the combustion process.

Working: When the piston moves from bottom dead centre to top dead centre, the fresh air and fuel mixture enters the crank chamber through the valve. The mixture enters due to the pressure difference between the crank chamber and outer atmosphere. At the same time the fuel-air mixture above the piston is compressed.

Ignition with the help of spark plug takes place at the end of stroke. Due to the explosion of the gases, the piston moves downward. When the piston moves downwards the valve closes and the fuel-air mixture inside the crank chamber is compressed. When the piston is at the bottom dead centre, the burnt gases escape from the exhaust port.

At the same time the transfer port is uncovered and the compressed charge from the crank chamber enters into the combustion chamber through transfer port. This fresh charge is deflected upwards by a hump provided on the top of the piston. This fresh charge removes the exhaust gases from the combustion chamber. Again the piston moves from bottom dead centre to top dead centre and the fuel-air mixture gets compressed when the both the Exhaust port and Transfer ports are covered. The cycle is repeated.

**FOUR-STROKE**

Engines based on the four-stroke ("Otto cycle") have one power stroke for every four strokes (up-down-up-down) and employ spark plug ignition. Combustion occurs rapidly, and during combustion the volume varies little ("constant volume").[10] They 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.

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.
4. Exhaust stroke: Exhaust is driven out. During the 1st, 2nd, and 4th stroke the piston is relying on power and the momentum generated by the other pistons. In that case, a four-cylinder engine would be less powerful than a six or eight cylinder engine.

There are a number of variations of these cycles, most notably the Atkinson and Miller cycles. The diesel cycle is somewhat different.

**DIESEL CYCLE**

Most truck and automotive diesel engines use a cycle reminiscent of a four-stroke cycle, but with a compression heating ignition system, rather than needing a separate ignition system. This variation is called the diesel cycle. In the diesel cycle, diesel fuel is injected directly into the cylinder so that combustion occurs at constant pressure, as the piston moves.

**FIVE-STROKE**

The British company ILMOR presented a prototype of 5-Stroke double expansion engine, having two outer cylinders, working as usual, plus a central one, larger in diameter, that performs the double expansion of exhaust gas from the other cylinders, with an increased efficiency in the gas energy use, and an improved SFC. This engine corresponds to a 2003 US patent by Gerhard Schmitz, and was developed apparently also by Honda of Japan for a Quad engine. This engine has a similar precedent in an Spanish 1942 patent (# P0156621 ), by Francisco Jimeno-Cataneo, and a 1975 patent (# P0433850 ) by Carlos Ubierna-Laciana ( www.oepm.es ). The concept of double expansion was developed early in the history of ICE by Otto himself, in 1879, and a Connecticut (USA) based company, EHV, built in 1906 some engines and cars with this principle, that didn't give the expected results.

**SIX-STROKE**

First invented in 1883, the six-stroke engine has seen renewed interest over the last 20 or so years.

Four kinds of six-stroke use a regular piston in a regular cylinder (Griffin six-stroke, Bajulaz six-stroke, Velozeta six-stroke and Crower six-stroke), firing every three crankshaft revolutions. The systems capture the wasted heat of the four-stroke Otto cycle with an injection of air or water.

The Beare Head and "piston charger" engines operate as opposed-piston engines, two pistons in a single cylinder, firing every two revolutions rather more like a regular four-stroke.

**BRAYTON CYCLE**

A gas turbine is a rotary machine somewhat similar in principle to a steam turbine and it consists of three main components: a compressor, a combustion chamber, and a turbine. The air after being compressed in the compressor is heated by burning fuel in it, this heats and expands the air, and this extra energy is tapped by the turbine which in turn powers the compressor closing the cycle and powering the shaft.

Gas turbine cycle engines employ a continuous combustion system where compression, combustion, and expansion occur simultaneously at different places in the engine—giving continuous power. Notably, the combustion takes place at constant pressure, rather than with the Otto cycle, constant volume.

