Chapter 7

Small Engines and Equipment

Learning Objectives
1. Determine whether a small engine is a two-cycle or four-cycle design
2. Explain the differences in maintenance, care and operation procedures for two-cycle and four-cycle engines
3. Explain the most commonly encountered problems with small engines and how to prevent or correct these problems
4. Select the proper type fuels and fuel mixes for use in small engines based on engine type, use and weather conditions at the time of engine operation
5. Explain the purpose of anti-freeze mixtures in water-cooled engines and why coolant mixtures must be replaced periodically based on type and use
Gardens should know more about their tools and equipment to better care for the tool investment. Tools are an extension of the gardener that cut, chop, saw and dig in the landscape. Without a functional tool, the landscape would look uncultivated and wild.

This chapter will provide Master Gardeners more detail than many owner’s manuals and contains information and explanations about the substances, functions and care of gardening equipment.

Small Engines
The information in this chapter is not intended to replace specific information in owner’s manuals about engine or equipment operation, care or maintenance. The information in this chapter is intended to facilitate both an understanding of the need for specific maintenance and an understanding of the instructions found in owner’s manuals.

Two- and Four-Cycle Engines for Lawn and Garden Equipment
Although gasoline engines power most types of lawn and garden equipment, some newer and larger equipment may be powered by diesel engines. Depending on the design, these engines are classed as either two-cycle or four-cycle engines. Two-cycle engines have a power stroke on every revolution of the engine crankshaft. Thus, they are called two-stroke-cycle engines, which is usually shortened to two-cycle engines when discussing engine type. Four-stroke-cycle engines, or four-cycle engines, have a power stroke every two revolutions of the crankshaft. An understanding of four-cycle engine operation is essential for better understanding of two-cycle engine operation.

As the name implies, four-cycle engines have four strokes, or movements, of the piston for each power stroke of the engine. The four strokes of these engines are intake stroke, compression stroke, power stroke and exhaust stroke. Each stroke performs a necessary function in the overall operation of the engine. The intake stroke allows gasoline and air needed for combustion to enter the combustion chamber. This mixture is about one part gasoline and 10,000 parts air. On this stroke, the piston is moving away from the cylinder head, which is down in most engines. The compression stroke uses the piston to squeeze the gas/air mixture to the top of the cylinder into an area that is about 1/8 the volume of the cylinder. In a 200cc engine, the compressed volume will be about 25cc. Compression is necessary to develop power when the gas/air mixture is ignited. The power stroke occurs when the spark plug in a gasoline engine sparks and ignites the compressed gas/air mixture, causing an explosion. The piston is pushed to the bottom of the cylinder by the explosion. The explosion during the power stroke is a controlled event, the speed of which is controlled by the equipment operator with the throttle control on the engine. The exhaust stroke occurs when the momentum of the power stroke causes the piston to move back to the top of the cylinder to push exhaust gases out of the engine in preparation for a new series of strokes to begin.

Some engines have more than one cylinder. In these engines, each piston is in a different part of the cycle during operation. This permits smoother operation of the engine and delivers power at different points in the revolution of the crankshaft. The V-8 engines, which are found in many automobiles, have...
eight different power strokes that occur during every two revolutions of the crankshaft. Now, it should be clear why eight cylinder engines are more powerful than single cylinder engines if both have the same size cylinders.

Two-cycle engines operate similar to four-cycle engines, but they combine intake and power into one stroke and compression and exhaust into another stroke. Since the two-cycle engine has twice as many power strokes per revolution of the crankshaft, the engine theoretically produces twice as much power as a four-cycle engine. However, by combining strokes, some efficiency is lost and the engine does not produce fully twice the power.

Two-cycle engines are lubricated from oil mixed with fuel. Four-cycle engines usually have an oil reservoir in the bottom of the engine that supplies lubrication. This results in four-cycle engines being larger and heavier. As a rough rule-of-thumb, a two-cycle engine will be about half the size and weight of the same horsepower four-cycle engine. This fact is very useful when putting engines on lawn and garden equipment. Larger equipment, such as lawn mowers, lawn tractors, pressure washers, wood chippers and garden tillers, will usually be equipped with four-cycle engines. Smaller equipment, such as chain saws, weed trimmers, leaf blowers, powered hedge clippers and small air compressors, are usually powered by two-cycle engines. Because the operator usually carries this equipment, it makes sense that it is lighter. Another advantage of two-cycle engines is that the equipment can be operated at virtually any position without fear of spilling oil or losing lubrication to the engine. This is because this engine has no oil
reservoir at the bottom. In contrast, four-cycle engines must be operated level or nearly level to maintain proper lubrication from oil in the reservoir, or the oil sump, as it is usually called.

Common Causes of Small Engine Failures and Starting Problems

Old Fuel

The most common reason for small engines not starting easily is old fuel. Gasoline ages from the day it is bought and it is considered to be too old for use after 90 days. As fuel ages, the lighter hydrocarbons in the fuel evaporate and are lost. These lighter hydrocarbons are the most volatile and combustible part of the gasoline. They ignite easily and make the engine easy to start when they are present in large numbers. Therefore, as more of the lighter hydrocarbons evaporate, the harder the engine becomes to start. Additionally, the longer the fuel ages, the more gum and varnish deposits accumulate. These deposits can plug or restrict fuel flow in the carburetor and prevent the engine from starting at all. Therefore, it is important to keep fresh fuel in the fuel tank and buy new fuel on a schedule that will prevent the fuel supply from aging. This will help eliminate the starting problems associated with old fuel. Furthermore, the speed of the aging process of fuel is determined by the temperature and humidity of the area where the fuel is stored. Hot, humid conditions cause fuel to age more quickly than cool, humid conditions.
Dirty Fuel

Another reason for small engines not starting easily is dirty fuel. Small particles, such as dirt, water, dust, insects, grass or rust, can stop up the fuel system and prevent the proper flow of fuel to the cylinder. Therefore, clean containers should be used to store fuel and a funnel with a mesh filter should be used to transfer fuel from containers to the fuel tank on the engine. Also, before re-fueling engines, the fuel tank cap and the area around it should be wiped off with a clean rag or an old, clean paintbrush. Finally, many metal fuel cans will eventually rust inside over time. Even those with epoxy coatings will eventually rust. Rust particles will flake off into the fuel and cause blockage problems in the fuel system. Thus, the inside of metal fuel cans should be checked, and if there is any visible rust, they should be replaced with new cans.

