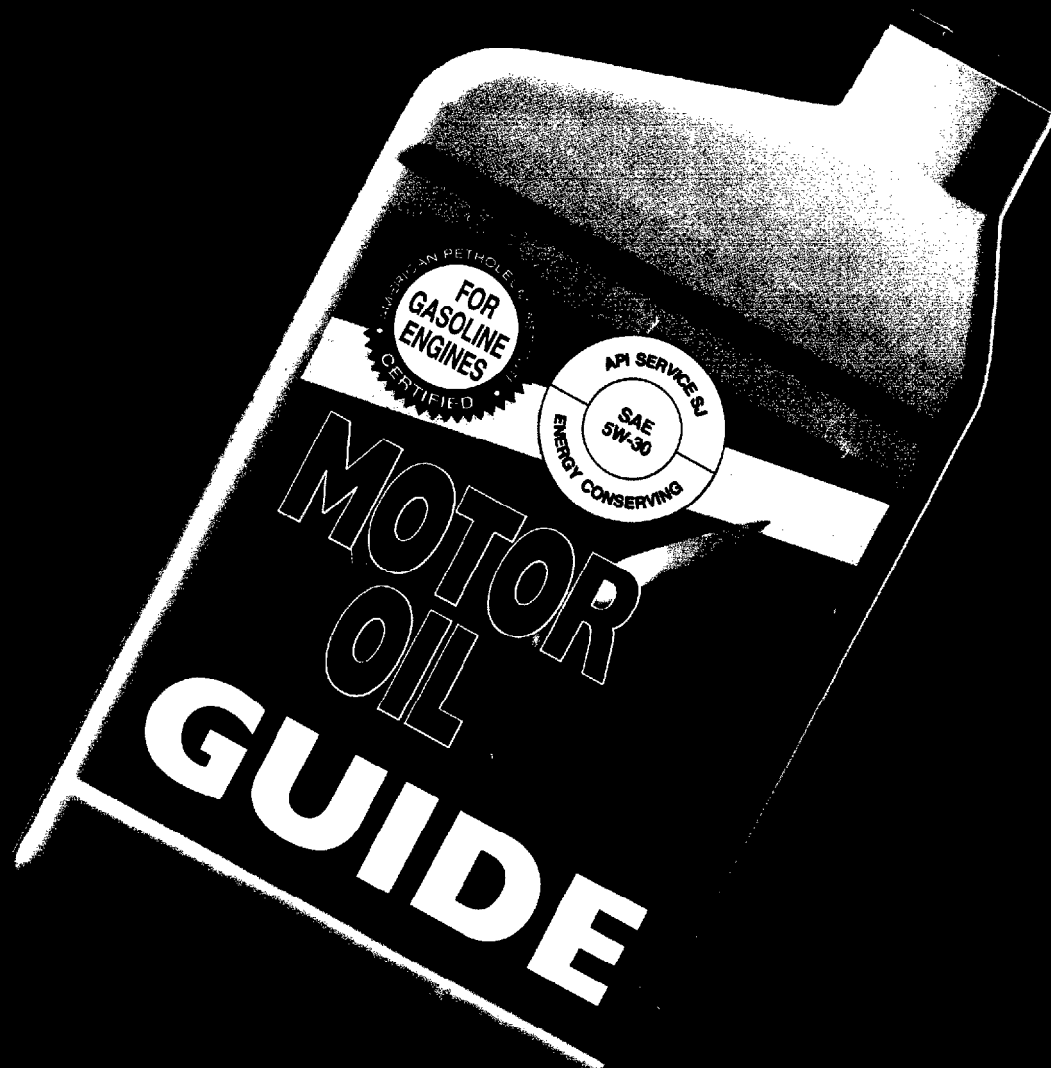
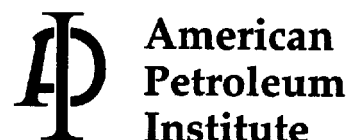




MOTOR OIL GUIDE

Manufacturing, Distribution and Marketing Department

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Foreword

This publication has been prepared to provide a better understanding of the important functions of today's motor oils and to explain what the motorist should do to protect and prolong engine life.