**OBSOLETE**

The very first internal combustion engines did not compress the mixture. The first part of the piston downstroke drew in a fuel-air mixture, then the inlet valve closed and, in the remainder of the down-stroke, the fuel-air mixture fired. The exhaust valve opened for the piston upstroke. These attempts at imitating the principle of a steam engine were very inefficient.

**MEASURES OF ENGINE PERFORMANCE**

Engine types vary greatly in a number of different ways:

* energy efficiency
* fuel/propellant consumption (brake specific fuel consumption for shaft engines, thrust specific fuel consumption for jet engines)
* power to weight ratio
* thrust to weight ratio
* Torque curves (for shaft engines) thrust lapse (jet engines)
* Compression ratio for piston engines, Overall pressure ratio for jet engines and gas turbines

**ENERGY EFFICIENCY**

Once ignited and burnt, the combustion products—hot gases—have more available thermal energy than the original compressed fuel-air mixture (which had higher chemical energy). The available energy is manifested as high temperature and pressure that can be translated into work by the engine. In a reciprocating engine, the high-pressure gases inside the cylinders drive the engine's pistons.

Once the available energy has been removed, the remaining hot gases are vented (often by opening a valve or exposing the exhaust outlet) and this allows the piston to return to its previous position (top dead center, or TDC). The piston can then proceed to the next phase of its cycle, which varies between engines. Any heat that isn't translated into work is normally considered a waste product and is removed from the engine either by an air or liquid cooling system.

Engine efficiency can be discussed in a number of ways but it usually involves a comparison of the total chemical energy in the fuels, and the useful energy extracted from the fuels in the form of kinetic energy. The most fundamental and abstract discussion of engine efficiency is the thermodynamic limit for extracting energy from the fuel defined by a thermodynamic cycle. The most comprehensive is the empirical fuel efficiency of the total engine system for accomplishing a desired task; for example, the miles per gallon accumulated.

Internal combustion engines are primarily heat engines and as such the phenomenon that limits their efficiency is described by thermodynamic cycles. None of these cycles exceed the limit defined by the Carnot cycle which states that the overall efficiency is dictated by the difference between the lower and upper operating temperatures of the engine. A terrestrial engine is usually and fundamentally limited by the upper thermal stability derived from the material used to make up the engine. All metals and alloys eventually melt or decompose and there is significant researching into ceramic materials that can be made with higher thermal stabilities and desirable structural properties. Higher thermal stability allows for greater temperature difference between the lower and upper operating temperatures—thus greater thermodynamic efficiency.

The thermodynamic limits assume that the engine is operating in ideal conditions: a frictionless world, ideal gases, perfect insulators, and operation at infinite time. The real world is substantially more complex and all the complexities reduce the efficiency. In addition, real engines run best at specific loads and rates as described by their power band. For example, a car cruising on a highway is usually operating significantly below its ideal load, because the engine is designed for the higher loads desired for rapid acceleration. The applications of engines are used as contributed drag on the total system reducing overall efficiency, such as wind resistance designs for vehicles. These and many other losses result in an engine's real-world fuel economy that is usually measured in the units of miles per gallon (or fuel consumption in liters per 100 kilometers) for automobiles. The miles in miles per gallon represents a meaningful amount of work and the volume of hydrocarbon implies a standard energy content.

Most steel engines have a thermodynamic limit of 37%. Even when aided with turbochargers and stock efficiency aids, most engines retain an average efficiency of about 18%-20%. Rocket engine efficiencies are better still, up to 70%, because they combust at very high temperatures and pressures and are able to have very high expansion ratios.

There are many inventions concerned with increasing the efficiency of IC engines. In general, practical engines are always compromised by trade-offs between different properties such as efficiency, weight, power, heat, response, exhaust emissions, or noise. Sometimes economy also plays a role in not only the cost of manufacturing the engine itself, but also manufacturing and distributing the fuel. Increasing the engine's efficiency brings better fuel economy but only if the fuel cost per energy content is the same.

**MEASURES OF FUEL/PROPELLANT EFFICIENCY**

For stationary and shaft engines including propeller engines, fuel consumption is measured by calculating the brake specific fuel consumption which measures the mass flow rate of fuel consumption divided by the power produced.