Obstructed Air Filter

Another main cause of small engine problems is foreign material entering the engine via the air filter. The air filter cleans air taken into the engine for the combustion process. If the filter has a damaged seal or if it does not make good contact with the filter housing it sits in, then dust and other material can bypass the filter and enter the carburetor. Dirt plugging or partially plugging the small fuel openings in the carburetor can reduce or stop the proper flow of fuel. This fuel flow obstruction can result in difficult starting or no starting. The air/fuel mixture ratio in most engines is about 10,000 parts of air to one part fuel. In other words, the air cleaner must filter about 10,000 gallons of air for every one gallon of fuel consumed by a gasoline engine. Thus, it is important to have a clean air filter.

Engine Oil Problems

A fourth major cause of small engine problems is associated with the lubricating oils. Lubricating oil can be a problem if:

▪ The wrong viscosity of oil is used
▪ The engine oil is not changed as often as required
▪ The proper amount of oil is not maintained in the engine during operation

Oil is sold in several viscosities, or thicknesses, which are used based on the type of engine and the conditions that the engine operates on most of the time. The Society of Automotive Engineers (SAE) sets testing guidelines for motor oils. For example, a lawn-mower used during the normal mowing season may require SAE-30 oil, while the same engine on a snow blower may require SAE-5W-30. The reason for the different viscosities in oils is due to the differences in weather and temperature at which the engine will operate. As temperatures decrease from freezing to several degrees below 0 degrees F, the oil thickens significantly. In fact, it may become too thick to flow and properly lubricate the engine. Therefore, if an engine is going to be operated in cold temperatures, it is important to use oil with a thinner viscosity.

Cold Weather Oils

Winter-grade oils, identified by a W in the viscosity rating, are needed under cold temperature (below freezing) operating conditions. In cold weather, a SAE 10W-30 or a SAE 5W-30 oil may be needed in place of a SAE-30 oil. The SAE-30 oil would be fine for temperatures above freezing.

Oils contain additives to improve the oil and to enhance its performance. One of these additives is a detergent to help keep the inside of the engine clean. Without this additive, the inside of the engine and the moving parts would accumulate a coating of material called oil sludge. Oil sludge is a greasy, black, sticky material that interferes with the proper lubrication process. Detergent additives keep the oil and the engine clean until they are either all used up or saturated with sludge. The engine oil should be changed before this occurs so that the engine stays clean inside along with the internal moving parts. The detergent additives are strongest when the oil is hot, so the oil should be changed at this time so all the sludge can be removed. However, while removing the sludge, extreme care should be taken to avoid the hot engine parts.
Most small engines are air-cooled. This means that they do not have a radiator and a water pump that circulate water and cooling liquids around the engine to help keep it cool. Instead, most small engines have a flywheel with small fan blades, or vanes, mounted around the outside edge that blow air over the engine to help cool it during operation. If the oil level in an air-cooled engine gets low, the remaining oil is subjected to extreme heat stress. Excessive heat is the worst enemy of engine oil. It causes the oil to break down, thin out and lose some of its lubricating ability. Therefore, the oil level should never be allowed to fall below the fill mark on the dipstick because this will damage the engine. On the other hand, overfilling the engine with oil can be detrimental also. Too much oil robs the engine of power and causes the excess oil to be burned off, fouling the spark plug.

Motor Oils for Four-Cycle Engines
The four primary functions of an engine lubricating oil are lubrication, sealing, cooling and cleaning.

Lubrication
Lubrication is the maintenance of a slippery surface, or an oil film, between moving parts. It is often referred to as “oiliness.” The lubrication must adhere very tenaciously to metal surfaces. It must resist being shoved away when either hot or cold, even though it is subjected to high pressures.

Sealing
Immediately following the burning of fuel in the combustion chamber of the engine, the gases formed are under high pressure. It is the pressure of these gases on the piston-head that is transmitted into working horsepower. The oil acts as a sealant to keep these gases from leaking past the pistons and valves. However, if the oil thins out too much, the gases will blow by.

Cooling
Although the cooling system removes much of the heat from an engine, the oil must also remove a large quantity of heat from the bearings and moving parts of the engine. Oil can reach a higher temperature than the cooling system fluid.

Cleaning
A variety of waste products are formed as fuel is burned in an engine. The type of fuel and the conditions of combustion influence the nature and the quantity of these waste materials. Many of these materials tend to remain in the engine and contaminate the oil. The oil holds these contaminants in a state of dispersion so

Ten Common Reasons Small Engines Will Not Start
1. The fuel tank is empty.
2. The fuel valve at the fuel tank is closed.
3. The engine has not been used for a long period and the fuel has aged.
4. The fuel in the re-fill can is old or dirty.
5. The fuel is dirty and has plugged the fuel system.
6. The spark plug is fouled.
7. The spark plug gap is too wide from long use and wear.
8. The air filter is dirty and not allowing air to enter the carburetor.
9. The spark plug wire is not firmly attached to spark plug.
10. The keyway in the flywheel is sheared or partially sheared and the engine ignition system is out of time (timing is off).
they may be removed when the oil is drained. If the oil is too thin or too dirty, it will be unable to hold the excess waste products and they will contribute to the formation of harmful, power-robbed deposits. To help with this cleaning process, additives are often added to the oil. Additives are discussed in more detail below.

**Oil Viscosity**

Viscosity is the measure of an oil's thickness and ability to flow at certain temperatures. It is also a measure of the physical ability of the fluid to maintain lubrication under specified conditions of operating speed, temperature and pressure. Oils that are thick, heavy and offer great resistance to flow - like molasses on a cold day - are said to possess a high viscosity. Oils that flow very easily - like water - are said to possess a low viscosity, or to be non-viscous. SAE viscosity number “A0” represents a low viscosity and number “A50” represents a high viscosity.

Viscosity is usually determined by counting the number of seconds required for a given quantity of oil to pass through a small orifice at an established temperature. The instrument used to measure viscosity is called a viscometer, and the most common unit of measure is called a centistoke. The SAE viscosity numbers constitute a classification of crankcase lubricating oils in terms of viscosity only.

