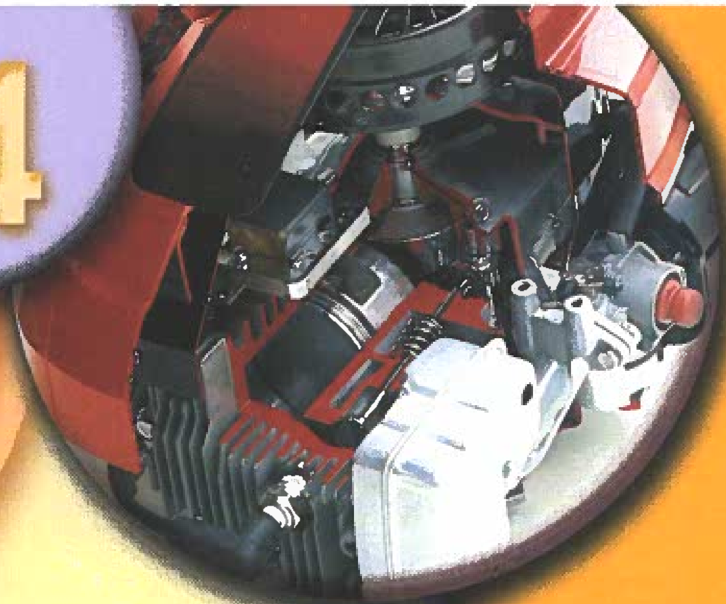
14

Small Gas Engines



Basic Concepts

- Identify the differences between internal and external combustion engines.
- Recognize the basic process by which two-stroke engines and four-stroke gasoline engines operate.
- Select the correct tool for a specific application.
- Accurately read a micrometer.

Intermediate Concepts

- Describe the operating procedures of at least five subsystems of the small gas engine.
- Discuss helpful hints for successfully disassembling and reassembling complex machinery, such as small gas engines.

Advanced Concepts

- Troubleshoot and diagnose six common causes of engine malfunctions.
- Perform live adjustments and take measurements from a running engine.
- Use repair manuals to locate specifications, such as torque ratings, clearances, torque patterns, and replacement part codes.

A little more than 100 years ago, internal combustion engines began to replace ***external combustion engines*** (steam engines) as the major source of power for vehicles and many other applications requiring mechanical power production. ***Internal combustion engines*** produce heat inside the cylinder containing the piston. They are more efficient and reliable than external combustion engines, which generate heat in a boiler or other device outside the cylinder. The ***cylinder***, more correctly identified as the *cylinder bore*, is a hole in the block of the engine that directs the piston during movement. See **Figure 14-1.** Internal combustion engines also produce much more power for a comparably sized unit. Today,

External combustion engine: The steam engine used a little over 100 years ago as the major source of power for vehicles and many other applications requiring mechanical power production.

Internal combustion engine: An engine that produces heat inside the cylinder containing the piston.

Cylinder: A hole in the block of an engine that directs the piston during movement.

Figure 14-1. An external combustion engine, such as this old steam tractor, generates heat outside the cylinder. Steam from the boiler (at the front, under the smokestack) is piped to the engine cylinder, where it expands to drive the piston in the power stroke. (Howard Bud Smith)

internal combustion engines power the majority of transportation vehicles in the United States. They also are used extensively for power in the construction and agricultural industries and are even employed to generate limited amounts of electricity.

Technology Link

Agriculture: Farming Equipment

Agricultural technology relies on energy and power to produce crops and raise livestock. Various applications of energy and power technology are essential to the farming industry. Many types of farming equipment require mechanical power, hydraulics, and electricity in order to operate.

Until about the mid-1920s, small gas engines were used in tractors and other farm equipment more than any other types of engines. By the 1930s, however, the shift toward diesel engines started to occur. Diesel fuel is more efficient than gasoline for these applications, so it is the more cost-effective choice. These days, farm equipment uses both types of engines, though diesel engines are still more common.

The main use of engines in the agriculture industry is to power equipment, such as tractors and combines. These machines play a large part in efficiently planting, cultivating, and harvesting crops, as well as tending to livestock. Engines are vital to transporting the products to market once the products have been harvested and prepared for sale. Gas and diesel engines power the trucks, river barges, and railroad cars that ship the goods from the farm to the end users. Engines are also used in farming to pump water for irrigation. The farming industry would not be nearly as efficient or profitable without energy and power technology.

Engine Theory

There are two main types of small gas engines, the four-stroke cycle engine and the two-stroke cycle engine. The two types perform the same function—converting chemical energy to mechanical power—and have many common mechanical elements. They differ considerably, however, in their methods of operation.

The Four-Stroke Cycle Engine

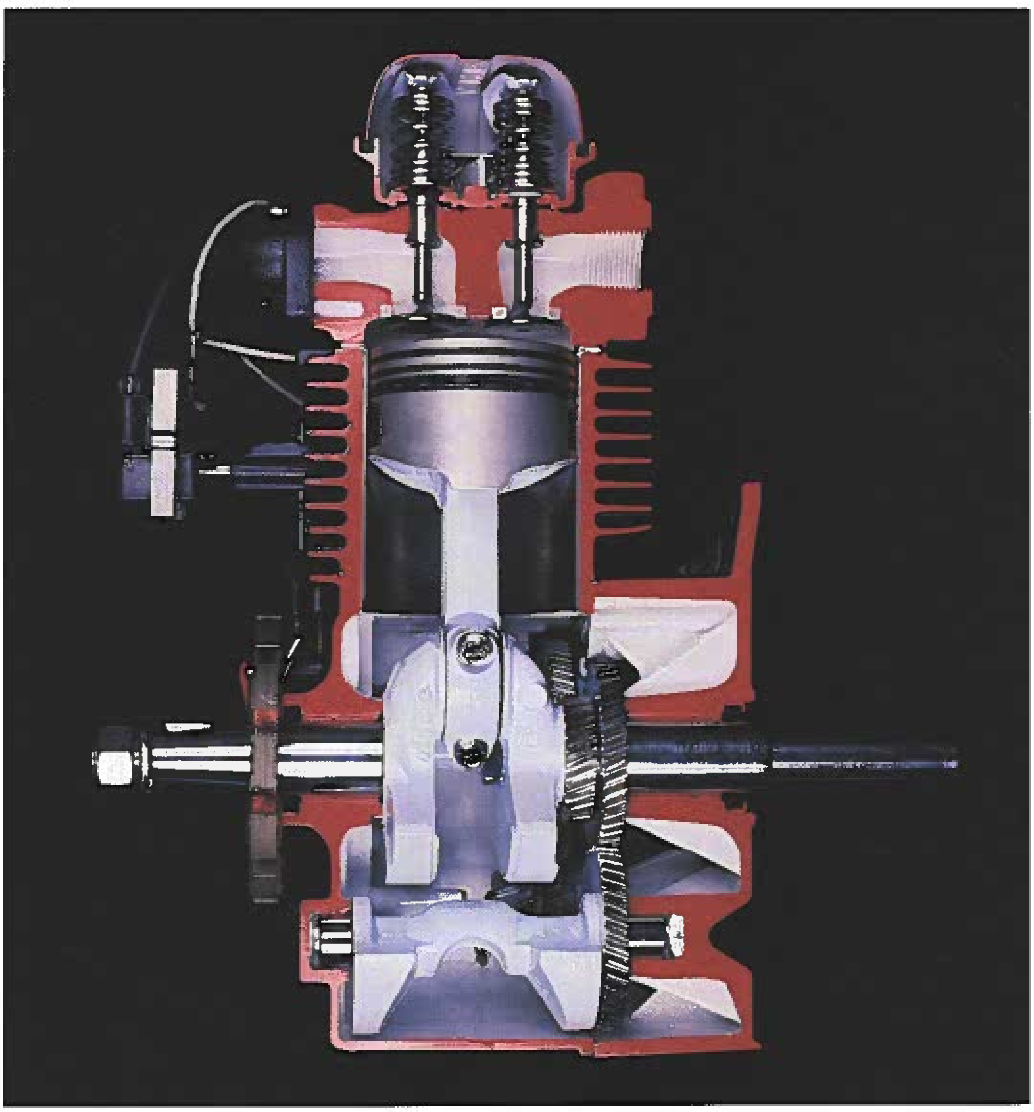
Automobiles use ***four-stroke cycle engines*** as their power source. The automobile engine has 4, 6, 8, or 12 cylinders, which are all coupled to one crankshaft. The ***crankshaft*** is an engine component that converts the reciprocating motion of the piston and rod assembly into rotary motion. It is also the shaft that powers the load. Most small gas engines have only one cylinder powering the crankshaft. See **Figure 14-2.** The ***piston*** is a cylindrical engine component that slides back and forth in the cylinder

Four-stroke cycle engine: An engine that requires four movements of the piston in its cylinder to complete a full cycle.

Crankshaft: An engine component that converts the reciprocating motion of the piston and rod assembly into rotary motion.

Piston: A cylindrical engine component that slides back and forth in the cylinder when propelled by the force of combustion.

Figure 14-2. In most small gas engines, a single piston is connected to the crankshaft.



Stroke: The movement of the piston from the bottom limit to the top limit (or vice versa).

Intake stroke: The downward stroke of the piston that begins the process of producing power.

Atomized: Broken into small droplets.

Fuel-air charge: Small droplets of liquid fuel and air.

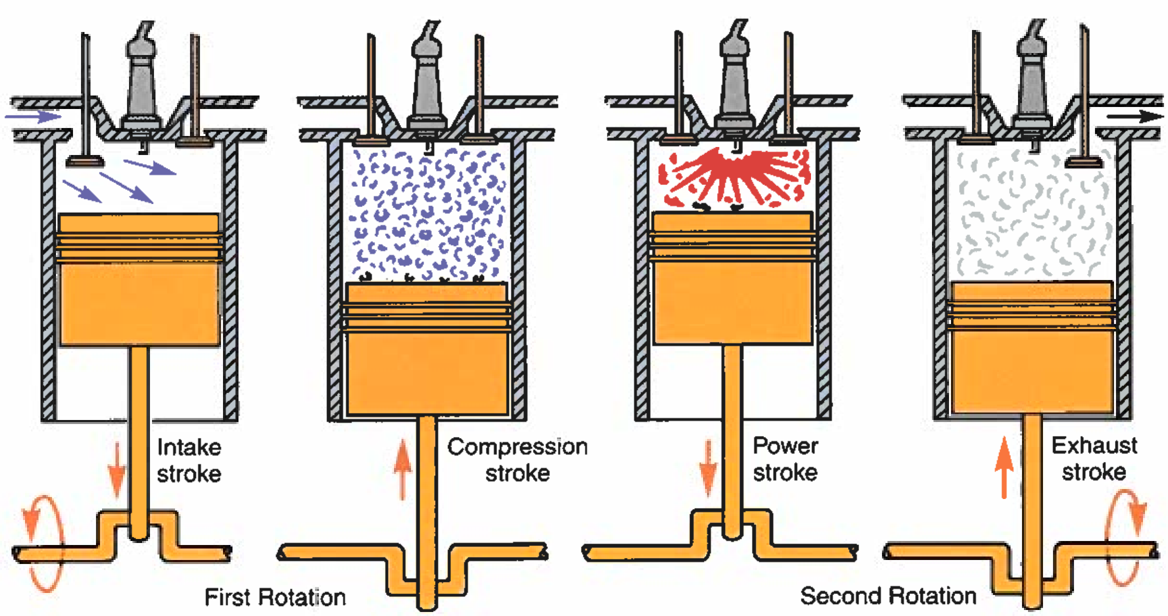
Compression stroke: An upward movement of the piston and connecting rod assembly.