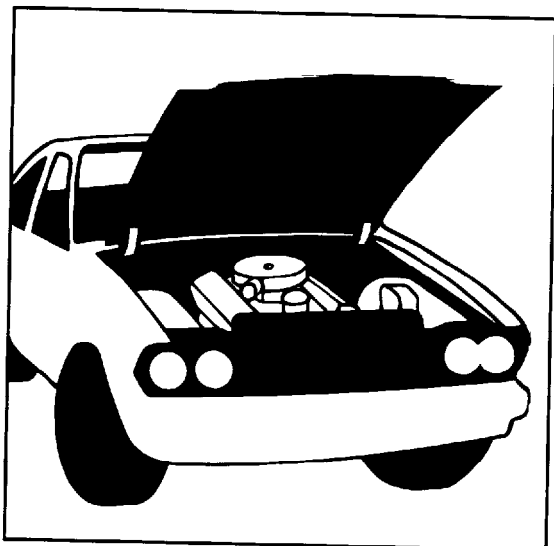
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THE IMPORTANCE OF ENGINE LUBRICATION



You've probably heard the phrase "Oil is the lifeblood of your engine." For a variety of reasons, this statement could not be more true, whether for your car, pick-up truck, eighteen-wheeler—whatever you drive. However, not just any oil will ensure the life of your modern engine. The oil needed by your engine for a long and trouble-free life should meet the viscosity and API performance category requirements specified in the owner's manual. Also, preventive maintenance, such as tune-ups and frequent oil and filter changes as recommended in the owner's manual, is essential for long engine life. Together, a quality motor oil that meets your engine's requirements and good maintenance are the lifeblood of your engine.

Modern motor oils are designed as carefully as the engines in which they are used. The oil designer evaluates the lubrication requirements of an engine under a wide variety of operating conditions. This work, coupled with knowledge of several basic functions of the oil, allows the designer to build an oil that performs satisfactorily in your engine.

One of the most important functions of a motor oil is to lubricate. An engine contains many moving parts that must be kept apart by a film of oil. Without oil, these parts can come in contact and produce severe wear. Hence, modern oils are designed to prevent engine wear by establishing and maintaining an oil film that is thick enough and strong enough to keep parts separated.

Similarly, a motor oil is designed to reduce friction between moving engine parts. Friction results from the resistance to movement of adjacent parts. In recent years, much automotive design work has been aimed at reducing internal engine friction to improve engine efficiency. Here again, the motor oil plays a major role by maintaining an oil film that keeps these surfaces apart. Additionally, the proper viscosity oil is necessary to ensure lubricant flow to critical areas and to minimize friction in both the engine and oil.

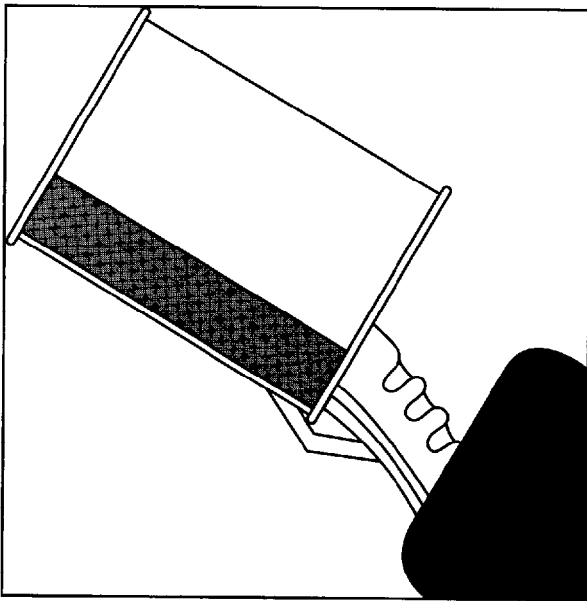
Today's motor oils do more than provide a lubricating film and reduce friction. An engine generates heat in a variety of ways, including heat from friction between closely fitted parts and during combustion of fuel. Motor oils also act as coolants to remove this heat. They remove heat generated by friction at the bearings and piston rings, for example. As the pistons and valve train heat up during engine operation, the oil must also cool these parts.