Manufacturers of engines frequently recommend crankcase oils in terms of SAE grades that vary with the expected temperature of use. At air temperatures above 40 degrees F, the manufacturers may recommend an SAE grade of 30, 10W-30, 10W-40, 20W-50 or 20W-40. At air temperatures below 0 degrees F, the recommendation may be for SAE grades of 5W-20, 5W-30 or 5W-40.

**Viscosity Index**

All oils thin when they get hot and thicken when they get cold. However, all oils do not react to temperature changes in the same way. Two oils with the same SAE grade that possess the same viscosity at 100 degrees C (221 degrees F) may have radically different viscosities at different temperatures. An oil with little change in viscosity over a wide range of temperatures is said to have a high viscosity index (V.I.). Oils affected greatly by temperature changes have a low viscosity index. The high viscosity index is most desirable when additives are not used to cause the high index.

### Table 1. Sources of Crude Oil and the Respective Before and After Viscosity Ratings

<table>
<thead>
<tr>
<th>Source of Crude</th>
<th>Viscosity Index Before Refining</th>
<th>Viscosity Index After Refining</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pennsylvania</td>
<td>95-100</td>
<td>100-110</td>
</tr>
<tr>
<td>Mid-Continent</td>
<td>65-75</td>
<td>80-75</td>
</tr>
<tr>
<td>East Texas</td>
<td>50-60</td>
<td>80-95</td>
</tr>
<tr>
<td>California</td>
<td>0-35</td>
<td>40-65</td>
</tr>
</tbody>
</table>
Borderline Pumping Temperature and Pour Point

Borderline pumping temperature (BPT) is the lowest temperature at which oil in the oil pan will flow to the oil pump to provide adequate oil pressure to various lubrication points. When oil is used below its BPT, a flow restriction occurs. Lubrication points will not receive oil and component, or engine part, failure can result. The pour point of an oil is the temperature below which an oil will not pour. Wax in the oil will become solid and traps the oil such that it will not pour or flow.

<table>
<thead>
<tr>
<th>Cold Weather Viscosities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only SAE viscosities with a “W” are suitable for below freezing operations. This is because at these temperatures, BPT and pour point become factors.</td>
</tr>
</tbody>
</table>

Additives

To help keep engines operating trouble-free, it is necessary to add a number of chemical agents, or additives, to an oil. These agents have specific jobs to do in assisting the oil to function properly. Additives are used to enhance detergency, to improve oxidation resistance and to prevent rusting, corrosion and foaming.

Enhance Detergency

Detergency helps with the dispersion of the oil. A detergent is a cleaning agent. However, detergents are not for cleaning dirty engines; they are for keeping the engine clean. During fuel combustion, products such as soot, carbon, water, acids, lead salts and others are formed. The additive keeps these particles dispersed so that they cannot collect and form deposits on the engine parts. When the crankcase oil is drained, the contaminants are removed and the engine remains clean.

Improve Oxidation Resistance

In time, acids and sludge form because of oxidation. To reduce this possibility, additive agents are added to the oil. The additives help keep the oil cleaner and prevent corrosion of the engine parts.

Prevent Rust, Corrosion and Foam

During the combustion of fuel, combustion acids and water are formed. These can lead to the formation of rust and corrosion on the engine. To prevent this formation, additives are added. Additives can also prevent oil from foaming. Oil foams when it is churned with the air. Specific agents can be added to the oil to break up the foam and prevent it from exceeding an acceptable level. An excessive amount of foam is harmful because it interferes with the ability of the oil pump to intake and pump oil to the lubrication points of the engine. This is because the pump can only pump liquid, not foam.

American Petroleum Institute (API) Service Classifications

Performance levels of crankcase lubricants can be described in three basic systems: military specifications, manufacturer’s specifications and American Petroleum Institute (API) service classifications.

Military Specifications

Military specifications are written for times of national emergency. A large supply of a low quality oil may be acceptable to the military. The same oil may not be desirable for long-term continued service in an engine.

Manufacturer’s Specifications

Manufacturers may decide that current testing or performance levels are not satisfactory for their engines. They then use a manufacturer’s number to identify an oil that meets their requirements. Examples are Ford M2C253B, GM 6048-M and Mack EO-J.
API Service Classifications

In 1970, the API instituted a new classification system for engine oil. The new system was open-ended so that new grades could be added. Two basic categories of oil were named: S and C. The S oils would be sold at service stations and the C oils would be commercial oils. Also, S oils were for gasoline engines and C oils were for diesel engines. Table 1 describes and explains some facts about these oil grades.