For internal combustion engines in the form of jet engines, the power output varies drastically with airspeed and a less variable measure is used: thrust specific fuel consumption (TSFC), which is the number of pounds of propellant that is needed to generate impulses that measure a pound force-hour. In metric units, the number of grams of propellant needed to generate an impulse that measures one kilonewton-second.

For rockets, TSFC can be used, but typically other equivalent measures are traditionally used, such as specific impulse and effective exhaust velocity.

**AIR AND NOISE POLLUTION**

**AIR POLLUTION**

Internal combustion engines such as reciprocating internal combustion engines produce air pollution emissions, due to incomplete combustion of carbonaceous fuel. The main derivatives of the process are carbon dioxide CO2, water and some soot — also called particulate matter (PM). The effects of inhaling particulate matter have been studied in humans and animals and include asthma, lung cancer, cardiovascular issues, and premature death. There are however some additional products of the combustion process that include nitrogen oxides and sulfur and some uncombusted hydrocarbons, depending on the operating conditions and the fuel-air ratio.

Not all of the fuel will be completely consumed by the combustion process; a small amount of fuel will be present after combustion, some of which can react to form oxygenates, such as formaldehyde or acetaldehyde, or hydrocarbons not initially present in the fuel mixture. The primary causes of this is the need to operate near the stoichiometric ratio for gasoline engines in order to achieve combustion and the resulting "quench" of the flame by the relatively cool cylinder walls, otherwise the fuel would burn more completely in excess air. When running at lower speeds, quenching is commonly observed in diesel (compression ignition) engines that run on natural gas. It reduces the efficiency and increases knocking, sometimes causing the engine to stall. Increasing the amount of air in the engine reduces the amount of the first two pollutants, but tends to encourage the oxygen and nitrogen in the air to combine to produce nitrogen oxides (NOx) that has been demonstrated to be hazardous to both plant and animal health. Further chemicals released are benzene and 1,3-butadiene that are also particularly harmful; and not all of the fuel burns up completely, so carbon monoxide (CO) is also produced.

Carbon fuels contain sulfur and impurities that eventually lead to producing sulfur monoxides (SO) and sulfur dioxide (SO2) in the exhaust which promotes acid rain. One final element in exhaust pollution is ozone (O3). This is not emitted directly but made in the air by the action of sunlight on other pollutants to form "ground level ozone", which, unlike the "ozone layer" in the high atmosphere, is regarded as a bad thing if the levels are too high. Ozone is broken down by nitrogen oxides, so one tends to be lower where the other is higher.

For the pollutants described above (nitrogen oxides, carbon monoxide, sulphur dioxide, and ozone), there are accepted levels that are set by legislation to which no harmful effects are observed — even in sensitive population groups. For the other three: benzene, 1,3-butadiene, and particulates, there is no way of proving they are safe at any level so the experts set standards where the risk to health is, "exceedingly small".

**NOISE POLLUTION**

Significant contributions to noise pollution are made by internal combustion engines. Automobile and truck traffic operating on highways and street systems produce noise, as do aircraft flights due to jet noise, particularly supersonic-capable aircraft. Rocket engines create the most intense noise.

**IDLING**

Internal combustion engines continue to consume fuel and emit pollutants when idling so it is desirable to keep periods of idling to a minimum. Many bus companies now instruct drivers to switch off the engine when the bus is waiting at a terminus. In England, the Road Traffic (Vehicle Emissions) (Fixed Penalty) (England) Regulations 2002 (Statutory Instrument 2002 No. 1808) has introduced the concept of a "stationary idling offence". This means that a driver can be subject to a fixed-penalty fine if he/she leaves a vehicle engine idling while stationary. So far, only a few local authorities have implemented the regulations, one of them being Oxford City Council.

**SEASONAL ENGINE MAINTENANCE**

"Winterizing" is not just for equipment in cold-weather climates. Any equipment that sits idle for long needs the extra attention.