Along with wear, heat, and friction, deposits such as rust, corrosion, sludge, and varnish greatly affect the life of your engine. Today's motor oil must also prevent buildup of these deposits.

Not only must the oil be compatible with the seals and gaskets used in an engine, the oil itself also acts as a seal. Proper lubrication of seals promotes longer life in these parts by keeping them from becoming brittle. Also, the oil plays a vital role in maximizing engine performance by becoming the final seal between the piston rings and cylinder wall.

With all the functions of a lubricant, it's easy to see that today's engines demand a high-performing motor oil and a small investment in preventive maintenance to provide years of life. After all, oil is the lifeblood of your engine.■

WHAT A MOTOR OIL MUST DO



Permit Easy Starting
Lubricate
Reduce Friction
Protect
Keep Clean
Seal and Cool
Be Nonfoaming
Aid Fuel Economy

A modern motor oil is a highly specialized product carefully developed by engineers and chemists to perform many essential functions. The efficient operation of an engine depends on the motor oil to do the following:

- a. Permit easy starting.
- b. Lubricate engine parts and prevent wear.
- c. Reduce friction.
- d. Protect against rust and corrosion.
- e. Keep engine parts clean.
- f. Minimize combustion chamber deposits.
- g. Cool engine parts.
- h. Seal combustion pressures.
- i. Be nonfoaming.
- j. Aid fuel economy.

These requirements are easy to set down, but improvements in engine design and more demanding driving habits have made them increasingly difficult to meet.

Permit Easy Starting and Pumping

The ease of starting an engine depends not only on the condition of the battery, starter, and ignition system, proper fuel volatility, and air/fuel ratio, but also on the flow properties of the motor oil. An engine must reach a critical cranking speed in order to start promptly and keep running. If the oil is too viscous, it will impose excessive drag on the moving parts so that the critical cranking speed cannot be achieved, and the engine will not start.

Viscosity is a measure of the oil's resistance to flow. The property of oil that determines ease of starting is its viscosity at the cranking temperature and critical cranking speed. Since it is this resistance to flow that is responsible for most of the drag put on the starter during cranking, it is important to be able to measure a "cranking viscosity." The American Society for Testing and Materials (ASTM) has developed a test method to do this using an instrument called the cold cranking simulator (CCS). Viscosities measured

by this method have been found to correlate well with engine speed developed during low-temperature cranking.

Since cold temperatures thicken all oils, an oil designed for winter use must have a sufficiently low cranking viscosity to permit adequate cranking speeds at the lowest anticipated starting temperatures. However, having the proper cranking viscosity does not ensure that an oil is fluid enough to flow quickly and continuously to the bearings and other moving parts immediately after the engine starts. In the wintertime, parked, unattended vehicles are often subjected to extended periods of below-freezing weather, that can play havoc with an oil's ability to flow on start-up. All oils thicken when the temperature drops, but under these conditions there is also the danger that wax and additive components of the oil, that are normally in solution, may precipitate, and, in so doing, convert the oil to a gel or even a solid. This structural modification results in increased viscosity and poor flow characteristics.

Two types of engine pumping failures result from this. One type of failure occurs when the oil that surrounds the pump inlet screen is sucked into the pump, but is not immediately replaced by oil in the sump. Consider a conventional drinking straw partially immersed in a thick, viscous milk shake. If the bottom of the straw is near the surface of the liquid and fluid is sucked up the straw too quickly, a vortex forms around the base of the straw and air becomes mixed with the fluid in the straw. In the case of a gelled oil, the oil pump inlet screen can become starved for fluid when a vortex forms and does not collapse. Oil pressure becomes erratic as air is entrained and oil flow through the tube is insufficient to maintain lubrication. This is called an **air-binding failure**.

Another type of failure mode is also possible. Consider the straw and milk shake example again. This time, replace the conventional straw with one having a very small diameter. Now it becomes very difficult to pull much fluid through the straw. Sometimes pumping failures occur because the motor oil becomes so viscous that it simply cannot be pumped through the inlet tube and through the narrow passages that convey the oil to the moving parts of the engine. When this happens, the failure is called a **flow-limited failure**.