Table 2. Oil Categories and Classifications

<table>
<thead>
<tr>
<th>API Service Classification</th>
<th>Military Specification</th>
<th>Manufacturers Specification</th>
<th>Recommended Use or Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA</td>
<td>None</td>
<td>None</td>
<td>Mineral oil</td>
</tr>
<tr>
<td>SB</td>
<td>None</td>
<td>None</td>
<td>Non-detergent oil</td>
</tr>
<tr>
<td>SC</td>
<td>None</td>
<td>Ford M2C101-A</td>
<td>1964-67 Gas engines</td>
</tr>
<tr>
<td>SD</td>
<td>None</td>
<td>Ford M2C101-B GM6041-M</td>
<td>1968-70 Gas engines</td>
</tr>
<tr>
<td>SE</td>
<td>None</td>
<td>Ford M2C253-B GM6136-M</td>
<td>Some 1971 and 1972 to 1979 gas engines</td>
</tr>
<tr>
<td>SF</td>
<td>None</td>
<td>Ford M2C153-B CM 6058-M Chrysler MS-6556</td>
<td>1980 and later gas engines</td>
</tr>
<tr>
<td>SG</td>
<td>None</td>
<td></td>
<td>1989 and later gas engines</td>
</tr>
<tr>
<td>SH</td>
<td>None</td>
<td></td>
<td>1993 and later gas engines</td>
</tr>
<tr>
<td>SJ</td>
<td>None</td>
<td>Ford M2C153-B CM 6058-M Chrysler MS-6556</td>
<td>1996 and later gas engines</td>
</tr>
<tr>
<td>SL</td>
<td>None</td>
<td></td>
<td>2002 and later gas engines</td>
</tr>
<tr>
<td>CA</td>
<td>MIL-L-2104A</td>
<td>None</td>
<td>Light-duty diesel engines</td>
</tr>
<tr>
<td>CB</td>
<td>US Army 2CI 04B</td>
<td>None</td>
<td>Moderate-duty diesel engines</td>
</tr>
<tr>
<td>CC</td>
<td>MIL-L-2104B</td>
<td>None</td>
<td>Moderate-duty gas/diesel engines</td>
</tr>
<tr>
<td>CD</td>
<td>MIL-L-45199</td>
<td>None</td>
<td>Severe-duty diesel engines</td>
</tr>
<tr>
<td>CE</td>
<td>MIL-L-45199</td>
<td>None</td>
<td>Severe-duty diesel engines</td>
</tr>
<tr>
<td>CF</td>
<td>MIL-L-45199</td>
<td>None</td>
<td>1994 or later off-road diesel engines</td>
</tr>
<tr>
<td>CF-2</td>
<td>MIL-L-45199</td>
<td>None</td>
<td>1994 or later two-stroke diesel engines</td>
</tr>
<tr>
<td>CF-4</td>
<td>MIL-L-45199</td>
<td>None</td>
<td>1994 or later high-speed, four-stroke diesel engines</td>
</tr>
<tr>
<td>CG</td>
<td>MIL-L-45199</td>
<td>None</td>
<td>1994 or later high-speed, four-stroke, off-road and highway applications</td>
</tr>
<tr>
<td>CH-4</td>
<td>MIL-L-45199</td>
<td>None</td>
<td>Four-stroke, off-road and highway applications</td>
</tr>
</tbody>
</table>

Synthetic Motor Oils

Synthetic motor oils raise many questions of quality and price when compared to conventional, petroleum-based motor oils. Synthetic motor oils are purported to be much better than petroleum-based oils and the price difference is substantial. However, many consumers wonder if the increased price for synthetic oils is justifiable. The following facts and information may assist in making decisions on the use of synthetic motor oils for lubrication needs.
Synthetic oil is a product made by scientists under controlled conditions. Synthetic oil is a pure, idealized lubricant made from select chemical base stocks and additives. It is engineered to perform under rigorous conditions and extreme temperatures. The molecules in synthetic oil are all the same size and shape. Synthetic oil is blended with a higher degree of lubricity, meaning it is slipperier. It contains more cleaning agents to keep the inside of the engine clean longer. Additionally, it contains no waxy contaminants that reduce lubrication in cold temperatures, and it contains fewer additives that can break down under adverse conditions, such as excessive heat and pressure.

On the other hand, natural petroleum-based motor oils are found in nature and contain natural contaminants. To make a natural petroleum-based motor oil, oil refineries take crude oil from an oil well and refine it by removing some of the contaminants and adding chemical additives to improve the performance and quality of the oil. However, some contaminants such as wax, which is difficult to remove in the refining process, remain in the oil. Natural oil is comprised of a mixture of hydrocarbons of assorted sizes and shapes.

**Precautions When Using Synthetic Oils**

If synthetic oils are going to be used in an engine, some precautions must be taken. Below is a list of these precautions.

- New engines should be broken in with a petroleum-based oil. This will allow moving parts to fit together before using a synthetic oil. Automobile engines should be operated at least 6,000 miles before changing over to a synthetic oil. Small engines, such as lawn mowers and garden tractors, should be used a minimum of 50 hours before switching to synthetic oil.

- Synthetic oils should not be used in older engines that are known to have heavy sludge deposits on internal engine parts. This is because the synthetic oil may clean false seals and actually cause the engine to leak or to start consuming oil. Also, older engines may have seal and gasket wear that causes oil to leak. Synthetic oil is too expensive to replace large quantities between oil changes.

- Synthetic oils should not be used in turbo-charged engines unless specifically recommended by the engine manufacturer.

- The same viscosity synthetic oil should be used as the petroleum-based oil recommended for the engine.

- The same oil change interval should be used for synthetic oil that would be used for petroleum-based oil, unless there is an oil analysis done at each oil change. If so, recommendations from the oil analysis results should be followed.

- Synthetic oil should not be used in diesel engines unless specifically recommended by the engine manufacturer.

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**Comparison of Synthetic Oil and Petroleum Oils**

- Synthetic motor oils will withstand higher engine temperatures than petroleum oils- 600 degrees F, as compared to 450 degrees F for petroleum oils.
- Synthetic oils will begin lubrication at lower temperatures than petroleum oils- about 35 degrees F, as compared to about 20 degrees F for petroleum oils.
- Synthetic oils contain molecules of the same size and shape. This reduces volatilization of molecules.
- Synthetic oils contain more detergent additives, which allows for more cleaning of internal engine parts.
- Synthetic oils are slicker than petroleum oils, which means less wear and tear, cooler engine temperatures and better performance.
- Synthetic oils are more resistant than petroleum oils to molecular chain shear, which reduces lubrication and cooling capability of the oil.
- Synthetic oils form fewer deposits inside the engine than petroleum oils.
Compatibility with Petroleum-Based Oils

Synthetic oils are completely compatible with petroleum-based oils. They can be mixed at any ratio with no problem. In fact, many users blend their oil to offset the extra cost of fully synthetic oil. Mixing will still provide some of the benefits of synthetic oil. A blend of 50 percent synthetic oil and 50 percent petroleum-based oil is a common mixture, but any amount of synthetic in the blend will improve the overall quality of the mixture.

Although in most ways synthetic oil is better than petroleum-based oil, the decision to pay the difference in price is the individuals. However, the application for the oil may help make the decision. Hardworking engines under a full load in hot temperatures will benefit most from synthetic oils. Also, engines working in cold climates will benefit from almost instantaneous lubrication.