Connecting rod: An engine component that connects the piston with the crankshaft.

when propelled by the force of combustion. A four-stroke cycle engine requires four movements (strokes) of the piston in its cylinder to complete a full cycle. A ***stroke*** is the movement of the piston from the bottom limit of its travel to the top limit (or vice versa). See **Figure 14-3.** The four-stroke cycle engine's strokes are the following:

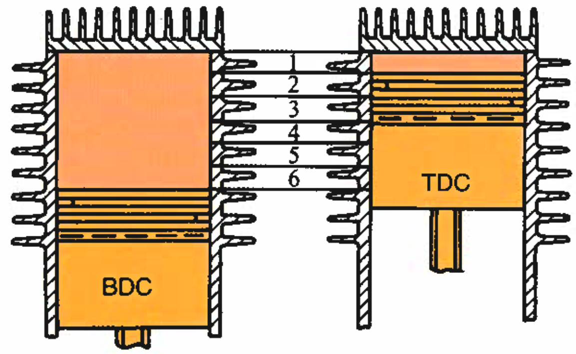
- ***Intake stroke.*** This is the downward stroke of the piston that begins the process of producing power. This movement creates a partial vacuum. The force of this vacuum draws air through the carburetor. Liquid fuel is drawn into the carburetor at the same time and is ***atomized*** (broken into small droplets) to mix with the air. This mixture is called the ***fuel-air charge***. It flows into the cylinder through the intake valve.
- ***Compression stroke.*** This is an upward movement of the piston and connecting rod assembly. The ***connecting rod*** is an engine component that connects the piston with the crankshaft. The fuel-air charge is typically squeezed to about one-ninth of its original volume. When the piston is as low in the cylinder as it can go, it is said to be at ***bottom dead center (BDC)***. When the piston is as high in the cylinder as it can go, it is said to be at ***top dead center (TDC)***. The ***compression ratio*** of an engine is the mathematical relationship between the volume available in the cylinder with the piston at BDC and the volume available in the cylinder with the piston at TDC. See **Figure 14-4.**
- ***Power stroke.*** This is the stroke in which power (mechanical movement) is transferred from the piston to the connecting rod and then to the crankshaft. As the piston approaches TDC on the compression stroke, the ***spark plug*** fires. It takes a fraction of a second for the gases in the ***combustion chamber*** to ignite and expand. This allows the piston to move past TDC, so the expanding gases will push down on the piston with tremendous force.

Figure 14-3. Sequence of events in a four-stroke cycle engine. This type of engine requires two revolutions of the crankshaft and provides one power stroke out of every four strokes.



- ***Exhaust stroke.*** This is the final movement in the four-cycle process—an upward stroke of the piston. The ***camshaft*** holds the exhaust valve open. Movement of the piston forces the spent fuel-air mixture out through the exhaust valve. As the piston clears TDC, the camshaft causes the exhaust valve to close and the intake valve to open. A new fuel-air charge is drawn into the cylinder, beginning the four-stroke cycle again.

Figure 14-4. The compression ratio is determined by comparing the volume of the cylinder with the piston at bottom dead center (BDC), which in this example, is 6 in^3, to the volume when the piston is at top dead center (TDC), which in this example, is 1 in^3. This is a compression ratio of 6 to 1, usually written in the form 6:1. (Briggs and Stratton Corporation)



The Two-Stroke Cycle Engine

All the functions that take place in a four-stroke cycle engine—intake, compression, power, and exhaust—also must happen in a two-stroke cycle engine. In a ***two-stroke cycle engine***, however, every upward stroke is a compression stroke, and every downward stroke is a power stroke. Intake and exhaust occur during the compression and power strokes. See **Figure 14-5.** This means it takes only one revolution of the crankshaft to produce a power stroke, instead of the two revolutions required by the four-stroke cycle engine.

The two-stroke design has both advantages and disadvantages when compared to the four-stroke design. See **Figure 14-6.** One advantage of the two-stroke design is that a power stroke occurs on every downward movement of the piston (as opposed to every other). This makes the two-stroke cycle engine very powerful for its size. It is also very good at applications with a high number of revolutions per minute (rpm). The two-stroke cycle engine has a design simpler than that of the four-stroke cycle engine, since it does not require a camshaft and valve train assembly.

Intake and exhaust are accomplished through the placement of ports along the cylinder. Since it has fewer parts, a two-stroke cycle engine is much lighter than a four-stroke cycle engine of comparable power. Because the two-stroke design does not require an oil reservoir, there is a further savings in weight. Oil is mixed with the fuel in this type of engine and burned in the combustion chamber. Since the combustion chamber is sealed tightly and there is no oil reservoir, the two-stroke cycle engine can be operated at any angle. This makes it ideal for string trimmers, chain saws, leaf blowers, and similar applications.

The two-stroke cycle design has some disadvantages as well. Since the lubricant is burned with the fuel, the exhaust of a two-stroke cycle engine is dirtier than that of a four-stroke cycle engine. The fact that every other stroke is a power stroke means that two-stroke cycle engines wear more rapidly than four-stroke cycle engines. It is unrealistic to expect a two-stroke cycle engine to last as long as a four-stroke cycle engine of similar power. Mixing the oil with the fuel is inconvenient, but forgetting to add the oil will result in major engine damage. On some larger two-stroke cycle engines, such as those used on snowmobiles, boats, and dirt bikes,

Bottom dead center (BDC): As low in the cylinder as the piston can go.

Top dead center (TDC): As high in the cylinder as the piston can go.

Compression ratio: The mathematical relationship between the volume available in the cylinder with the piston at bottom dead center (BDC) and the volume available in the cylinder with the piston at top dead center (TDC).

Power stroke: The stroke in which mechanical movement is transferred from the piston to the connecting rod and then to the crankshaft.

Spark plug: A part that fits into the cylinder head of an internal combustion engine and carries two electrodes separated by an air gap across which the current from the ignition system discharges to form the spark for combustion.

Combustion chamber: An enclosed space in which burning takes place.

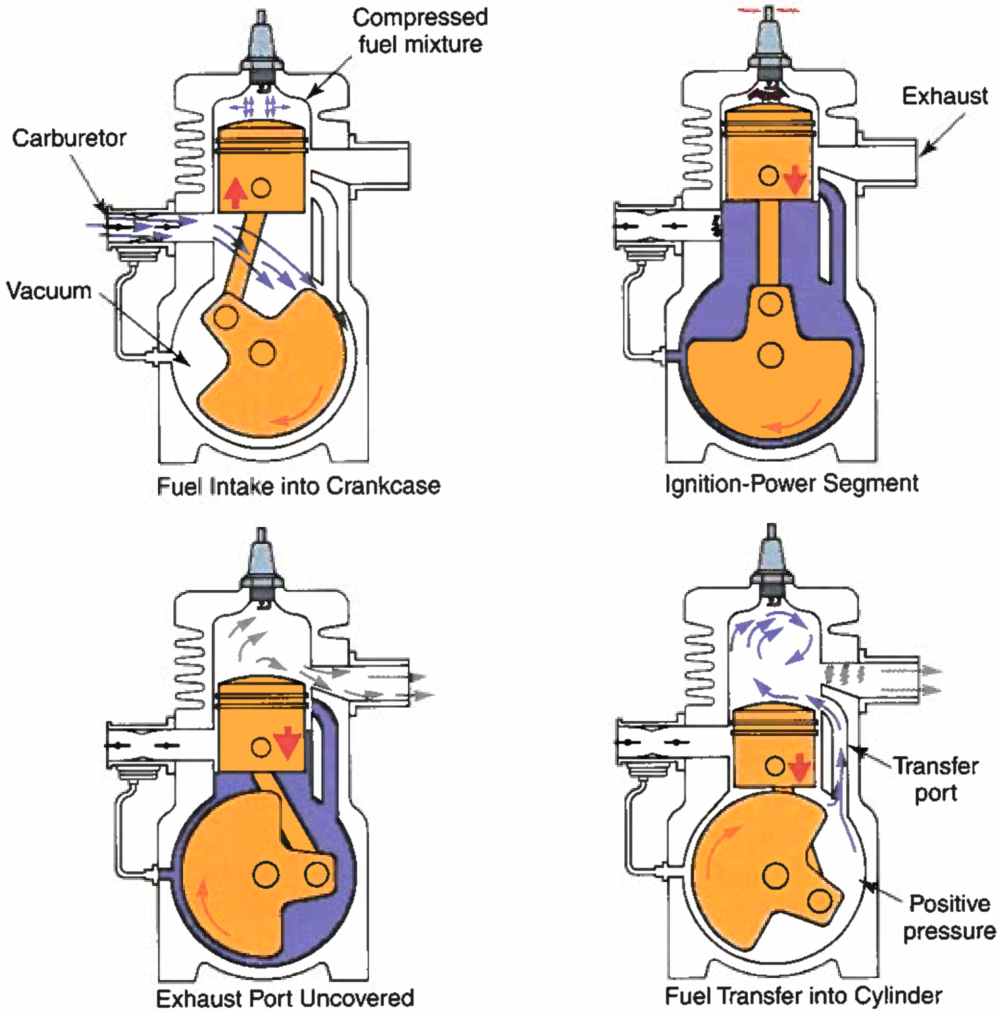
Exhaust stroke: The final movement in the four-cycle process—an upward stroke of the piston.

Camshaft: A shaft to which a cam is fastened.

Two-stroke cycle engine: An engine in which every upward stroke is a compression stroke and every downward stroke is a power stroke.

GREEN TECH
Because two-stroke cycle engines require oil and fuel to be mixed together, there is more pollution from the exhaust than there is in four-stroke cycle engines.

Figure 14-5. The sequence of events in a two-stroke cycle engine. Compression and intake occur simultaneously, and then ignition occurs. Exhaust precedes the transfer of fuel during the lower portion of the power stroke. The piston functions as a valve, opening and closing the intake and exhaust ports as it moves up and down in the cylinder. (Rupp Industries, Inc.)



oil injector pumps have been added to mix the lubricant with the gasoline. The pump reservoir can hold enough oil to provide an adequate mix for several tanks of gasoline, making these types of two-stroke cycle engines somewhat more convenient.

Engine Subsystems

An internal combustion engine is a complex machine because it has multiple subsystems, all of which must perform properly for the engine to run at peak performance. These subsystems include the cooling subsystem, the lubrication subsystem, the mechanical subsystem, the electrical subsystem, the governing subsystem, and the fuel subsystem. They are described in the following sections, along with some information critical to diagnosis of problems with each particular subsystem.

Figure 14-6. Differences between two-stroke cycle and four-stroke cycle engines.

Characteristics	Four-Cycle Engine (Equal hp) One Cylinder	Two-Cycle Engine (Equal hp) One Cylinder
Number of major moving parts	Nine	Three
Power strokes	One every two revolutions of crankshaft	One every revolution of crankshaft
Running temperature	Cooler running	Hotter running
Overall engine size	Larger	Smaller
Engine weight	Heavier construction	Lighter in weight
Bore size equal hp	Larger	Smaller
Fuel and oil	No mixture required	Must be premixed
Fuel consumption	Fewer gallons per hour	More gallons per hour
Oil consumption	Oil recirculates and stays in engine	Oil is burned with fuel
Sound	Generally quiet	Louder in operation
Operation	Smoother	More erratic
Acceleration	Slower	Very quick
General maintenance	Greater	Less
Initial cost	Greater	Less
Versatility of operation	Limited slope operation (receives less lubrication when tilted)	Lubrication not affected at any angle of operation
General operating efficiency (hp/wt. ratio)	Less efficient	More efficient
Pull starting	Two crankshaft rotations required to produce one ignition phase	One revolution produces an ignition phase
Flywheel	Requires heavier flywheel to carry engine through three nonpower strokes	Lighter flywheel

The Cooling Subsystem

The *cooling subsystem* of the engine is responsible for keeping the engine operating within a comfortable temperature range. Engines are cooled by air or liquid. Most small gas engines are air cooled.

The primary parts of an air-cooled system are the cooling fins on the head and block of the engine, the blades on the flywheel, and various sheet metal parts that enclose the engine. The *flywheel* blades create a flow of air that cools the engine. The sheet metal shrouds channel the airflow across the hottest parts of the engine, which are the cooling fins surrounding the combustion chamber. The *cooling fins* conduct heat from the combustion chamber and transfer it to the surrounding atmosphere. See **Figure 14-7.** It is important that all sheet metal shrouds are in place, so the airflow produced by the rotating flywheel is channeled to the proper areas of the engine. See **Figure 14-8.**

Some larger engines may use a liquid cooling system that includes a water pump, radiator, and thermostat. Since water is much denser than air, it can absorb and dissipate much more heat from an engine. In this type of system, a water and antifreeze solution is pumped through

Cooling subsystem: The system responsible for keeping the engine operating within a comfortable temperature range.