Fortunately, ASTM has developed procedures using an instrument called a mini-rotary viscometer, or MRV, that can be used to tell whether either type of failure is likely and at what temperature the failure may occur. In this test, oils are subjected to a two-day cool-

down cycle before evaluation at a specified temperature. Measurements are then taken to ensure that there will be no air-binding problem and that the pumping viscosity is low enough that flow-limited failures will not occur. The pumping viscosity is a measure of an oil's ability to be pumped through the oil pump inlet tube so that adequate oil pressure is obtained during the initial stages of operation. In addition to the MRV, a variety of other low temperature tests are often used by oil formulators to ensure that commercial oils have good pumpability characteristics at the temperatures for which they are designed to be used.

Since low-temperature properties are critical to starting and pumping, it is important to have the right oil in the crankcase when temperatures drop. This can be determined by consulting your vehicle owner's manual. The Society of Automotive Engineers (SAE) has established a viscosity classification system for crankcase lubrication oils. All motor oils are classified according to this system, which is used worldwide.

Single grade oils in common use today are labeled SAE 5W, 10W, 15W, 20W, 20, 30, 40, 50, and 60. Thick, slow-flowing oils have high numbers, while thin, free-flowing oils have low numbers. The W denotes oils that are suitable for use at low ambient temperatures. To ensure that W oils do, in fact, have proper flow characteristics, their viscosities are defined at appropriate low temperatures. For example, SAE 10W oils are tested in the CCS at -20°C (-4°F), while SAE 5W oils are evaluated for cranking viscosity at -25°C (-13°F) since they are designed for use at lower ambient temperatures. Even lower temperatures are used to establish that oils have good pumpability characteristics. The MRV test temperature for any W-grade oil is always 5°C (9°F) below the designated CCS test temperature. Thus, SAE 10W oils are tested in the MRV at -25°C (-13°F) and 5W oils are tested at -30°C (-22°F). SAE-designated oils without W designations are measured for viscosity at 100°C (212°F) to ensure adequate viscosity at normal engine operating temperatures.

When consulting the owner's manual, you may find recommendations include single grade oils as well as oils labeled SAE 5W-30, SAE 10W-30, SAE 10W-40, SAE 15W-40, SAE 20W-50, or other combinations. These oils are known as multigrade oils. They can be used over a wider temperature range than single grade oils. Their temperature/viscosity characteristics provide for easy starting and pumping at low temperatures; yet, they are viscous enough at high temperatures to lubricate like thick, single grade oils. These oils meet the viscosity requirements and do the

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work of two and usually three or more SAE viscosity grades. For example, an SAE 10W-30 oil is formulated to meet the CCS and MRV low-temperature viscosity requirements of an SAE 10W single grade and the high temperature viscosity requirements of an SAE 30 single grade.

Often multigrade oils are also called by names that imply all-season usage, since they perform satisfactorily in both winter and summer. Their availability stems from the use of high viscosity index base stocks and polymeric additives called viscosity modifiers, which enhance lubricant flow characteristics over a wide temperature range. An oil with a higher viscosity index is one that shows less change in viscosity over a wide range of temperatures.

Lubricate and Prevent Wear

Once an engine is started and pumping of the oil begins, the oil quickly circulates to all moving surfaces to prevent metal-to-metal contact that would result in wear, scoring, or seizure of engine parts. Oil films in bearings and on cylinder walls are sensitive to movement, pressure, and oil supply. These films must be continually replenished by adequate oil flow and proper oil distribution.

As mentioned earlier, the viscosity of an oil must be low enough at the starting temperature to permit rapid cranking and starting, and high enough at peak operating temperatures to ensure adequate engine protection. Once the oil reaches moving parts, the oil's function is to lubricate and prevent wear of the moving surfaces. In many parts of the engine the oil is expected to establish—and consistently replenish—a complete, unbroken film between surfaces. Lubrication engineers call this full-film or hydrodynamic lubrication.