Oils for Two-Cycle Engines

In 1947, the Society of Automotive Engineers established a standard for motor oils used in four-cycle engines. The standard was updated and changed in 1970 to reflect improvements in oil quality mandated by engine manufacturers. This current rating system for motor oils has assisted consumers in selecting the proper oil for use in their four-cycle engines. However, for a long time, there was no rating system for oils used in two-cycle, air-cooled engines. In fact, many owners of two-cycle engines used motor oil designed for four-cycle engines. The reason for this was that the four-cycle engine motor oils mixed well with gasoline and appeared to function as well as two-cycle engine oils. Unfortunately, in this case, appearances were deceiving. Four-cycle motor oil contains additives such as detergents, anti-foam agents, oxidation inhibitors and viscosity index improvers that prevent and interfere with proper lubrication of two-cycle engines. Additionally, two-cycle engine oils need to minimize spark plug fouling and residue formation. They also need to reduce pre-ignition, ring sticking, scuffing, carbon formation and crankcase sludge. These are the major enemies of two-cycle engines that reduce engine life and performance.

In 1975, the Society of Automotive Engineers (SAE) formed a committee to address the problem of two-cycle engine oil classification. In 1976, the American Society for Testing and Materials (ASTM) and the API joined SAE’s effort. These three organizations formed a group responsible for most industry-accepted lubrication specifications in the U.S. In 1988, following 12 years of development, the classification system for air-cooled two-cycle engines was completed.

Part of the problem of establishing a standard was that the oil for two-cycle engines is usually mixed with the fuel for combustion. Thus, problems were encountered in determining miscibility, which is the ability of the oil to mix with the gasoline, and fluidity, which is the ability of the oil to flow in oil injection systems. Fortunately, testing procedures and equipment that became available eliminated these two testing problems. The new classification system has been initiated at the request of two-cycle engine manufacturers. The new system is based on a combination of engine performance attributes and the oil’s physical properties. In the performance category, there are four designations for two-cycle oils: TA, TB, TC and TD. These designations are detailed below.

An oil’s performance rating is determined by a three-part engine test that evaluates anti-
scuff characteristics, ring sticking and engine cleanliness, and pre-ignition.

Physical properties of two-cycle oils are evaluated in the second part of the classification system. Miscibility and fluidity are the two properties tested. In the evaluation process, candidate oils are compared to ASTM reference oils at various temperatures. There are only four grades of four miscibility/fluidity. To achieve a particular SAE grade, a candidate oil must match the performance of the applicable reference oil. To determine miscibility, gasoline and the test oil are chilled to a target temperature. The gas is then poured on top of the oil and the mixture is turned over for a specific number of rotations. The number of rotations needed to obtain a homogeneous mixture of oil and gas is recorded. This number is compared to the number of rotations the reference oil required to form a homogeneous mixture. The candidate oil can then be placed in a grade based on performance when compared to a reference oil. To determine fluidity of a candidate oil, the oil is evaluated in a Brookfield viscometer. This instrument measures an oil's ability to flow in cold temperatures. When the oil is labeled for the miscibility/fluidity category, only one grade appears on the label. An oil certified under the new classification system would bear a label designation such as: API service TC, SAE Miscibility/Fluidity Grade 3.

The new classification system permits engine manufacturers to select a specific oil performance level for an engine and communicate these requirements to the consumer. The whole point of the system is to help consumers select the proper grade of oil for use with a particular engine. Although most manufacturers will continue to recommend their own brand of oil for use in their engines, if that particular lubricant is not available, an alternate oil of the same grade can be substituted. This system should eliminate confusion by engine owners as to selection of appropriate oil for specific engines.

### Mix Ratios for Two-Cycle Engines

Most two-cycle engine manufacturers specify a mix ratio for each engine they make. This mix ratio is the amount of gasoline and oil to be mixed for that particular engine. The mix ratio for a particular engine is determined by several things including maximum engine speed, manufacturing tolerances for the engine, duty cycle of the engine, and temperatures at which the engine will most likely be operated. A mix ratio is designated as a ratio of numbers such as 32:1. The 32 is the parts of gasoline in the mix and the 1 is the parts of oil in the mix. Therefore, a 32:1 mix ratio calls for 32 parts of gasoline to 1 part two-cycle oil mixed together. Thus, an engine designed for a mix ratio of 16:1 requires more oil in the fuel mix than does an engine designed for a 40:1 mix ratio. The parts are usually fluid ounces to make it easy to make smaller batches, but parts could be 32 gallons of gas to 1 gallon of oil. As most homeowners only need small quantities of gas/oil mixtures for normal use, mixes are usually specified to make a 1-gallon mixture of gasoline and oil. With a specified mix ratio of 16:1, the easiest way to determine how much oil is needed to make a 1-gallon mixture is to divide 128 ounces, which is 1 gallon, by the first number in the ratio. In this case it is 16, so 128 / 16 = 8. Thus, 8 ounces of oil would be used for every gallon of gasoline to make the proper 16:1 mix ratio.

Many homeowners have more than one two-cycle engine powering lawn or garden equipment. Each piece of equipment may require different mix ratios. Therefore, a separate container of fuel should be mixed for each engine that has a different mix ratio. However, most people do not want numerous gas/oil containers taking space up in their garage or storage area. Fortunately, there is a two-cycle oil product that can be used to make mix ratios anywhere from 1:1 to 50:1 using the same...
amount of oil in 1 gallon of gasoline. This product can be found at most hardware stores.

**Fuels for Small Engines**

The primary criterion used by most consumers to gauge the quality of gasoline is the octane rating. The octane rating of a fuel is a measure of how well the fuel burns during the combustion process inside an engine. Higher-octane level fuels tend to burn more smoothly and evenly in gasoline engines. Lower octane levels may cause an engine to knock. Knock is caused by an uneven combustion of fuel. It results in severe engine vibrations that produce high-frequency sound waves and a sharp metallic noise that may sound like a pinging or a knocking sound. Engine knock is produced while the engine is running, usually under loaded conditions. Besides producing an unpleasant sound, knock can be damaging to an engine because valves, pistons and bearings are subjected to abnormal forces and temperatures.

The octane rating scale was developed by the ASTM. The scale begins at zero and runs to numbers above 100. Fuels on the lower end of the scale, 0 to 85, tend to knock during the combustion process inside an engine. The engine manufacturer usually states the octane rating recommendations for a given engine. The compression ratio of an engine usually determines the recommended octane rating of the fuel to be used in the engine. Engines with high compression ratios, such as 8.5 to 1, can use higher-octane fuels more efficiently. The higher the compression of the engine, the higher the power output of the engine. This is because more of the fuel energy is converted to useful power.