Flywheel: A heavy wheel for opposing and moderating any fluctuation of speed in the machinery with which it revolves.

Cooling fin: A projecting rib on an engine cylinder that moderates heat.

Figure 14-7. The cooling system on a small gas engine. The vanes on the flywheel generate air movement, which is directed upward by a sheet-metal shroud (removed in this photo to show the flywheel). The air stream moves over the cooling fins on the cylinder to carry away heat. It is important to keep the cooling fins on the engine clean of debris so they can function efficiently.

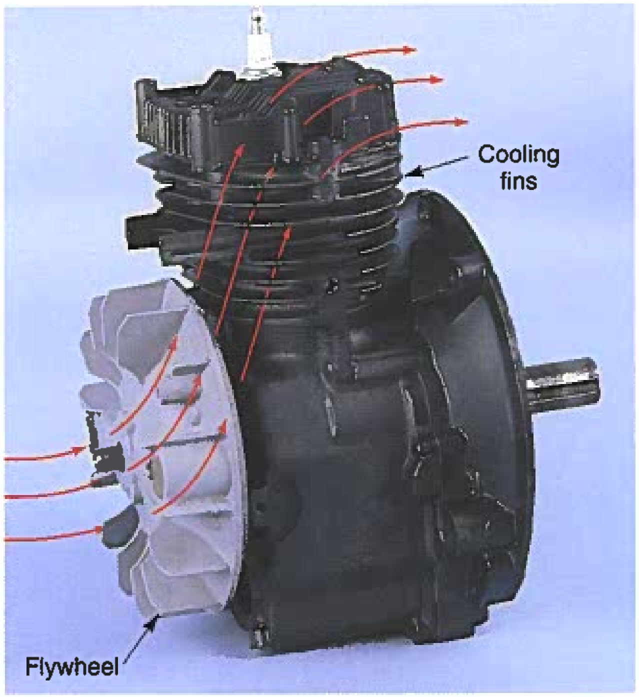


Figure 14-8. A shroud is fitted over the flywheel to direct air movement over the cooling fins. The air intake screen should be cleaned regularly to provide an unrestricted flow of air. (Honda)

Water jacket: A space machined into the block of an engine.

Thermostat: A temperature-controlled flow valve.

Radiator: A heat exchanger that transfers the heat from a liquid to the surrounding environment.

water jackets, or spaces machined into the block of the engine, surrounding each cylinder. When the liquid heats up, a ***thermostat*** (a temperature-controlled flow valve) opens, allowing the liquid to flow to the radiator. The ***radiator*** is a heat exchanger that transfers the heat from the liquid to the surrounding environment. The cooled water is pumped back to the engine block to absorb more heat from the engine and transfer it to the radiator.

The Lubrication Subsystem

The ***lubrication subsystem*** of a small gas engine includes the oil distribution mechanism, the oil seals, the piston rings, and the lubricating oil itself. See **Figure 14-9.** There are several ways to distribute oil to the working parts of an engine. Some distribution mechanisms work better for smaller engines, however, and others work better for larger engines. See **Figure 14-10.**

It is important that all moving parts within the engine are lubricated. The splash lubrication method is usually acceptable for a small gas engine. This splash is created by an ***oil dipper*** attached to the bottom of the connecting rod. As the connecting rod moves up and down during the four-cycle process, the dipper drops down into the reservoir in the bottom of the crankcase. As it rises up out of the oil reservoir, it splashes oil onto the moving parts of the engine that must be lubricated whenever the engine is running. If a dipper has been replaced, it is vital to properly torque the connecting rod bolts. Undertorquing the bolts could cause the dipper and connecting rod cap to become loose, leading to catastrophic engine failure.

Lubrication of the cylinder wall is necessary. The ***engine rings*** serve to limit the amount of oil that makes its way into the combustion chamber. Too much oil entering the combustion chamber creates excessive emissions, usually in the form of thick smoke, and it also can foul spark plugs, causing the engine to stop running all together. The oil ring is the bottom ring on the piston. It is designed to allow a small amount of oil to make its way through the holes in the ring, through the matching holes in the piston, and out onto the cylinder wall. The bottom compression ring

Figure 14-9. A thin film of oil provides for almost friction-free movement between closely fitted metal parts, such as the crankshaft journal and connecting rod assembly. This reduces wear on the parts.

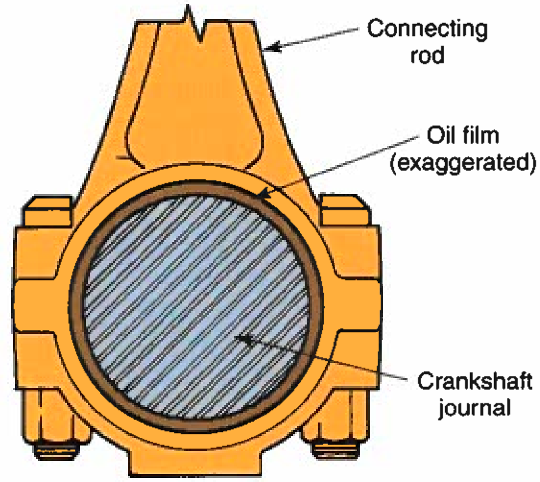
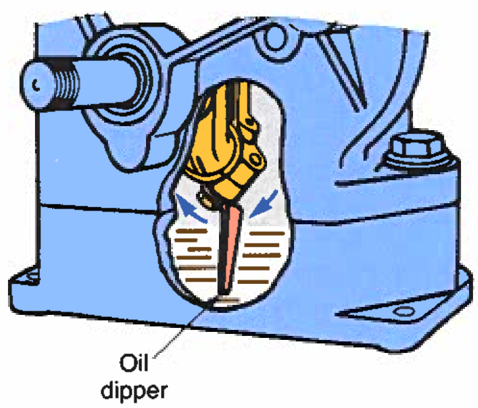
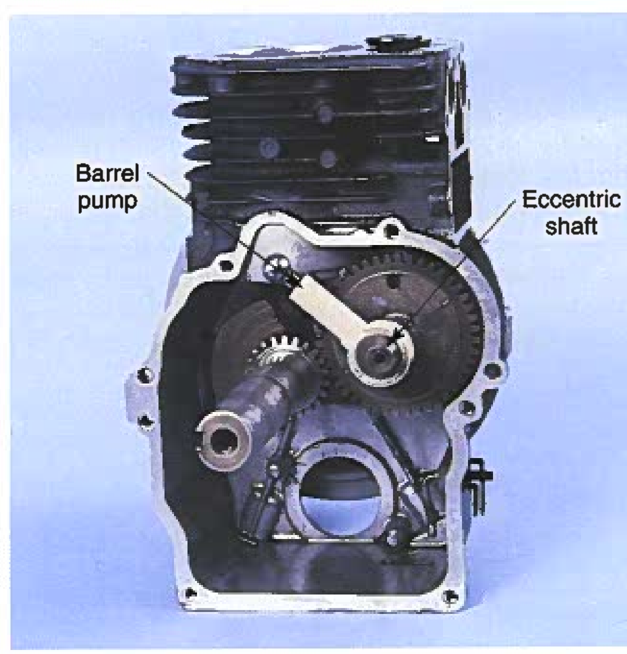


Figure 14-10. Oil distribution mechanisms. A—An oil dipper that attaches to the connecting rod cap is common for many small gas engines. The dipper simply splashes the moving parts of the engine with oil when the engine is running. An oil slinger works in a similar fashion, but it is often driven by the cam gear. The slinger has a series of paddles to move more oil and is often found on higher-horsepower (hp) small gas engines. (Briggs and Stratton Corporation) B—An oil pump can be used to force the lubricant to distant places. Oil pumps are frequently used on larger engines, where the moving parts are not in close proximity to the oil reservoir. Some small gas engines, however, make use of a piston-style pump to provide oil distribution.

A



B



usually has a groove or a bevel to scrape excess oil off the cylinder wall and send it back down into the block where it is stored. Oil seals serve a similar function on the valve stems.

Lubrication maintenance on small gas engines includes the following:

- Changing the oil at regular intervals.
- Wiping debris and sludge from the bottom of the oil reservoir every few oil changes, since most small gas engines do not contain oil filters.
- Ensuring that rings and seals are installed correctly during engine reassembly.
- Inspecting seals for wear.

It is important to recognize all the functions an engine lubricant performs. In addition to lubricating the engine's working parts, oil also serves to do the following:

- Protect the internal engine parts from corrosion.
- Cleanse the engine of foreign matter by transferring it to the engine block, where the foreign matter settles to the bottom of the oil reservoir and can do little harm.
- Seal the engine by filling the small space between moving parts, such as the piston rings, and the cylinder wall.
- Cushion moving engine parts from the tremendous force of the power stroke on combustion.
- Improve fuel economy.

Oil selection is critical to the performance of an engine. The viscosity of an oil is a measure of its resistance to flow. The viscosity ratings for engine oils were established by the ***Society of Automotive Engineers (SAE)***, but they vary significantly from manufacturer to manufacturer. See **Figure 14-11.** Oils labeled with a winter rating, such as 10W-40, are known as ***multigrade***, multiweight, or multiviscosity oils.

Lubrication subsystem: The oil distribution mechanism, the oil seals, the piston rings, and the lubricating oil itself.

Oil dipper: A device that splashes the moving parts of the engine with oil when the engine is running.

Engine ring: A circular band for sealing and limiting the amount of oil that makes its way into the combustion chamber.

Society of Automotive Engineers (SAE): An organized group of individuals working together because of common training in the branch of engineering relating to self-propelled vehicles.

Figure 14-11. A comparison of viscosity grade recommendations by five major engine manufacturers. These recommendations do not cover all model engines by any particular manufacturer. Note that the *W* stands for a "winter" rating. Oils labeled with a winter rating are blended to operate under the varying temperature conditions that occur during summer and winter in many locations.

<table>
<tr><th colspan="6">Viscosity-Grade Recommendations by Manufacturers for Four-Cycle Crankcase Lubrication</th></tr>
<tr><th>Manufacturer</th><th>Above 40°</th><th>Above 32°F</th><th>Below 5°F</th><th>Below 0°F</th><th>Below –10°F</th></tr>
<tr><td>Briggs and Stratton</td><td>SAE 30 or 10W-30</td><td colspan="4">5W-20 or 10W</td></tr>
<tr><td>Clinton</td><td colspan="2">SAE 30</td><td colspan="2">10W</td><td>5W</td></tr>
<tr><td>Kohler</td><td colspan="2">SAE 30</td><td>SAE 10W</td><td colspan="2">5W or 5W-20</td></tr>
<tr><td>Wisconsin</td><td>SAE 30</td><td>SAE 20 or SAE 20W</td><td colspan="3">10W</td></tr>
<tr><td>Tecumseh</td><td colspan="2">SAE 30</td><td colspan="3">10W-30</td></tr>
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The Mechanical Subsystem

The *mechanical subsystem* converts the force of the expanding gases during combustion into mechanical power, delivering the power to the crankshaft. The mechanical subsystem begins with the block of the engine, which is the main housing for the engine components. See **Figure 14-12.**

The piston and connecting rod are within the cylinder of the block. The expanding gases that result from combustion exert force on the piston, which moves downward, transferring power to the connecting rod. The connecting rod attaches to the *crankpin journal*, which is an offset on the crankshaft that converts the downward movement of the piston and connecting rod into rotary motion. See **Figure 14-13.**

On four-stroke cycle engines, the crankshaft also powers a camshaft. The purpose of the camshaft is to open the appropriate valve at the correct time during intake and exhaust strokes. See **Figure 14-14.**

Figure 14-12. A combination cylinder block and crankcase. The cylinder head and sealing gasket are bolted to the cylinder block. The cylinder block houses all the mechanical components of the engine and keeps them aligned. The head of the engine contains the combustion chamber. On some small gas engine configurations, it may contain the intake and exhaust valves.