Full-film lubrication occurs when the moving surfaces are continuously separated by a film of oil. The determining factor in keeping these parts separated is the viscosity of the oil at its operating temperature. The viscosity must remain high enough to prevent metal-to-metal contact. Since the metals do not make contact in full-film lubrication, wear is negligible unless the separated parts are scratched by particles thicker than the oil film itself. Crankshaft bearings, as well as connecting rods, camshafts, and piston pins normally operate with full-film lubrication.

Under some conditions, it is impossible to maintain a continuous oil film between moving parts, and there is intermittent metal-to-metal contact between the high spots on sliding surfaces.

Lubrication engineers call this boundary lubrication. Under these circumstances, the load is only partially supported by the oil film. The oil film is ruptured, resulting in significant metal-to-metal contact. When this occurs, the friction generated between the surfaces can produce sufficient heat to cause one or both of the metals in contact to melt and weld together. Unless counteracted by proper additive treatment, the result is either immediate seizure or the tearing apart and roughening of the surfaces. Today's motor oils contain extreme pressure/antiwear additives that minimize wear under boundary lubrication conditions.

Boundary lubrication conditions always exist during engine starting and often during the operation of a new or rebuilt engine. Boundary lubrication is also found around the top piston ring where oil supply is limited, temperatures are high, and a reversal of piston motion occurs.

Extreme pressure conditions can develop between heavily loaded parts from lack of lubrication, inadequate clearance, extreme heat, and sometimes as a result of using the wrong type or grade of lubricant for the operating conditions of the engine. In modern engines the valve train, with its cams, valve lifters, push rods, valve stem tips, and rocker arms, operate under conditions of extreme pressure because they carry heavy loads on very small contact areas. Unit loading, that may be as high as 200,000 pounds per square inch, is many times greater than the loads on the connecting rod bearings or on the piston pins.

Reduce Friction

Under full-film lubrication conditions, a thick film of oil prevents metal-to-metal contact between moving engine parts. Relative movement of these lubricated parts requires enough force to overcome the fluid friction of the lubricant. The viscosity of the oil should be high enough to maintain an unbroken film but should not be higher than necessary, since this increases the amount of force required to overcome this fluid friction. If the oil viscosity is too high, the engine must do additional work to overcome increased viscous drag. To do this work, additional fuel must be consumed, so engine fuel economy is reduced. This can also result in higher oil operating temperatures that put an increased strain on the oil's ability to impede oxidation.

Car manufacturers specify proper oil viscosity ranges by recommending the SAE grades according to expected atmospheric temperatures. This is to ensure that the lubricant will provide ade-

quate, but not excessive, viscosity at normal operating conditions. When oil becomes contaminated, its viscosity changes. With soot, dirt, oxidation, or sludge, viscosity increases; with fuel dilution it decreases. Both directions of viscosity change are potentially harmful to the engine. For this reason contaminant levels in motor oil must be kept low. This can be accomplished best by changing the oil and filter at proper intervals.

The amount and type of chemical additives become more important than viscosity to the effectiveness of a motor oil in reducing friction under the extreme pressure conditions of boundary lubrication. The proper balance of the total additive system in a modern motor oil is critical if all lubrication requirements of an engine are to be satisfied. The oil chemist can achieve this balance of motor oil compounding only through much research, with emphasis on proof-testing in actual engines, both in the laboratory and in field service.

Protect Against Rust and Corrosion

Under ideal conditions, fuel burns completely to form carbon dioxide and water. For a variety of reasons, an engine does not burn all the fuel completely. Unburned and partially burned fuel, either gasoline or diesel, may undergo complex chemical changes during combustion and, under some conditions, form soot or carbon. Some of this soot, water, and partially burned fuel escapes through the exhaust in the form of black smoke, particularly when an engine is misfiring or running rich. However, some of these combustion by-products may escape past the piston rings into the crankcase. This can cause numerous problems with which the oil must contend.

Water is one problem that the oil must deal with. For each gallon of fuel burned in an engine, more than one gallon of water is formed. Although most of this water escapes as a vapor out the exhaust, some condenses on the cylinder walls or escapes past the piston rings and is trapped, at least temporarily, in the crankcase. This occurs most frequently in cold weather before the engine has warmed up.