Engines with low compression ratios may not need high-octane fuel. If the engine performs satisfactorily without knocking on lower octane fuels, use of high-octane fuels is wasteful and expensive. More crude oil is required to make a gallon of high-octane fuel than is required to make a gallon of low-octane fuel.

Motor and research ratings are test methods used to determine the octane ratings of fuels. Octane ratings found on pumps at gasoline stations will usually be an average of the motor-octane rating and the research-octane rating. Premium, regular and super grades of fuel are rough measures of octane ratings. Regular unleaded fuel will usually have an octane rating of 87. Premium grades will have an octane rating of 89 and super grades will have an octane rating of 91 or more. Most four-cycle small engines on lawn and garden equipment will require 87-octane fuel. However, it is important to always consult the owner’s manual to be sure that the proper octane fuel for the equipment is being used.

**Gasoline Additives**

In the past, tetraethyl lead (TEL) was commonly used to increase the octane rating of gasoline. The addition of 3 ml of TEL per gallon of gasoline raised the octane level about 10 points. Today, gasoline containing lead is difficult to find. This is because the Environmental Protection Agency (EPA) had the lead removed to reduce toxic emissions from automobile exhaust gases. Unfortunately, the removal of TEL as an additive to gasoline has created some problems for owners of older gasoline engines. This is because in addition to increasing octane levels, TEL had a secondary benefit of lubricating exhaust valves. Without lubrication from the TEL, exhaust valves and valve seats experience accelerated wear. Fortunately, in 1974 and 1975 manufacturers started using hard metal alloys for valves and valve seats. The hard metal alloys made TEL unnecessary for lubrication. Therefore, most engines built after 1975 do not need leaded fuel for valve lubrication. However, most engines built before 1975 will experience excessive valve wear if leaded fuel is not used.

Currently, additives are available to replace lead in gasoline, although many have not been tested to determine effectiveness as compared to TEL. Therefore, owners of older, pre-1975, engines should burn leaded fuel as long as it is available or until a valve replacement or grinding job is required for the engine.
Gasoline Volatility
Gasoline companies blend gasoline for the season of the year it will be used. Summer blends of fuel have low volatility, which means that they are less likely to evaporate. This prevents large amounts of vapor during hot weather. This can be very dangerous if fuel is stored in cans in garages or in other enclosed areas. Winter blends of fuel have high volatility so that sufficient vapor is present to easily start the engine under cold conditions. However, gasoline with high volatility is prone to carburetor icing and vapor lock under adverse atmospheric conditions. Therefore, for best starting and running results, gasoline should be used during the season for which it was blended. Storing winter fuels for warm weather use can be explosive, and storing summer blends for winter use can cause difficult starting. Spring and fall blends have volatilities somewhere between summer and winter fuel blends.

Fuel Stabilizers
Gasoline is best used before it ages more than about 90 days; but how fast a gasoline ages depends primarily upon temperature and humidity. High temperatures and high humidity tend to cause gasoline to age faster than cold temperatures and low humidity. Also, the addition of two-cycle oil to gasoline for two-cycle engines shortens the useful life of gasoline to about 60 days.

One way to lengthen the useful life of gasoline and gas/oil mixes is to use a fuel stabilizer. A fuel stabilizer is mixed with the fuel when the fuel is fresh. The stabilizer prevents volatilization of the lighter hydrocarbons that result in aged fuel. Several brands of stabilizers are sold in discount and auto-parts stores. Usually 2 ounces of stabilizer in each gallon of gasoline is sufficient to keep the fuel fresh for up to 2 years. However, stabilizer used with two-cycle oil/gas mixtures will usually keep the mixture fresh for up to 1 year. If oil/gas mixes in chainsaws, weed trimmers and similar two-cycle equipment contain stabilizer, then the tank and any containers should be emptied every year so that there will be no risk of fuel blockages caused by aging fuel.

Gasohol Fuels
Gasohol is a mixture of gasoline and alcohol. It is used as fuel in gasoline engines. In Tennessee, the most common form of alcohol used to make gasohol is ethanol. Ethanol is typically produced from corn and/or sugar cane. Federal law limits the amount of ethanol in gasoline to 10 percent of the total mixture. Most gasoline engines can use as much as 10 percent alcohol in the fuel without modifications to the existing fuel system. More than 10 percent alcohol requires significant adjustments to an engine to get proper combustion and performance. Federal law also requires fuel retailers to label gasoline pumps with the kind and amount of alcohol used to make gasohol.

Alcohol is mixed with gasoline to make gasohol for two primary purposes. First, using alcohol saves gasoline. Every gallon of alcohol used saves a gallon of gasoline. Second, alcohol is an excellent octane improver. Regular grades of gasoline usually have an octane rating of 87. Ethanol has an octane rating of 105. By mixing alcohol and gasoline, the octane rating of the gasohol mixture can be raised to between 89 and 93.

Ethanol is not the only form of alcohol that can be added to gasoline to make gasohol. Four other forms of alcohol can be used in varying amounts to make gasohol: methanol, methyl tertiary butyl ether, tertiary butyl alcohol and oxinol. Methanol is produced from coal, wood, natural gas or garbage. Normally called wood alcohol, it can be used up to a limit of 5 percent in the gasohol mixture. Methanol is poison to humans and animals and is very corrosive to fuel system components. Methanol has much less energy per gallon than gasoline and poses starting problems in cold weather. Methyl tertiary butyl ether (MTBE) is another form of alcohol used to make gasohol.
make gasohol. It is manufactured by combining methanol and isobutylene. MTBE has been banned for use in gasoline due to the contamination of clean water supplies. It was used for several years as an octane enhancer until it was detected in water supplies all over the U.S. Tertiary butyl alcohol (TBA) is permitted at levels up to 15.7 percent in gasoline. TBA is used very little in fuels today. Oxinol is a mixture of TBA and methanol. Oxinol is permitted at levels up to 9.6 percent in gasoline. Currently, oxinol is also rarely used to make gasohol.