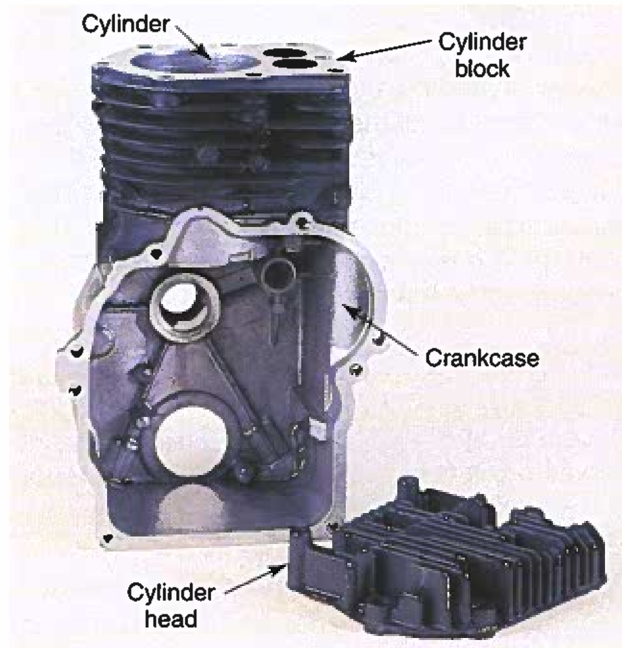
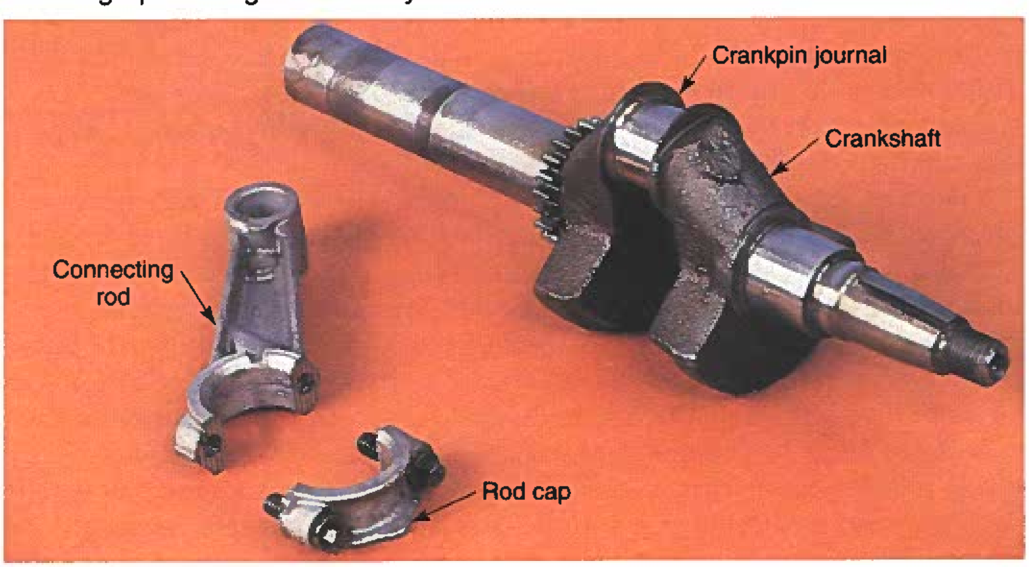


Figure 14-13. Connecting rod and crankshaft. The connecting rod pivots on the crankpin journal. It is subject to severe stress as it transfers power from the piston to the crankshaft during power strokes. The large counterweights on the crankshaft, opposite the crankpin journal, balance the rotational forces of the crankshaft during the power stroke of the piston. When the piston reaches bottom dead center (BDC), the continuing rotary motion will start it traveling upward again in the cylinder.



Multigrade: Many positions in a scale of qualities.

Mechanical subsystem: The subsystem that converts the force of the expanding gases during combustion into mechanical power, delivering the power to the crankshaft.

Crankpin journal: An offset on the crankshaft that converts the downward movement of the piston and connecting rod into rotary motion.

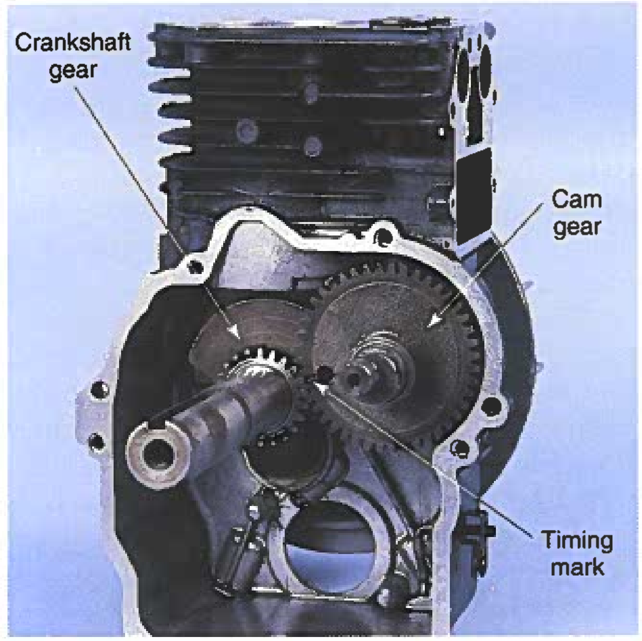


Figure 14-14. The camshaft gear is driven from the crankshaft and provides power to the valve train. The camshaft and crankshaft must be properly aligned so the valves are held closed during the compression and power strokes. Otherwise, it will not be possible to achieve compression. The camshaft gear is always twice as big as the crankshaft gear, since valve action is only required on two out of every four strokes of the piston. Usually, the camshaft gear is located next to the crankshaft gear within the block of the engine, but some large engines use an overhead camshaft located outside the engine block. A timing belt or chain can be used to connect the cam gear and crank gear if they are not located next to one another within the block.

Cam lobe: A curved projection of the rotating piece in a mechanical linkage used to open and close the valves by pushing on rods.

Valve lifter: A lifter that transfers power from the cam lobe to the valve.

Inertia: The tendency of a body in motion to remain in motion.

Key: A small metal piece that holds the flywheel in a properly aligned position on the crankshaft for spark to occur.

Micrometer: A basic precision measuring instrument used to check for wear points on engine parts.

Cam lobes on the camshaft open and close the valves by pushing on rods called lifters. ***Valve lifters*** often can be readjusted to maintain optimum clearances as valves and cam lobes wear. See **Figure 14-15.**

The flywheel on a four-stroke cycle small gas engine is proportionally much heavier than the flywheel on a larger engine or a two-stroke cycle engine. This weight is needed because the flywheel is used to store the energy provided by the power stroke in the form of ***inertia*** (the tendency of a body in motion to remain in motion). The inertia stored in the heavy flywheel helps the engine coast through the exhaust, intake, and compression strokes and smoothes out the power produced by the engine so the engine does not appear to constantly slow down and speed up. See **Figure 14-16.**

A small metal piece known as a ***key*** holds the flywheel in place on the crankshaft. The key fits in matching slots on the flywheel and crankshaft, and it serves as both a coupling device and a safety device. It is made of a softer metal than the flywheel and crankshaft. If the engine stops suddenly, the key will shear, allowing the heavy flywheel to freewheel. This protects the internal parts of the engine from serious damage. Another function the key performs is to keep the flywheel aligned properly on the crankshaft.

The mechanical subsystem is subject to the most wear. This wear is often not visible to the eye because it is only a few thousandths of an inch. The ability to measure with micrometers, feeler gauges, hole gauges, and telescoping snap gauges is very important. ***Micrometers*** are the basic precision measuring instruments used to check for wear points on engine parts. ***Feeler gauges,*** sometimes referred to as *thickness gauges,* are thin strips of metal machined to a specific thickness, often measured in thousandths of an inch. The metal strips are used to verify a gap between two parts. A feeler gauge that is too thick cannot enter the gap. One that is too small moves around too freely in the gap. Measurements are typically

Figure 14-15. A complete valve train with all its components. The lifters transfer power from the cam lobe to the valve. The valve springs hold the valve closed tightly during compression and power strokes.

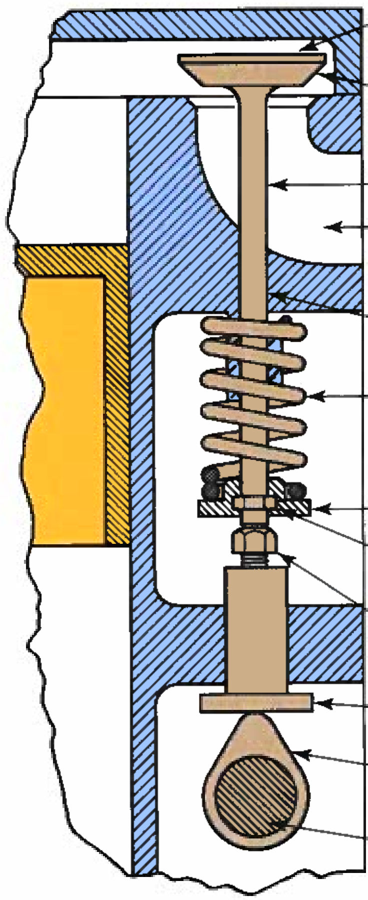
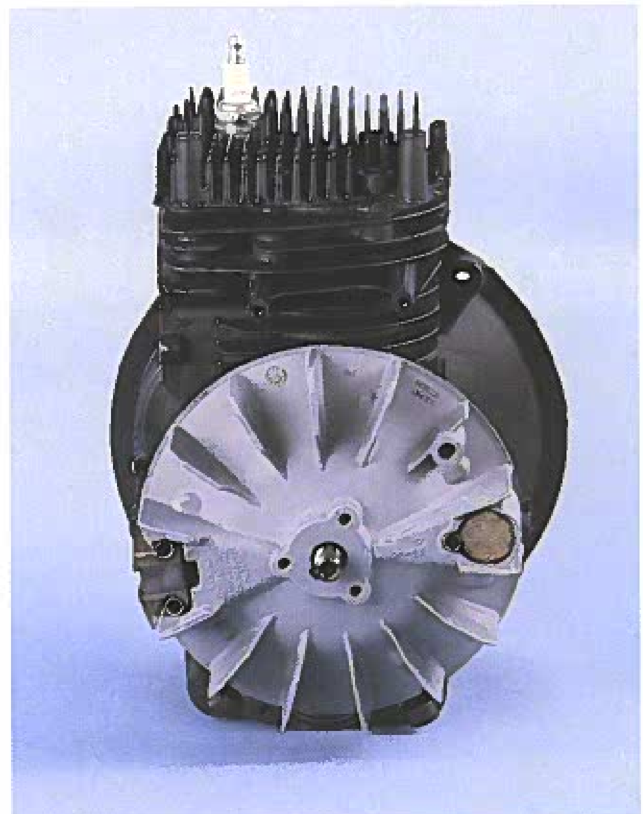


Figure 14-16. The flywheel on a small gas engine plays a part in most of the engine's subsystems. In addition to the mechanical subsystem, the flywheel is part of the cooling subsystem, the electrical subsystem, and the governing subsystem on some small gas engines.



taken in only the most critical areas, such as valve guides, bearing surfaces, and journals, where wear is most likely to occur. Following is a list of the most critical wear areas in most engines.

- Crankshaft front, rear, and crankpin journals.
- Crankshaft front and rear bearings.
- Camshaft front and rear journals.
- Camshaft front and rear bearings.
- Cam lobes.
- Intake and exhaust valves.
- Intake and exhaust valve guides.
- Cylinder diameter (top).
- Cylinder diameter (bottom).
- Cylinder head (for warpage).

In addition to measuring valve stem wear, check the stems for squareness and concentricity of the valve face to the seat. The ***margin thickness*** on the valve also must be checked because the margin is what wears away as the valve operates. To check the valve stems for squareness, roll them

Feeler gauge: A thin strip of metal machined to a specific thickness.

Margin thickness: The dimension of the degree of difference.

on a surface plate to determine if there is any warping. To check for concentricity between the valve face and the seat, place the valve stem in the valve guide and rotate the valve 360° to determine if it rides up or down. Measure the margin thickness by using a steel rule that measures in sixty-fourths of an inch.