On equipment with plastic fuel tanks (like that above), drain the tanks before storage. Conversely, you should fill metal fuel tanks to prevent them from rusting. In either case, drain the carburetor bowl.

Generally, equipment managers "winterize" equipment to increase or maintain performance in winter or prevent problems after long periods of winter storage. However, this is not only necessary in the winter. Many engines that operate in areas that see no winter at all still need this type of service. Therefore, I like to refer to this as seasonal service, not "winterizing."

Some people perform seasonal maintenance simply because the owner’s manual tells them to, without understanding that good practical reasons exists to perform this maintenance. It helps the engine perform better and last longer. Seasonal maintenance also reduces down time and repair bills. Whenever an engine does not run for an extended time (6 to 8 weeks or more), regardless of climate, you should perform this service.

Step1: Choose a suitable storage site

The storage location you choose for your equipment is important. If you store the engine out of direct sunlight, your results will be far better. Sunlight causes problems because it warms up metal parts, which then cool down when the sun no longer strikes the equipment. This causes water condensation to form. In a semi-sealed area such as a carburetor fuel bowl or a crankcase, this condensation can accumulate. When this happens in cold climates, ice can form in these areas. The result may be broken parts and big repair bills.

However, even in warm climates this is still a problem because water in the fuel system will cause an engine to run roughly or quit. Plus, if you allow water to remain in the fuel bowl for an extended period, it can cause oxides to form on the aluminum parts. These white particles often dislodge and plug vital parts such as the fuel passages. I have even found such severe pitting that I had to replace the entire carburetor because some parts had completely dissolved.

Water in the crankcase can blend with the oil or cling to unprotected metal, causing rust to form on machined parts. Sunlight can also cause plastic and rubber parts-such as hoses and rubber manifolds-to fail from prolonged intense exposure. Good storage sites are cool and dark (shaded). In such sites, the temperature is less likely to vary enough to cause condensation to form.

Step 2: Prepare the fuel system

Cooler temperatures also minimize evaporation of the fuel during storage. Usually a smaller volume of fuel evaporates more quickly than a large volume of fuel. For this reason, I suggest that you drain your carburetor fuel bowls, but keep the fuel tank as full as you can. Another reason to keep the fuel tank full is to keep the unpainted surfaces of the tank coated with fuel. This will keep rust from forming on exposed areas. One last reason to keep fuel tanks full is that air temperature changes more quickly than liquid temperatures. Thus, the temperature swings won’t be as great with a full tank, and you won’t end up with nearly as much condensation.

If your equipment has a plastic fuel tank, don’t think that you are in the clear. The tank may not rust, but you still have to deal with condensation. Therefore, if the size and situation allows, drain the plastic tank as well as the carburetor. Then you should not have any metal parts that will rust.

This is a good place for a word of caution about two-stroke engines that use a diaphragm-type carburetor. If you drain the fuel from these engines, you may cause diaphragms to crack or harden. In this case, I feel it’s wise to keep the fuel tank full and to use a chemical fuel additive designed for storage. In addition, these small carburetors are especially susceptible to varnish formation. This is another reason to use chemical fuel additives instead of draining the system.

Step 3: Repairing any fuel-system problems after storage

If you stored your equipment properly, you will probably have few repairs to make when you bring it back into service. However, if you neglected to prepare your equipment properly for storage, you may need to perform some repairs.