Gasohol and Two-Cycle Engines
Gasohol usually works well in automobile engines and other four-cycle engines, although some problems have been attributed to gasohol when used in fuel-injected engines. However, big problems arise when gasohol is used in two-cycle engines. Gasohol poses three major types of problems for two-cycle engines: lubrication, deterioration of rubber and plastic parts, and corrosion.

Lubrication
Many two-cycle engines currently use lean fuel/oil mix ratios of 100:1 or 200:1. The oils used for these mixtures contain large amounts of additives that tend to separate from the mixture when alcohol is present. This separation leaves the engine with little or no lubrication to prevent wear and tear.

Rubber and plastic parts deterioration
Alcohol attacks the plasticizers found in many of the fuel system components such as fuel lines, carburetors, seals, floats and diaphragms. Plasticizers are chemical compounds that keep plastic parts soft and pliable. Fortunately, new materials are replacing components with plasticizers to reduce problems associated with alcohol.

Corrosion
Alcohol draws moisture from the air into a fuel system. The resulting corrosion can be severe. Engines stored for even short periods of time, as many two-cycle engines are, are prone to this type of damage. Damage can occur in as little as 1 week and it can be so severe that complete replacement of carburetors and fuel pumps is sometimes necessary.

Ethanol and Engines
Ethanol is by far the most common form of alcohol used to make gasohol in Tennessee. Some of the advantages of using ethanol are that it increases the octane rating, it is a renewable resource, and it produces less carbon monoxide and carbon dioxide than gasoline per mile. However, there are some disadvantages to using ethanol. Ethanol provides less energy per gallon, it is about twice the cost of gasoline to produce, it may promote smog formation as a gasoline additive, it is slightly corrosive to some fuel system components, and it is attracted to water chemically, meaning it can pull moisture into a vehicle fuel system.

Comparison of the Amount of Energy Provided by Ethanol Versus Gasoline
Ethanol contains 76,000 BTU’s per gallon; gasoline contains 115,000 BTU’s per gallon.

Preparing Small Engines for Off-Season Storage
Small engines that will not be used for several months should be prepared for storage before they are put away for the season. This will prevent damage to the engines and will help the engines to last longer and perform better when they are ready for use. Preparation techniques are discussed below.

- The outside of the engine should be cleaned to remove dust, oil, grease and other foreign materials. An inexpensive can of aerosol engine cleaner/degreaser will work well to clean the engine quickly and efficiently. The instructions on the can should be followed for best results.
▪ The engine oil in four-cycle engines should be drained while the oil is hot. The oil drain plug will be at the very bottom of the engine and will usually have a square head. On many push mowers, the drain plug will be underneath the mower deck on the bottom of the engine. After draining the used oil, the engine should be refilled with new oil of the proper viscosity as recommended by the manufacturer. Then, the engine should be run to circulate and coat the internal engine parts with new, clean oil. This procedure is important because used oil contains corrosives that can pit and corrode engine parts if they are left in the engine while in storage.

▪ The air cleaner should be serviced and replaced if needed. The air cleaner may be covered with a plastic bag to prevent insects, dust and foreign material from getting into the engine while stored.

▪ All gasoline should be drained from the fuel tank, fuel lines and carburetor. The fuel line should be removed at the carburetor and the fuel should be allowed to run out until flow stops. The engine should be started so that all the remaining fuel in the system is used. This procedure is important because gasoline can form gum and varnish deposits if it is allowed to remain in the fuel system for more than 3 months. These deposits can plug openings in the carburetor.

▪ If the equipment has a metal tank, then another option is to fill the fuel tank and add fuel stabilizer. If this is done, the engine should be run for 3 to 5 minutes to circulate the stabilizer throughout the fuel system. Metal fuel tanks can eventually rust from condensation if the tank is empty during the storage season.

▪ The spark plug(s) should be removed and a tablespoon of new oil should be poured into each cylinder. The plugs should then be replaced and the engine should be turned over by hand for two complete revolutions of the crankshaft to distribute the oil in the upper cylinder area.

▪ The entire engine should be covered with plastic, tarp or a similar material. The engine should then be stored in a clean, dry area. However, care should be taken not to seal the engine in plastic or tarps. This is because condensation can form and damage the engine.

▪ When engines are removed from storage, fresh fuel should be added and the engine should start with a few pulls of the starter rope.

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### What to do with Used Oil

Used oil should be put into a container and taken to the nearest oil recycling center when the container is full. A plastic gas can will work well for permanent use. Every county in Tennessee has at least one location for recycling. Call 800-287-9013 or the Tennessee Department of Environment and Conservation (www.tdec.net) for recycling locations in your county.

### Antifreeze for Water Cooled Engines

Air-cooled engines have been in use for many years and most operators are familiar with the maintenance procedures for these engines. However, more and more equipment manufacturers are building and selling lawn and garden equipment with liquid-cooled engines. Although liquid-cooled engines require extra maintenance for proper care of the engine cooling system, the extra maintenance will greatly extend the useful life of the engine and enhance the overall performance of the engine.

Liquid-cooled engines are made with built-in water jackets surrounding most of the engine block. Liquid is circulated inside the water jackets to remove surplus heat from combustion and friction while the engine is operating. A radiator and a fan are usually employed in the system to facilitate removal of excess heat by conduction and convection. The liquid circulated throughout the cooling system is usually a mixture of water and a chemical commonly called antifreeze. Most antifreeze...
Cooling System Mixtures

The most common mixture for Tennessee climates is one part water to one part antifreeze. This 50/50 mixture gives a freeze level of -34 degrees F and a boil-over protection to 265 degrees F.

Disadvantages to Some Additives

Some of the additives, such as silicates and phosphates, can lead to overheating, formation of silicate gels and hard water scales in the system.

solutions are either ethylene glycol or propylene glycol. Ethylene glycol is extremely toxic to humans and animals. Propylene glycol is non-toxic. When mixed with water, antifreeze mixtures will freeze at different temperatures depending on the ratio of water-to-antifreeze in the mixture. Distilled water, available at most grocery stores, should be mixed with the antifreeze because the mineral deposits in most tap water will cause plugging of the radiators and the small openings in the cooling system.