STEM Connection

Math: Measuring with a Micrometer

The micrometer is a precision instrument used to measure parts and determine whether they are within specifications. In a small gas engine, wear of a few thousandths of an inch on a part could be very critical to engine performance. Before you learn how to read a micrometer, it is important to learn about handling a micrometer. Since it is a precision measuring instrument, it should be held gently and with care. See **Figure 14-A.** Never over-tighten a micrometer, and be sure to keep it clean and free of debris, which could cause an inaccurate reading.

Figure 14-A. The proper way to hold a micrometer is to hold the micrometer in one hand, while holding the piece to be measured in the other hand. Rotating the ratchet at the end of the thimble will tighten the micrometer until it free-wheels. The measurement is then taken.

The Electrical Subsystem

The ***electrical subsystem*** produces the current that fires the spark plug. It begins with the permanently mounted magnets within the flywheel. As the flywheel spins, the small amount of magnetism induces a low voltage in the armature each time the magnets pass the armature. This low voltage is then converted to high voltage in the ignition coil when the primary field collapses on the secondary field, causing the spark plug to fire.

Electrical subsystem: The subsystem that produces the current that fires the spark plug.

Reading the micrometer is a three-step additive process. Each small line on the sleeve represents 0.025″, or 1/40″. See **Figure 14-B.** Every fourth line on the sleeve is longer. These lines represent 0.100″, or 1/10″. The rotating thimble on the micrometer is divided into 25 equal parts, each measuring 0.001″ or 1/1000″. The additive process used to obtain a measurement consists of these steps:

1. Count all the long lines you can see on the sleeve. Let us say there are three. They represent 0.300″.
2. Next, add 0.025″ for each small line you can see beyond the last long line. Again, let us say you can see three. These three lines represent 0.075″, collectively (0.025″ × 3).
3. Finally, add the number from the thimble closest to the main measuring line on the sleeve. See **Figure 14-C.** Let us say the number is *18.* This number would represent 0.0018″. The total measurement would equal 0.393″, as shown in the following calculation:

   0.300″
   0.075″
   + 0.018″
   0.393″ total

   Practice by using a micrometer to measure a few spare parts. Ask your instructor to check your readings.

Figure 14-B. Each of the small spaces on the micrometer's sleeve is equal to one-fortieth of an inch. The distance between each large line is .100″, or one-tenth of an inch. The reading on this micrometer is .550″.

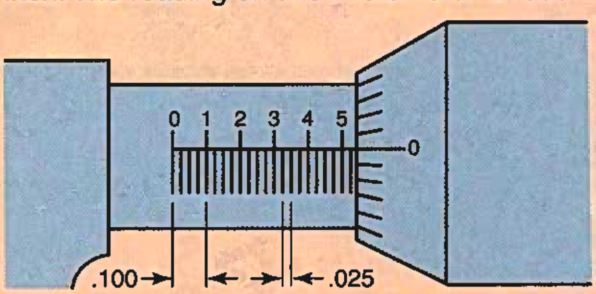


Figure 14-C. Each small line on the thimble is equal to .001″, or one-thousandth of an inch. One complete revolution of the thimble moves the spindle 25 thousandths of an inch, or one complete line on the sleeve.

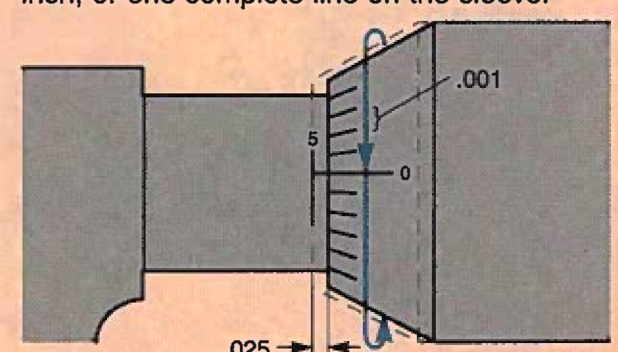


Figure 14-17. The major parts of a small gas engine ignition system typically include a flywheel, a spark plug, a spark plug wire, and a solid-state ignition unit.

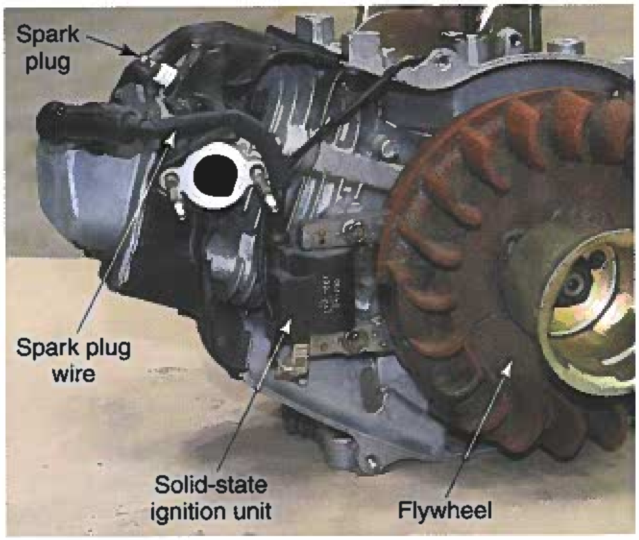
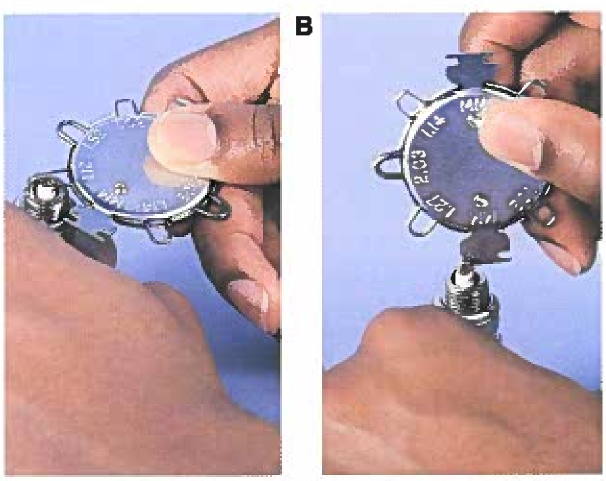


Figure 14-18. Spark plug electrode gapping. A—Checking the gap with a spark plug feeler gauge. Do not use a standard flat-bladed feeler gauge. Since the electrodes on a spark plug are rounded, this type of gauge will not provide an accurate reading. B—Bending the electrode to set the proper plug gap.

A B



The flywheel must be aligned properly on the crankshaft for spark to occur. It is held in place by a small metal piece known as a key. If no key is installed, or if the key shears (breaks), the position of the flywheel on the crankshaft can shift. If the flywheel shifts position, the magnets will not be in the proper location at the time ignition is supposed to occur. See **Figure 14-17.** Also, for spark to occur, the armature must be located the proper distance from the flywheel. If the armature is over-gapped (too far from the flywheel), a weak orange spark may result. Undergapping can cause the armature to rub against the flywheel and result in failure to produce a spark. To set the gap on some small gas engines, place an index card of appropriate thickness on the flywheel, and then bring the armature down onto the flywheel and lock it in place. Remove the index card, leaving the proper air gap.

A good spark plug is essential to proper engine performance. If the plug is cracked, the spark will jump through the ceramic insulator and over to the block, rather than jumping between the spark plug electrodes to create ignition. Plugs must be gapped properly. Overgapping or undergapping may result in failure to fire. To properly gap the plug, use a ***spark plug feeler gauge*** and bend the electrode as necessary. See **Figure 14-18.** Here are some generic diagnostic procedures for inspecting and reinstalling the electrical subsystem on a small gas engine:

- Inspect the flywheel key to ensure that the flywheel is seated in the proper location.
- Determine the proper armature air gap. When reinstalling, make sure the armature is properly spaced from the flywheel.
- Remove and inspect the spark plug. Look for cracks around the ceramic insulator ring. Determine the proper spark plug gap, and then use a spark plug feeler gauge and regap the plug as necessary.

- Inspect the thin wire that goes to the kill switch, if the engine is so equipped. Make sure the coating on the wire is not skinned or pinched anywhere along the way to the switch. If this wire is shorted to (in contact with) the block of the engine, spark will not occur.
- Test for spark by disconnecting the plug wire and using a spark plug tester. Be sure that a strong blue spark is being fed to the plug.

Spark plug feeler gauge: A tool used to properly gap a spark plug.

Governing subsystem: The subsystem designed to keep an engine running at a desired speed, regardless of the load applied to the engine.

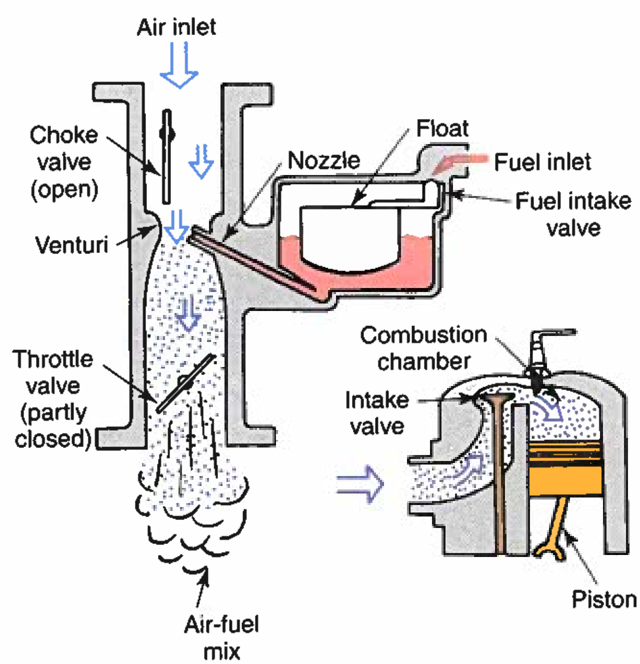
The Governing and Fuel Subsystems

The governing subsystem and the fuel subsystem are described together because they work in conjunction with each other. The ***governing subsystem*** is designed to keep an engine running at a desired speed, regardless of the load applied to the engine. The ***fuel subsystem*** is responsible for creating the fuel-air mixture used to power the engine and delivering that charge to the combustion chamber, based on how much fuel-air charge the governing system allows. See **Figure 14-19.**

Some engines use a fuel injection system to introduce the fuel to the combustion chamber, instead of a carburetion system. When an engine is fuel injected, air is compressed, and fuel is injected into the cylinder prior to the piston reaching TDC. This type of system is common in many automobile and truck engines, including diesel engines, but carburetion is much more common in small gas engines. Major carburetor components and associated carburetor terms are described below:

- ***Venturi.*** The narrow, restricting section of the carburetor, where air speed increases and drafts the fuel vapor along with it into the combustion chamber.
- ***Choke.*** Usually, a platelike device that varies the amount of air that can enter the carburetor. When the engine is "choked" (the plate is mostly closed), more fuel vapor and less air are entering the combustion chamber. The primary reason for choking an engine is to create a ***rich mixture*** (a mixture with more fuel vapor than normal), which is desirable to get the engine started and warmed up to temperature during a cold start.
- ***Throttle.*** Another platelike device, located in back of the venturi, that regulates the amount of fuel-air mixture entering the carburetor.
- **Load.** The condition under which an engine runs when it is called on to do work. When an engine is running under load, both the choke and the throttle are fully (or almost fully) open.

Figure 14-19. The main components and operation of a carburetor. Fuel vapor is drawn through the carburetor by the air that rushes past it as a result of a vacuum created by the intake stroke of the piston. The spark plug ignites the fuel-air mixture, and the expanding gases create a tremendous power surge that is transferred from the piston down to the crankshaft. (Deere & Company)



Fuel subsystem: The subsystem responsible for creating the fuel-air mixture used to power the engine and delivering that charge to the combustion chamber, based on how much fuel-air charge the governing system allows.

Venturi: The narrow, restricting section of the carburetor, where air speed increases and drafts the fuel vapor along with it into the combustion chamber.

- ***Idle.*** The condition an engine will run under when it is warmed up to temperature and not under load. When an engine is at idle, the choke is generally open, and the throttle is generally closed.
- ***Idle bypass circuit.*** A small passageway that allows some fuel-air mixture to escape around the throttle plate and keep the engine running, even when the throttle is closed.