* Four-stroke engines. With four-stroke engines, the storage damage you are most likely to experience is gummy carburetors or dirt. The dirt is usually a result of the varnish (the residue left behind after fuel has evaporated) remaining in the fuel bowls. If you catch it early enough, it may be soft and gummy. However, if you leave it for an extended time, it turns to hard crystals. These crystals can dislodge and float around in the fuel bowl when you add new fuel. They then can plug the small orifices that control the fuel flow to the motor.
* To remove varnish in the early stages is easy. Simply spray some choke-and-carburetor cleaner in the problem areas, and it will rinse away. Another trick is to use compressed air for the problem areas and tight passages. The problem becomes more difficult the longer you leave it unattended. If the varnish is hard, you first must use dip-type carburetor cleaner. You usually can find this type of cleaner at automotive-supply stores.
* Dip-type cleaner is highly caustic, so be careful in how you handle this material. Read the label for soak times and proper clean up. Most carburetor part dips can dissolve small rubber parts, so you must completely dismantle the entire carburetor and remove all rubber pieces before using the dip. Take the carburetor completely apart so the chemical can reach all parts and passages. In many cases, it may be necessary to soak the carburetor two, three or more times.
* Be sure to follow the label’s time schedule for keeping the carburetor in the solvent because it can destroy the metal parts if you leave them in the dip for too long. If the dip needs additional time to remove deposits completely, remove and clean the parts and then repeat the process rather than exceed the recommended time limits in a single dip. I have seen some cases where aluminum parts were pitted so badly from excessive dip times that they required replacement.
* If you find that your problem areas are in the small air bleeds and vents, use a small parts-tag wire or a torch tip cleaner. However, use caution with this method because it is easy to enlarge the holes if you are too forceful.
* Two-stroke engines. You can use many of the same methods for two-stroke engines. However, be aware that you may find more rubber parts and diaphragms that the solvents can damage. Fortunately, the oil/gas mixture in two-stroke engines helps keep the varnish in a softer, gummier stage for a longer time.

Step 4: Clean and repair fuel tanks if needed

You can clean fuel tanks in much the same way as carburetors-you just don’t have as many parts with which to deal. The first step in cleaning a fuel tank is to drain it to see what kind of problem you may have.

If the problem is rust, pour a small pack of BBs in the tank with some parts-washing solution and shake it vigorously. This loosens the large, scaly pieces of rust. After you have shaken them around, pour the BBs into a paint strainer (to save them for use later). Now flush the tank several times with clean parts-washing solvent to remove any remaining loose debris.

If you caught the problem early, you might not have to do anything more than this. However, if you find pitting or small holes in the tank, you will need to seal the inside of the tank with a liquid seal made specifically for gas tanks. Avoid other types of sealers because the fuel might dissolve them, causing more problems farther downstream (in the carburetor).

Just because you have a plastic fuel tank on your equipment, you are not out of danger. Dried fuel can still cause a varnish-type material to form in the tank, and it can plug the fuel system just as badly as rust. Fortunately, the BB method works as well in plastic tanks as it does in steel tanks. Although plastic tanks are not maintenance-free, they still are more trouble-free than steel tanks. Thus, if you have to buy a replacement, select a plastic tank if it’s available for your equipment.

If you use fuel additives, be sure they are compatible with your fuel system. Keep in mind that manufacturers usually market these additives for automobiles. Therefore, the containers often are scaled for a 15- to 20-gallon fuel tank, not a 2- to 5-gallon tank. Read the label to see if it provides specific instructions regarding how much to add. If not, be sure to proportionally reduce the amount you add to account for the smaller tank size.

Step 5: Maintaining fuel- and oil-injection systems

If an oil-injection system (most smaller engines such as trimmers and saws do not use oil injection) requires repair, it’s usually because of dirt that got into the system, not because of some problem with the oil itself. Cleaning oil systems is simple: just disassemble them, wash the parts and reassemble. Oil is quite stable and has a long shelf life. Therefore, storage doesn’t usually affect its quality. The best advice I can give you is to stay with a known brand of oil instead of a generic type.

Conversely, fuel-injection systems are prone to some long-term storage problems. One of the most common is gumming from varnish buildup. This will cause injector units to malfunction. No really good way exists to drain an injector unit completely, so the best prevention is to use chemical fuel additives for storage instead of trying to drain the system.

If an injector still works but you don’t feel it is running quite right, you can try additives for injection systems that you pour directly into the gas tank. As the fuel passes through the system, it will clean light deposits from injectors. Other than this, the only way to repair an injector is to replace it with a new one, so heavier deposits may require you to replace the injectors.