Antifreeze contains several additives that protect the engine and the cooling system. Additives include water pump lubricant, corrosion inhibitors, heat transfer enhancers, sealers and protectants. All of these additives are depleted over time and must be replaced periodically to maintain proper function and operation of the cooling system. The interval between replacements depends upon the type of antifreeze used in the engine. Traditional antifreezes require drainage from the system, flushing with clean water and replacement every 1 to 2 years or every 250 hours of use. Traditional antifreeze is usually green when new or greenish-brown if the system has some rust or corrosion. Comparatively, the newer, extended-life antifreeze lasts for 5 years or for 12,000 hours of operation. This longer-life antifreeze reduces the number of times coolant must be replaced and reduces the time and labor associated with proper maintenance of the cooling system. Extended-life antifreezes are orange, red or a similar color. They cost about one dollar more per gallon than traditional antifreeze and they save considerable time and expense over the life of an engine. Extended-life antifreeze uses organic additives that deplete very slowly and do a better job of protecting the engine and the cooling system.

NEVER mix extended-life antifreeze with the traditional green types of antifreeze!

Although switching over to extended-life antifreeze can save considerable time and expense on cooling system maintenance, before making the switch the owner’s manual or the equipment dealer should be consulted to verify that the cooling system is compatible with the new type of antifreeze. Fortunately, most systems are compatible with extended-life antifreeze.

Finally, the freeze level of a coolant mixture can be determined using inexpensive testers that can be purchased at discount and auto parts stores. However, the freeze level of a coolant mixture only gives an indication of the temperature that the mixture will freeze at in cold weather. Freeze level does not give any indication of the age or condition of the coolant mixture. Therefore, records regarding cooling system fluid changes and the types of antifreeze used need to be kept.

Ecofriendly Mowers

Reel mowers and electric mowers are becoming increasingly popular as more gardeners are becoming more environmentally aware. Both mowers have little to no emissions and are simple to maintain. The reel mower is considered practical for a lawn area of 8,000 square feet (0.18 of an acre). Reel mowers are powered by the pusher and can provide an excellent form of physical exercise, with well maintained machines requiring less effort.

Electric mowers are powerful options for gardeners and can provide many of the same options as gas-powered mowers Some of these options include a mulcher, power, price, adjustable height and coverage. Some electric mower models are corded and some are cordless-rechargeable.

Garden Tools

It is important to use the correct tool for the task and for the body (ergonomics). The size of the handles should be appropriate for the height of the gardener. Shorted handled tools (hoes, shovels, mattock) should be longer for
taller individuals. However, if a taller gardener is kneeling rather than standing, shorted handled tools are suitable.

Gardeners should always choose hand tools that fit the handgrip. There are ergonomic options that have extended handles, comfort grips and arm braces for gardeners with special needs. The better the tool fits, the more time an individual will be able to enjoy working in the garden.

**Maintaining for Garden Tools**

A properly maintained garden tool is sharpened, oiled and easy to use. Dull or rusty tools require more effort from the gardener. Many gardeners recommend creating an annual schedule to care or maintain tools. It is best to clean tools after each use or to clean them before storing them for the season.

Wooden handled tools (or fiberglass) should also be inspected annually. The causes of failure are usually due to weather and improper use or storage. Wood and fiberglass breakdown and deteriorate when exposed to the elements. These tools should be cleaned and sanded to remove any rough areas or potential splinters. Wooden handled tools can be wiped down with linseed oil or wood oil before storing. While cleaning, it is a good idea to check handle attachments, tighten bolts or determine if it is time to replace a handle. Preparing tools at the end of a season will allow gardeners to have tools ready to garden with in the early spring or later winter.

Shovels, pruners, loppers, clippers, shears, hoes and weeders need periodic sharpening and oiling of the blades. Shovels and hoes should not be as sharp as pruners or other cutting implements, but they will be more effective and function better if the dull edge is smoothed with a metal file. Hoes and shovels should never be sharp enough to cut a person.

However, pruners, clippers and shears must be sharp enough to cut through woody plant tissue. Caution should be taken when sharpening these blades. Some blades are considered “ever-sharp” and may be damaged by basic sharpening methods. Check the manufacturer’s information and follow the instructions for sharpening and care. Below are some basic tips for sharpening tools.

- Always wear gloves when sharpening any tool
- Open the tool wide (if sharpening a pruners loppers etc.)
- Oil the metal lightly
- Push the whet (sharpening) stone or metal file away from the body along the metal edge at a 20-degree angle; motorized sharpeners can be used for larger tools like shovels, hoes mattocks and axes
- Oil the blade again and store in moisture free area
Clean tools work better, and they are also healthier for plants. It is recommended to disinfect pruners and loppers after each use with a disinfectant spray or alcohol. If pruning disease material, gardeners should disinfect between each cut so that the disease is not spread to another part of the plant or to other plants in the landscape.

Sterilizing Pots
Pots used for planting should be free of soil, mold and fungus so that plants can start off in a healthy base. To clean: scrub pots with a pot-scrubbing brush and then soak in 10 percent bleach solution for 10 minutes. This sanitizing solution kills bacteria, viruses, fungi and insects on pots. Allow pots to air dry completely before stacking for storage or using to plant.

Summary
After reading this chapter, Master Gardeners should have a better understanding of when engine maintenance is needed and of how to read the instructions found in owner’s manuals. This chapter has described how to determine if an engine is a two- or four-cycle, how to maintain and correct common problems with each of these types of engines, how to select proper fuel and fuel mixes for these engines and what the purpose of anti-freeze is.

Test Your Knowledge
1. What are the four strokes of a four-cycle engine?
2. Explain the difference between how the oil is used in the four-cycle versus the two cycle engine.
3. What are three common oil problems in small engines?
4. Name three common problems with spark plugs that can cause an engine to fail to start.
5. Are synthetic oils compatible with petroleum-based oils?

Resources
The following materials are available from your local Extension service agent or the University of Tennessee Biosystems Engineering and Environmental Science Department, 2506 E.J. Chapman Drive, Knoxville, TN 37996. They can provide more detailed information about many of the topics discussed in this chapter.

Tennessee Department of Environment and Conservation
tn.gov/environment/swm/oil

The University of Tennessee Extension Publications
utextension.tennessee.edu