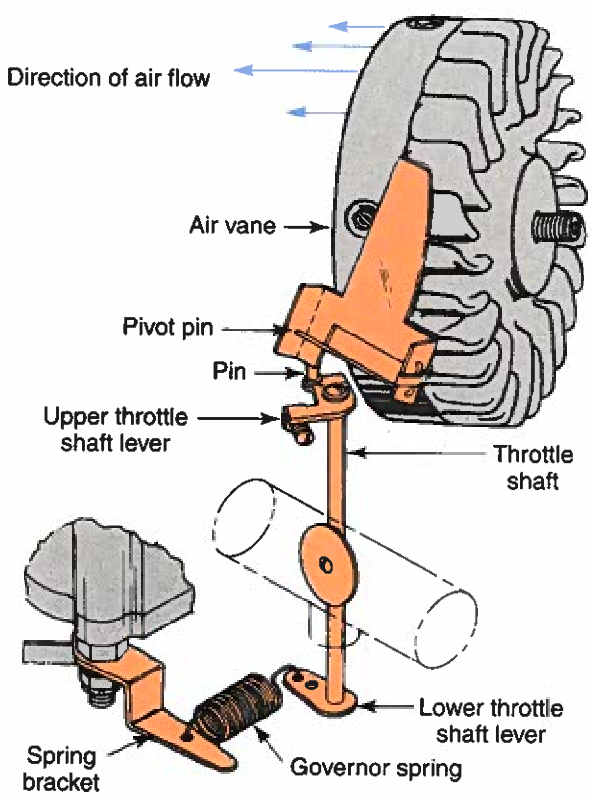
How much fuel-air mixture enters the combustion chamber is the result of the ***governing mechanism***. Most types of governing mechanisms rely on the speed of the engine to determine whether more or less fuel-air mixture is needed. See **Figure 14-20.**

A centrifugal governor is directly linked to the throttle plate. See **Figure 14-21.**The faster the engine turns, the more the governor pulls the throttle toward its closed position, allowing less fuel-air mixture to enter. When the engine begins to slow down, the governing mechanism moves inward, opening the throttle. This allows more fuel-air mixture to enter the combustion chamber.

Measuring, Testing, and Troubleshooting

Like any complex machine, an engine needs maintenance, periodic testing, and troubleshooting. The following sections describe common terminology used when measuring and testing an engine. They also provide some helpful troubleshooting hints for small engine repair.

Figure 14-20. An air vane governing system for small gas engines. Increasing or decreasing airflow from the flywheel vanes is used to adjust the throttle position.



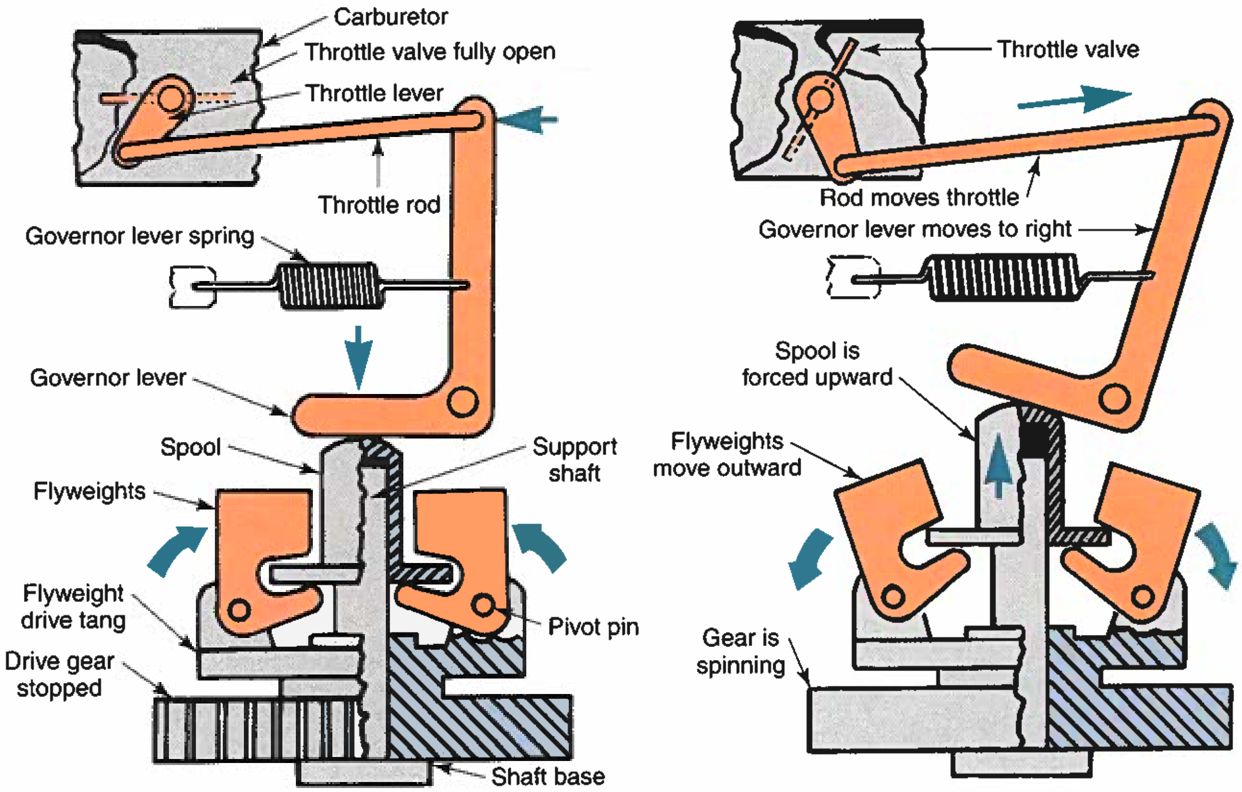
Efficiency

Volumetric efficiency measures how well the engine breathes. Breathing, in this sense, compares the amount of fuel-air mixture actually drawn into the cylinder with the maximum amount of fuel-air that could be drawn into the cylinder if it were completely filled. ***Mechanical efficiency*** is the percentage of power developed in the cylinder compared to the power actually delivered to the crankshaft.

Thermal efficiency, sometimes referred to as *heat efficiency*, is a measurement of how much heat is actually used to drive the piston downward. Internal combustion engines are not particularly efficient conversion devices. You may be surprised to learn that about 75% of all the heat produced during combustion is not transferred to the piston.

Practical efficiency is perhaps the most useful term of all. It is simply a measurement of how efficiently an engine uses its fuel supply. If an engine is used for motive power, this could be expressed in terms of miles per gallon. The practical efficiency measurement of

Figure 14-21. Operation of a centrifugal governor. The governing mechanism automatically regulates the amount of fuel-air mixture required to keep the engine running at a relatively constant speed under load conditions ranging from idle through full load.



an engine takes into account all losses (such as frictional loss, incomplete combustion, and thermal loss), leaving only a comparison of potential energy in to useful power out.

Horsepower (hp)

There are many different uses of the term *horsepower (hp)*. As described in Chapter 9, the term came about as a means of comparing the power output of James Watt's steam engine to the amount of work a horse could do. Watt's constant for hp was determined to be 550 foot-pounds (ft.-lbs.) per second, meaning that a draft horse could perform about 550 ft.-lbs. of work in 1 second. Engines are typically rated in terms of their hp capability. This capability is affected by many factors, but the two most important are the bore and the stroke of the engine. The ***bore*** refers to the diameter of the cylinder. The stroke refers to the maximum length of piston travel. An engine with a greater bore or stroke (or both) should yield greater hp. Another factor that greatly influences hp output is frictional loss. Antifriction bearings will help to reduce friction, but they are more expensive to use than friction bearings.

The characteristics of power produced by a small gas engine can be measured on a dynamometer and used to calculate hp. See **Figure 14-22.** Today, there are several different terms for hp, all with different meanings. Following are the most common terms for hp, along with a brief explanation of each.

Choke: A platelike device that varies the amount of air that can enter the carburetor.

Rich mixture: A fuel mixture with more fuel vapor than normal.

Throttle: A platelike device, located in back of the venturi, that regulates the amount of fuel-air mixture entering the carburetor.

Idle: The condition an engine will run under when it is warmed up to temperature and not under load.

Idle bypass circuit: A small passageway that allows some fuel-air mixture to escape around the throttle plate and keep the engine running, even when the throttle is closed.

Governing mechanism: A mechanism that determines how much fuel-air mixture needs to enter the combustion chamber, based on the speed of the engine.

Volumetric efficiency: A measurement of how well the engine breathes.

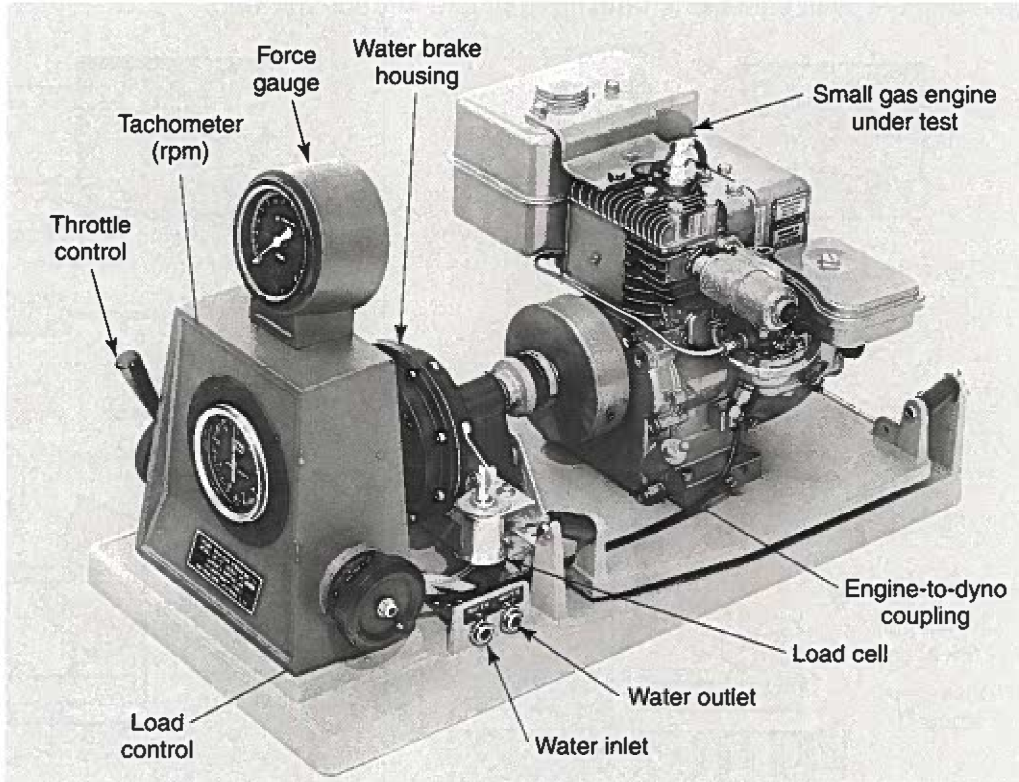
Mechanical efficiency: The percentage of power developed in the cylinder compared to the power actually delivered to the crankshaft.

Thermal efficiency: A measurement of how much heat is actually used to drive the piston downward.

Practical efficiency: A measurement of how efficiently an engine uses its fuel supply.

Bore: The diameter of a cylinder.

Figure 14-22. A dynamometer is used to measure the horsepower (hp) output of a small gas engine. (Go-Power Corporation)



Brake horsepower (bhp) is the hp available for use at the crankshaft. Typically, bhp will increase with engine rpm. It will actually decrease, however, if the engine rpm climbs into a range beyond the engine's normal rating.

Indicated horsepower (ihp) is a more theoretical hp term. It measures the power developed by the fuel-air charge upon ignition in the combustion chamber. This type of hp is actually derived by taking an average of the pressure within the cylinder during all four strokes. Other factors involved when calculating ihp include the volume within the cylinder and the number of cylinders in the engine.