In addition to water and the by-products from incomplete combustion of the fuel, other corrosive combustion gases, such as nitrogen oxides, also get past the rings and are condensed or dissolved in the crankcase oil. Add to this the acids formed by the normal oxidation of oil, and the potential for rust and corrosion becomes significant.

The life of engine parts depends in part on the ability of the motor oil to neutralize the effects of these corrosive substances. Thanks to much research by oil formulators, effective oil-soluble chemical compounds have been developed. These are added to motor oil during manufacture to provide vital protection against rust and corrosion of engine parts.

Keep Engine Parts Clean

In formulating today's quality motor oils, a basic objective is not only to protect engine parts from rust and corrosion, but to keep these parts clean and prevent sludge and varnish deposits from interfering with proper engine operation.

Engine sludge formation is generally a problem of low engine temperature operations. Engine sludge deposits are formed by combinations of water from condensation, dirt, the products of oil deterioration, and the by-products of incomplete combustion of the fuel. Sludge-forming materials are often so small initially that no oil filter can remove them. They are much smaller than the thickness of the oil film on engine parts and therefore cause no wear or damage as long as they remain small and well-dispersed. However, as their levels increase in the oil during normal engine use, they tend to join together to form larger masses, and oil flow can be restricted.

Sludge formation is aggravated by water vapor that condenses in the crank-case during cold engine operation. The rate at which sludge-forming materials accumulate in the crankcase oil may be increased by several factors of engine operation, such as rich air-fuel mixtures which occur during starting or from poor engine tuning, operation with dirty air cleaners, or ignition misfiring.

Straight mineral oils have only a very limited ability to keep these contaminants from agglomerating and forming masses of sludge within the engine. Modern motor oils contain detergent/dispersant additives to keep parts clean and prevent sludge formation. In addition to using an oil meeting the API performance requirements specified in the owner's manual, regularly scheduled oil and filter changes will help maintain the oil's ability to disperse sludge.

Detergents/dispersants are also very effective in preventing varnish deposits within an engine. Varnish-forming materials react chemically or combine with oxygen in the crankcase to form complex chemical compounds. These compounds continue to react with each other and with oxygen and are baked by engine

heat into a hard coating on the hotter parts of the engine. The piston rings and pistons are particularly sensitive to varnish deposits. If varnish-forming materials are allowed to accumulate in these areas, engine operations are impaired or the engine may seize.

Engines cannot tolerate excessive amounts of sludge and varnish on sensitive parts. Sludge deposits collect on oil pump screens, limiting the flow of oil to vital engine parts, and result in rapid and destructive wear. Piston rings that are stuck or sluggish because of varnish accumulation prevent the engine from developing full power. Sludged or plugged oil-control rings prevent removal of excess lubricant from the cylinder walls and result in excessive oil consumption.

Minimize Combustion Chamber Deposits

In performing its lubrication function, some oil must reach the area of the top piston ring in order to lubricate the rings and cylinder walls. This oil is then exposed to the heat and flame of burning fuel, and part of this oil actually burns off.

Modern refining techniques have produced oils that burn cleanly under these conditions, leaving little or no carbon residue. The detergent/dispersant additives in modern motor oils keep the piston rings free in their grooves, thereby maintaining compression pressures and minimizing the amount of oil reaching the combustion chamber. This not only reduces oil consumption but, more importantly, keeps combustion chamber deposits at a minimum.

Excessive combustion chamber deposits adversely affect engine operation. Deposits that form on spark plugs may cause the plugs to short out. Deposit buildup causes pinging, knock, or other combustion irregularities that reduce engine efficiency and economy. Because these deposits act as heat barriers, pistons, rings, spark plugs, and valves are not properly cooled. This can result in damage or failure of the engine parts, necessitating premature overhaul.

In preventing excessive combustion chamber deposits, it is important that a motor oil accomplish two things:

- a. The oil must keep the rings free so that they can minimize the amount of oil reaching the combustion chamber, and
- b. The portion of the oil reaching the combustion chamber should burn as cleanly as possible.