If you have to change an injector, be sure to wait until all of the engine parts (especially mufflers and manifolds) are completely cool. Moreover, be sure to clean up any spills that happened during the repair. Remember to change all the fuel filters as well as the injectors. This will prevent any fuel contamination from entering your new injectors.

A few final notes about fuel:

* Although it is possible that dirt or water in your fuel system came from your fuel supplier, don’t overlook your own storage containers.
* All fuel systems benefit from in-line fuel filters, but make sure the ones you use are suitable for your system-fuel-injection systems use high pressure or volume and can tear a conventional filter apart.
* Reformulated gasoline usually contains alcohol, which has a natural tendency to draw moisture from the air around it. If you are in a region where reformulated gasoline is used, be aware that storing your equipment with this type of fuel in an environment with high humidity can cause a buildup of water in the gas just by letting it sit around. Don’t forget that this can happen with gas cans too, not just fuel tanks.

Step 6: Consider seasonal service for cooling systems

Up until now, this discussion has applied to air-cooled as well as liquid-cooled engines. However, the cooling system itself also needs attention-every year on your liquid-cooled machines. Most equipment today is either all aluminum or at least has aluminum heads and radiators. Thus, it is important to use only coolants that are compatible with aluminum systems. Fortunately, most coolants are suitable. The problem usually shows up with fleet accounts that buy coolant in 55-gallon drums. Occasionally, an equipment manager will purchase bulk coolant that is suitable only for steel protection and then, forgetting this fact, use the coolant that’s on hand for all the engines.

Aluminum radiators transfer heat efficiently until they begin to plug with mineral and dirt buildup. Thus, you should change the coolant at least once a season. Use distilled water when blending the 50/50 mix to prevent mineral buildup in the cooling system. At the same time, also check all hoses for cracks and soft spots that could cause costly downtime the following season. In addition, inspect the belts for cracks or other damage and check the operator’s log for any reported cases of overheating. If so, now would be a good time-while the system is drained and flushed-to replace head gaskets and thermostats. These are the two most common causes for overheating.

Finally, always check the coolant level and, in cold climates, check the level of freeze protection your coolant offers. Testing laboratories can evaluate coolants and give an indication of system wear and other problems before they get out of hand. This type of testing is called "cool scan."

Step 7: Don’t forget the rest of the equipment

Finally, remember that the engine is only part of the equipment. Gearboxes and drive trains also have special needs for seasonal storage. These components are often sealed and forgotten?until they fail. When they do, they can be as costly to repair and cause as much downtime as any engine.

When you shop, look for features such as plastic tanks and the quality of the fuel and cooling systems. These are often-overlooked aspects, but making the right choices could save you a lot of maintenance expense down the road.

**SEASONAL MAINTENANCE TIPS**

For proper long-term storage:

* Choose a shaded, cool storage site
* Keep metal fuel tanks full, but drain plastic fuel tanks
* For 4-stroke engines, drain the carburetor bowls
* For 2-stroke engines and those with fuel injection, use chemical additives (fuel stabilizers) instead of draining the carburetor
* Be especially wary of storing reformulated gasoline, which can absorb water directly from a humid atmosphere.

To repair rusted or varnished fuel tanks:

* Shake BBs and parts cleaner in the tank to remove debris
* Use a fuel-tank sealer to repair any pitting on the inside of the fuel tank
* If you need to replace a tank, use a plastic replacement.
* To remove varnish deposits:
* Use "choke-and-carburetor cleaner" to remove light varnish deposits in carburetors
* For heavy deposits, dismantle carburetor and clean with dip-type carburetor cleaner
* For small air bleeds and vents, use a tip cleaner or small wire to clear the orifice.

For fuel-injection systems:

* Use "fuel-injection cleaner" (fuel additive) for light varnish deposits in the injectors
* Replace injectors with heavy varnish deposits
* Be sure you also replace fuel filters when you service the injectors.
* For good cooling-system performance:
* Use only distilled water for your coolant/water radiator mix
* Make sure the coolant is aluminum-compatible
* Have your coolant tested for freeze protection.