Frictional horsepower (fhp) represents the part of the potential hp or ihp lost due to friction within the engine. It can be calculated by subtracting the bhp available at the crankshaft from the ihp. The ihp is the theoretical hp available from the fuel-air charge in that size cylinder or engine:

ihp – bhp = fhp

Rated horsepower (rhp) is another often-used hp term. It typically represents about 80% of the engine's bhp capability. (Engines should not be run at full load for extensive periods of time. Doing so will cause excessive wear and premature engine failure.) The rhp is what is labeled on the engine. The 80% rule can be helpful in sizing engines for specific applications. For instance, if a portable pump requires a constant 6 hp to operate, it would be desirable to power it with an engine rated at 7.5 hp or greater to provide an adequate safety margin. Using an undersized engine could lead to increased fatigue and premature engine failure.

Engine Testing

Testing hp typically occurs at the factory to ensure that new engines are performing up to specification. A series of more practical tests can be performed in the field to determine the causes of engine malfunctions. Two of the most common field tests are spark tests and compression tests.

A ***spark test*** can be performed to determine if the magneto is producing appropriate spark. It does not indicate whether or not the spark is occurring at the correct time, but it can determine the presence and quality of spark. The tester is connected between the plug wire and the top of the spark plug. See **Figure 14-23.** When the starter cord is pulled to rotate the flywheel, the quality of the spark can be observed through a sight hole (window) in the tester. A strong blue spark is desirable. An orange color indicates a weak spark that may not jump across the plug electrodes. When performing a spark test, be careful to avoid a shock. Do not touch any exposed electrical connections.

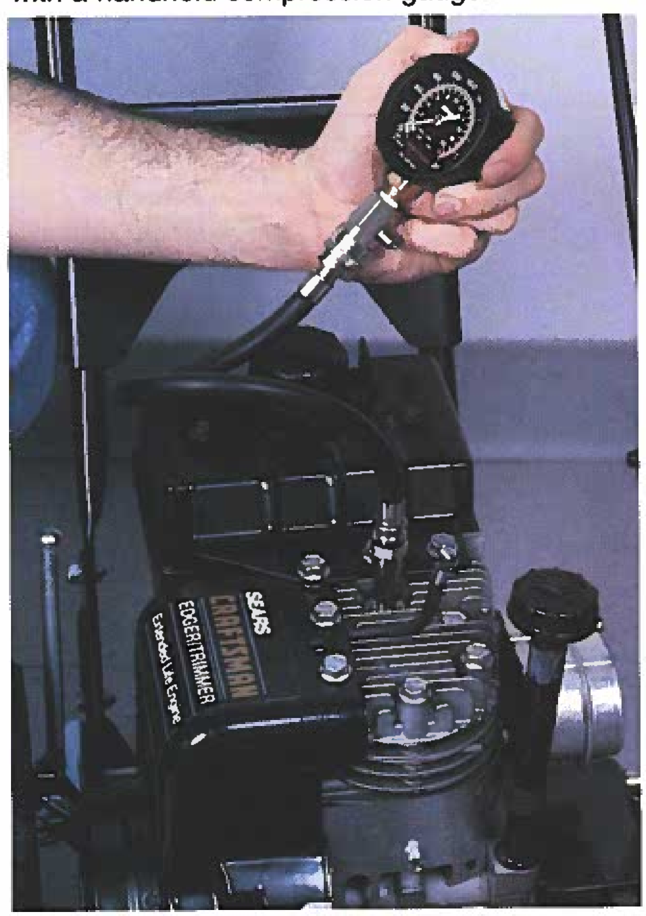
Another way to check for spark is to unscrew the plug from the cylinder head. Reconnect the plug wire, and use insulated pliers to hold the bottom electrode of the plug tight against the engine block. Have someone pull the starter cord. Watch as the spark jumps across the electrodes on the plug.

A ***compression test*** can be performed with a pressure gauge covering the spark plug hole. Some compression gauges thread into the spark plug hole. Once the gauge is installed, the engine is rotated as it would be for starting. If the pressure that would build up during compression is significantly less than the manufacturer's specification, a leak is likely occurring. See **Figure 14-24.** A loss of compression could occur from any of the following:

- A cracked compression ring.
- A blown head gasket.
- Worn valves.
- Poor seating of valves.
- A worn cylinder.

Figure 14-23. Using a spark tester to check for spark.

Figure 14-24. Performing a compression test with a handheld compression gauge.



Rated horsepower (rhp): About 80% of the engine's brake horsepower (bhp) capability.

Spark test: A test performed to determine if the magneto is producing appropriate spark.

Compression test: A test performed with a pressure gauge covering the spark plug hole. Once the gauge is installed, the engine is rotated as it would be for starting. If the pressure that would build up during compression is significantly less than the manufacturer's specification, a leak is likely occurring.

Troubleshooting

There are a number of common problems associated with small gas engines. See **Figure 14-25.** Use the list of various possible causes and remedies as a starting point for troubleshooting.

Basic Tools for Small Engine Repair

Prior to disassembling an engine or any other complex piece of machinery, it is always wise to review the tools you will need. This is especially true if the task requires specialty tools. Such is the case with repairing the small gas engine. See **Figure 14-26.** Some of the tools needed are found in most toolboxes, and others are specific to working on engines. Tools for testing and measuring are also needed.

Helpful Hints about Engine Disassembly

When all else fails, you may have to disassemble the engine to perform internal troubleshooting or to replace such parts as gaskets or seals. Engine disassembly is easy (compared to engine reassembly), because you do not need to worry about critical tolerances during disassembly. There is a correct way and an incorrect way, however, to take apart an engine or any other complex piece of machinery with many parts. Seasoned engine technicians use several specific techniques to ensure that parts are reinstalled correctly, in the appropriate sequence, and are not misplaced. Here are a few helpful hints from veteran mechanics about engine disassembly that will prove to be very helpful when it is time to reassemble the engine:

- When possible, replace bolts in the same holes from which they were removed. For example, once the starter housing has been removed, the screws that held the housing to the face of the engine should be screwed back into the engine block. Using this technique, it is virtually impossible to lose a screw or to mistake one screw for another taken from some other part of the engine. This is important because even screws and bolts that are the same size as one another can be made of different alloys for different purposes. For example, some may be intended for high-torque and high-heat applications, while others are not.
- Prior to disassembly, make drawings of complex linkages, such as the governor linkage on the top of the engine. You might think you will remember where all those springs and linkage arms belong, but chances are, you will not. For more complex engines, photographs can be helpful. Pictures probably will not be necessary for small gas engine disassembly, but drawings of complex assemblies might be very useful.
- Use pencil marks and notes to indicate the locations of variable adjustments prior to disassembly. This will help you restore the initial settings following reassembly.
- Pay particular attention to small, easily misplaced parts, such as the key that holds the flywheel onto the crankshaft. You may wish to store such parts in a special place so they are not misplaced.

Figure 14-25. A troubleshooting chart for small gas engines.

Engine Troubleshooting Chart	
Cause	**Remedy**
Engine fails to start or starts with difficulty	
No fuel in tank.	Fill tank with clean, fresh fuel.
Shut-off valve closed.	Open valve.
Obstructed fuel line.	Clean fuel screen and line. In necessary, remove and clean carburetor.
Tank cap vent obstructed.	Open vent in fuel tank cap.
Water in fuel.	Drain tank. Clean carburetor and fuel lines. Dry spark plug and points. Fill tank with clean, fresh fuel.
Engine overchoked.	Close fuel shut-off and pull starter until engine starts. Reopen fuel shut-off for normal fuel flow.
Improper carburetor adjustment.	Adjust carburetor.
Loose or defective magneto wiring.	Check magneto wiring for shorts or grounds; repair if necessary.
Faulty magneto.	Check timing, point gap; if necessary, overhaul magneto.
Spark plug fouled.	Clean and regap spark plug.
Spark plug porcelain cracked.	Replace spark plug.
Poor compression.	Overhaul engine.
No spark at plug.	Disconnect ignition cut-off wire at the engine. Crank engine. If spark at spark plug, ignition switch, or safety switch, interlock switch is inoperative. If no spark, check magneto.
Crankcase seals and/or gaskets leaking (two cycle only).	Replace seals and/or gaskets.
Exhaust ports plugged (two cycle only).	Clean exhaust ports.
Engine knocks	
Carbon in combustion chamber.	Remove cylinder head and clean carbon from head and piston.
Loose or worn connecting rod.	Replace connecting rod.
Loose flywheel.	Check flywheel key and keyway; replace parts if necessary. Tighten flywheel nut to proper torque.
Worn cylinder.	Replace cylinder.
Improper magneto timing.	Time magneto.
Engine misses under load	
Spark plug fouled.	Clean and regap spark plug.
Spark plug porcelain cracked.	Replace spark plug.
Improper spark plug gap.	Regap spark plug.
Pitted magneto breaker points.	Replace pitted breaker points.
Magneto breaker arm sluggish.	Clean and lubricate breaker point arm.
Faulty condenser.	Check condenser on a tester; replace if defective.
Improper carburetor adjustment.	Adjust carburetor.
Improper valve clearance.	Adjust valve clearance to recommended specifications.

(Continued)

Figure 14-25. *Continued.*

Engine Troubleshooting Chart	
Cause	**Remedy**
Engine misses under load	
Weak valve spring.	Replace valve spring.
Reed fouled or sluggish (two cycle only).	Clean or replace reed.
Crankcase seals leak (two cycle only).	Replace worn crankcase seals.
Engine lacks power	
Choke partially closed.	Open choke.
Improper carburetor adjustment.	Adjust carburetor.
Magneto improperly timed.	Time magneto.
Worn rings or piston.	Replace rings or piston.
Air cleaner fouled.	Fill crankcase to proper level.
Lack of lubrication (four cycle only).	Clean air cleaner.
Valves leaking (four cycle only).	Grind valves and set to recommended specifications.
Reed fouled or sluggish (two cycle).	Clean or replace reed.
Improper amount of oil in fuel mixture (two cycle only).	Drain tank; fill with correct mixture.
Crankcase seals leak (two cycle only).	Replace worn crankcase seals.
Engine overheats	
Engine improperly timed.	Time engine.
Carburetor improperly adjusted.	Adjust carburetor.
Air flow obstructed.	Remove any obstructions from air passages in shrouds.
Cooling fins clogged.	Clean cooling fins.
Excessive load on the engine.	Check operation of associated equipment. Reduce excessive load.
Carbon in combustion chamber.	Remove cylinder head and clean carbon from head and piston.
Lack of lubrication (four cycle only).	Fill crankcase to proper level.
Improper amount of oil in fuel mixture (two cycle only).	Drain tank; fill with correct mixture.
Engine surges or runs unevenly	
Fuel tank cap vent hole clogged.	Open vent hole.
Governor parts sticking or binding.	Clean and, if necessary, repair governor parts.
Carburetor throttle linkage or throttle shaft and/or butterfly binding or sticking.	Clean, lubricate, or adjust linkage and deburr throttle shaft or butterfly.
Intermittent spark or spark plug.	Disconnect ignition cut-off wire at the engine. Crank engine. If spark, check ignition switch, safety switch, and interlock switch. If no spark, check magneto. Check wires for poor connections, cuts, or breaks.
Improper carburetor adjustment.	Adjust carburetor.
Dirty carburetor.	Clean carburetor.

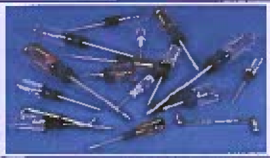
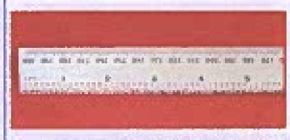
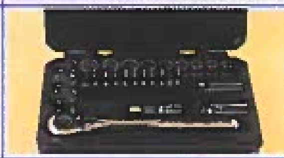
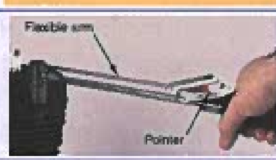
(Continued)

Figure 14-25. *Continued.*

Engine Troubleshooting Chart	
Cause	**Remedy**
Engine vibrates excessively	
Engine not securely mounted.	Tighten loose mounting bolts.
Bent crankshaft.	Replace crankshaft.
Associated equipment out of balance.	Check associated equipment.
Engine uses excessive amount of oil (four cycle only)	
Engine speed too fast.	Using tachometer, adjust engine rpm to specifications.
Oil level too high.	To check level, turn dipstick cap tightly into receptacle for accurate level reading.
Oil filler cap loose or gasket damaged, causing spillage out of breather.	Replace ring gasket under cap and tighten cap securely.
Breather mechanism damaged or dirty, causing leakage.	Replace breather assembly.
Drain hole in breather box clogged, causing oil to spill out of breather.	Clean hole with wire to allow oil to return to crankcase.
Gaskets damaged or gasket surfaces nicked, causing oil to leak out.	Clean and smooth gasket surfaces. Always use new gaskets.
Valve guides worn excessively, thus passing oil into combustion chamber.	Ream valve guide oversize and install 1/32" oversize valve.
Cylinder wall worn or glazed, allowing oil to bypass rings into combustion chamber. Piston rings and grooves worn excessively.	Bore hole or deglaze cylinder as necessary. Reinstall new rings, check land clearance, and correct as necessary.
Piston fit undersized.	Measure and replace as necessary.
Piston oil control ring return holes clogged.	Remove oil control ring and clean return holes.
Oil passages obstructed.	Clean out all oil passages.