Cool Engine Parts

Many people assume that engine cooling is accomplished only through the action of the water-antifreeze mixture used in the cooling system. In fact, this mixture does only about 60 percent of the cooling job. It cools several engine parts—the cylinder heads, cylinder walls, and the valves. The crankshaft, the main and connecting rod bearings, the camshaft and its bearings, the timing gears, the pistons, the turbocharger, and many other components of the engine are directly dependent on the motor oil for necessary cooling. All of these parts have finite temperature limits that must not be exceeded. Some can tolerate fairly high temperatures, while others, such as the bearings, must run relatively cool to avoid failure. These parts must get an ample supply of cool oil to pick up the heat and carry it back to the crankcase, where it is cooled by heat transfer to the surrounding air.

Some idea of the temperatures an oil experiences may be helpful in understanding the role of oil as a coolant. Combustion temperatures are 1093-1649°C (2000-3000°F). Certain parts of the valves may reach temperatures of 538-1093°C (1000—2000°F). Piston temperatures can reach 538°C (1000°F) and this heat travels down the connecting rods to the rod bearings. Tin and lead, which are the more sensitive of the metals commonly used in bearings, become very soft around 177°C (350°F). Tin melts at 232°C (450°F), while lead will melt at 327°C (620°F). After warmup, crankcase oil temperatures reach 93-135°C (200-275°F), and oil is supplied to the bearings at this temperature. The oil picks up heat at the bearings and leaves them at temperatures around 121-149°C (250-300°F), well below the critical temperatures of bearing failure. The continual cooling of the oil by recirculation to the crankcase is essential to maximizing bearing life.

To keep this cooling process working, large volumes of oil must constantly be circulated to the bearings and other engine parts. If the oil supply is interrupted, either by deposit formation, oil pump problems, or low crankcase oil levels, for example, these parts can heat up rapidly from increased friction and combustion temperatures or decreased cooling by the oil. A bearing failure is often referred to as a “burned-out bearing” because temperatures rose high enough to actually melt the bearing metal.

While only a small quantity of oil is required at any one time and any one place to provide lubrication, the oil pump must circulate many gallons of oil per minute in order to achieve lubrication and properly cool these parts. Chemical additives and the physical

properties of the oil have little effect on its ability to provide adequate cooling. What is critical is the continuous circulation of large volumes of oil throughout the engine and over hot engine parts. This is made possible through the use of an oil of the right viscosity for that engine, high-volume oil pumps, and oil passages adequate to handle the required volume of oil. These oil passages cannot do the job properly if they are allowed to become partially or completely clogged with deposits. When this happens, the oil cannot circulate or cool properly, and early engine failure may result. This is yet another reason for using the proper performance oil and for changing the oil before the contaminant level becomes too high. Proper cooling also requires that the oil level in the crankcase never be permitted to remain below the "add oil" line on the dipstick.

Seal Combustion Pressures

The surfaces of the piston rings, ring grooves, and cylinder walls are not completely smooth. If examined under a microscope, these surfaces would show minute hills (asperities) and valleys. For this reason, the rings alone can never completely prevent high combustion and compression pressures from escaping into the low pressure area of the crankcase with the consequent reduction in engine power and efficiency. Motor oil fills in these hills and valleys on ring surfaces and cylinder walls and helps to seal the combustion chamber. Because the oil film at these points is rather thin—generally less than 0.025 millimeter (0.001-inch) thick—it cannot compensate for existing excessive wear of rings, ring grooves, or cylinder walls. Where such conditions already exist, oil consumption may be high. Oil consumption may also be high in a new or rebuilt engine until the hills and valleys on these surfaces have smoothed out enough to allow the oil to form a tight seal.

Be Nonfoaming

Because of the many rapidly moving parts in an engine, air in the crankcase is constantly being whipped into the oil. This may produce foam, which is simply a lot of air bubbles that may or may not readily collapse. They normally rise to the surface and break, but water and certain other contaminants slow down the rate at which this occurs, and the result is foam.

Foam is not a good conductor of heat, so if the amount of foam is excessive, engine cooling will be impaired because the heat will not be dispersed. Foam also does not have much ability to carry