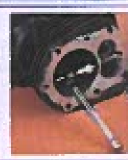
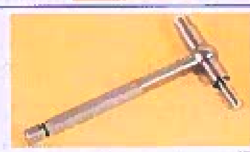
- If possible, try to salvage gaskets. An actual engine overhaul will require a replacement set of gaskets and seals to restore the engine to original condition. If the engine is being taken apart simply as a learning experience, however, saving the existing gaskets and seals is much less costly than using replacement items. Sometimes, it is simply not possible to salvage a particular gasket or seal, and using a replacement is the only option.
- Use a repair manual that has been designed for your specific engine, if possible. There are critical specifications and information about replacement parts that will be difficult to track down without the assistance of such a manual.

Figure 14-26. The most essential tools necessary for engine disassembly, inspection, repair, and reassembly. (Monarch Instruments)

Screwdrivers		Small hand tools used for turning screws. They may be regular or Phillips head screwdrivers.
Nut drivers		Small hand tools used for turning nuts.
Slip-joint pliers		Small hand tools used for gripping and holding objects.
Steel rule		A small hand tool used for measuring in 1/64≤ divisions. It can be used to make measurements in both U.S. customary and SI metric units.
Quarter-inch drive socket set		Small hand tools used for installing and removing nuts and bolts in hard-to-reach places.
Combination wrenches		Small hand tools used for loosening and tightening nuts and bolts on the engine that cannot be addressed with sockets.
Adjustable wrench		A small hand tool used for loosening and tightening nuts and bolts.
Torque wrench		An engine tool used for installing fasteners, such as head bolts and connecting rod bolts, which must be torqued to specification. It can measure torque in inch-pounds (in.-lbs.) or foot-pounds (ft.-lbs.).
Ring expander		An engine tool used for removing the rings from the piston so they can be examined for wear.
Ring compressor		An engine tool used for holding the rings tightly to the piston. It wraps around the rings so the piston and rod assembly can be reinserted into the cylinder.
Valve spring compressor		An engine tool used for overcoming tension from the intake and exhaust valves so the valves can be removed for inspection or replacement. It squeezes the valve spring so the keeper can be easily removed.

(Continued)

Figure 14-26. *Continued*

Square and surface plate		A testing tool used for checking parts for warpage. It is a highly polished stone that has been ground perfectly flat. Engine parts, such as the engine head, valves, and valve springs, can be checked for straightness, proper length, and squareness.
Feeler gauge		A testing tool used for checking critical gaps within an engine. The fine blades are used to ensure that gaps are within critical tolerances.
Spark plug feeler gauge		A testing tool used for gapping the electrodes on a spark plug.
Outside micrometer		A precision measuring tool used for checking for critical wear points on engine parts. It is used to measure the external diameter of a part, such as a piston pin.
Inside micrometer		A precision measuring tool used for checking for critical wear points on engine parts. It is used to measure the internal diameter of a part, such as a cylinder.
Telescoping gauge		A measuring tool used for checking the diameter of interior openings, such as valve guides or engine cylinders. It is used in conjunction with a micrometer to yield accurate measurements.
Tachometer		A measuring tool used for measuring the speed of an engine for diagnosis and tune-up.

Career Connection

Diesel Mechanics

Transportation, Distribution & Logistics

Trucks, buses, and other large machines may be powered by diesel engines. When these machines no longer function correctly, mechanics are needed to service and maintain them. Diesel mechanics' tasks are very similar to those of other automotive technicians. These mechanics are required to diagnose and repair problems with such equipment as brakes and suspension systems. Diesel engines, however, are different from small gas engines. To repair an engine, a mechanic in this field must possess working knowledge of the assembly and functions of the diesel engine. This is especially important in cases of rebuilding engines.

Apart from mechanical skills, diesel mechanics must be able to work with customers, which may require both written and verbal communication skills. They must be able to conduct tests within accepted safety limits. A working knowledge of computers and design techniques is also important. A vocational certificate is necessary to be a worker in this field. The yearly salary may range from $26,000 to $59,000.

Small Gas Engines and the Environment

When it comes to protecting the environment, air pollution from small gas engines might not immediately come to mind, but it should. Emissions from lawn mowers, chain saws, and other outdoor equipment powered by small gas engines are significant sources of pollution in the United States. According to one estimate, small gas engines produce almost 7 million tons of air pollution yearly. It is also estimated that mowing a lawn for about half an hour will produce emissions equivalent to driving a car for 172 miles! See **Figure 14-27.** Small gas engines contribute about half of all nonroad exhaust emissions.

The result is that small gas engines have come under increasing scrutiny from environmental agencies. Regulations were first established by the California Air Resources Board in 1995. Because California is such a huge market, the regulations have caused manufacturers to redesign small gas engines to be more environmentally friendly. The Environmental Protection Agency (EPA) proposed tougher federal standards during the 1990s. These standards are being phased in, with all expected to be in place soon. To date, most small gas engine manufacturers claim to be meeting the detailed regulations set in place by California and the EPA through a combination of modifications, including the use of adjustable overhead valve trains, solid-state ignition systems, and better oil control designs. These modifications add cost to a new engine, but they are having some impact. It is estimated that a reduction of 390,000 tons of hydrocarbons and nitrous oxides going into the atmosphere will occur annually by 2027, as a result of these engine modifications. The best part—all this is anticipated to occur, while fuel consumption per engine is expected to decrease!

Figure 14-27. Nonroad exhaust gas emissions by percentage.

Urban Summertime Hydrocarbon Nonroad Sources	
Small spark-ignition engines	50%
Recreational boats	30%
Other nonroad engines	20%

Career Skills

Problem-Solving Skills

Employers value workers who have the ability to make sound decisions and solve problems. Problem-solving skills will help you identify the issue, identify possible solutions, make a decision, implement the decision, and evaluate the results.

Having the ability to solve problems on the job shows an employer that you are able to handle more responsibility. The ability to make decisions and solve problems requires critical-thinking skills. These are higher-level skills that enable you to think beyond the obvious. You learn to interpret information and make judgments. Supervisors appreciate employees who can analyze problems and think of workable solutions.

Summary

Engines can be of either internal or external combustion design. Internal combustion engines can be further classified as either two-stroke cycle or four-stroke cycle engines. Regardless of engine type, the processes of intake, compression, power, and exhaust must occur. Two-stroke cycle engines have some inherent advantages over four-stroke engines, but they also have some disadvantages, such as shorter service lives. The type of engine used is often determined by the application. Engines are complex machines because they require several subsystems, all of which must be operational for the engine to function properly. These subsystems include the mechanical, electrical, fuel, governing, lubrication, and cooling subsystems. The power produced by an engine is typically rated in terms of horsepower (hp). There are many different ways to measure hp, but brake horsepower (bhp) and the rated horsepower (rhp) are the two used most often. Frictional horsepower (fhp) refers to hp lost as the result of internal friction within the engine. Working on an engine requires many tools, including specialty items, such as ring compressors, ring expanders, strap wrenches, valve spring compressors, and precision measuring instruments. In the 1990s, several pieces of legislation were passed to protect the environment by regulating emissions produced by small gas engines. These regulations have resulted in the redesign of small gas engines to make them more environmentally friendly.

Key Words

All the following words have been used in this chapter. Do you know their meanings?

atomized
bore
bottom dead center (BDC)
cam lobe
camshaft
choke
combustion chamber
compression ratio
compression stroke
compression test
connecting rod
cooling fin
cooling subsystem
crankpin journal
crankshaft
cylinder
electrical subsystem
engine ring
exhaust stroke
external combustion engine
feeler gauge
flywheel
four-stroke cycle engine
fuel-air charge
fuel subsystem
governing mechanism
governing subsystem
idle
idle bypass circuit
inertia
intake stroke
internal combustion engine
key
lubrication subsystem
margin thickness
mechanical efficiency
mechanical subsystem
micrometer
multigrade
oil dipper
piston
power stroke
practical efficiency
radiator
rated horsepower (rhp)
rich mixture
Society of Automotive Engineers (SAE)
spark plug
spark plug feeler gauge
spark test
stroke
thermal efficiency
thermostat
throttle
top dead center (TDC)
two-stroke cycle engine
valve lifter
venturi
volumetric efficiency
water jacket

Test Your Knowledge

Write your answers on a separate sheet of paper. Do not write in this book.

1. Heat is generated outside the cylinder in a(n) _____ combustion engine.
2. A comparison of the volume in the cylinder with the piston at bottom dead center (BDC) versus TDC is known as the _____.
3. *True or False?* Ignition occurs before the piston reaches top dead center (TDC) on the intake stroke.
4. Describe each step in the four-stroke cycle process.
5. What are the two strokes commonly associated with a two-stroke cycle engine?
   A. Intake and exhaust.
   B. Intake and power.
   C. Compression and power.
   D. Power and exhaust.
6. One complete revolution of the crankshaft will produce a power stroke in a(n) _____ engine.
7. List two advantages of four-stroke engines over two-stroke engines.
8. A(n) _____ attached to the connecting rod provides splash lubrication for many small gas engines.
9. Describe four things that oil does besides provide lubrication.
10. *True or False?* The camshaft is responsible for opening the valves.
11. Identify three things that the flywheel is responsible for in a small gas engine.
12. List at least four critical wear areas within an engine.
13. *True or False?* The choke is responsible for varying the percentage of air in the fuel-air mixture that enters the cylinder.
14. When starting a cold engine, a(n) _____ fuel-air mixture is desirable.
15. Identify six causes of malfunctions in engines.
16. If your small gas engine will not start and you know it has fuel, a logical troubleshooting step would be to:
    A. check for oil.
    B. check the cooling fins.
    C. check the intake valve.
    D. check for spark.
17. *True or False?* An outside micrometer can be used to measure the thickness of a valve stem.

STEM Activities

1. If lab facilities are available, work in a team with several other students to completely disassemble and reassemble a small gas engine. The engine should then be tested and adjusted for optimal performance, if possible.
2. Disassemble a carburetor and identify all the necessary components found within it.
3. Research a topic related to internal combustion engines, such as new engine designs, pollution control devices, or improvements in efficiency. Write a short paper or make a presentation to the class.

Career Skills

Teamwork

Employers seek employees who can effectively serve as good team members. Due to the nature of most work today, teamwork is necessary. A team is a small group of people working together for a common purpose. Cooperation often requires flexibility and willingness to try new ways to get things done. If someone is uncooperative, it takes longer to accomplish the tasks. When people do not get along, strained relationships may occur, which get in the way of finishing the tasks.

A big advantage of a team is its ability to develop plans and complete work faster than individuals working alone. In contrast, a team usually takes longer to reach a decision than an individual worker does. Team members need some time before they become comfortable with one another and function as a unit. You will be more desirable as an employee if you know how to be a team player.

Team development goes through various stages. In the beginning, people are excited about being on a team. Later, disagreements may replace harmony. The good result of this is people express themselves and learn to trust the other team members. Eventually leaders emerge and the team develops a unique pattern of interaction and goal attainment. Finally, the team becomes very productive and performs at its highest level. It takes time and a genuine desire to work together to build a strong team.

Creative ideas often develop from building on another person's idea. Honesty and openness are essential. Also, trying to understand the ideas of others before trying to get others to understand your ideas is an effective skill to develop.

Belonging to an organization can also help you develop your teamwork skills. You will learn how to work well in a group as you plan events, create projects, and accomplish goals together.