Reeds —

Volume 51 MAY-JUNE, 1965 Number 5

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

This Issue

TEXACO

DSW 202193

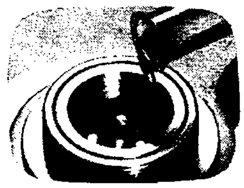
PUBLISHED BY
TEXACO INC.
TEXACO PETROLEUM PRODUCTS

Texaco's New Havoline has Reserve Lubrication: more lubrication than the other 6 top premium motor oils

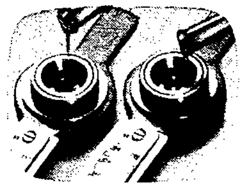
Who needs it?

You do. Because lubrication fails in more cars' engines than drivers realize. When it does, actual spot welding occurs. You never know it happens, though, because the power of the engine breaks the weld immediately. Jagged metal can be left to rip and gouge precision parts. Soon your car is burning more oil, guzzling more gasoline than it should.

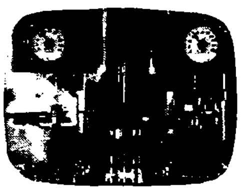
Here's proof!



1. In a regular industry test of motor oil, four steel balls are protected with the oil to be tested.

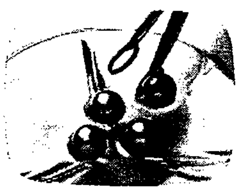


2. New Havoline is used on the right . . . a top competitive premium oil on the left.



3. The same extreme pressure is applied to both in these machines. Pressure that's actually designed to break the limits of lubrication.

4. Friction causes the balls to weld together with the competitive oil. The same thing happened when the 5 other leading competitive oils were used.



5. Under the same conditions Texaco's New Havoline, now with Reserve Lubrication, keeps right on lubricating. That's lubrication you can trust.

6. Trust *your* car to the man who wears the star. Texaco's New All-Temperature Havoline Motor Oil exceeds all car manufacturers' requirements.

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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AUTOMOTIVE ENGINE OILS

THE modern automotive engine and the high quality motor oil which lubricates and protects it are tributes to continuing research and product development. The numerous engine and power train options available show that terms such as displacement, brake horsepower and torque have real meaning to a high percentage of car buyers. Each year more of these knowledgeable motorists insist that the oil for their engines must be the best available. Such oils usually have a designation on the container to denote that the oil meets or exceeds all car manufacturers' service requirements. The wide acceptance of these high quality, premium, heavy duty motor oils is evidence that many car owners recognize that a fine engine is no better than the care it receives. The following article will show how better engines and better lubricants are companion developments.

In the day of the wooden spoke wheel and soft top sedan, engine lubrication was not very difficult. Engines were large relative to the power output, operating temperatures were low, clearances were large by today's standards and high oil consumption rates assured frequent new oil additions to the crankcase. Trips were infrequent and fairly long. Limited access, high speed thruways were still a dream and commuting to work with the family car was a matter of circumstances rather than desire. These factors imposed no severe work load on the motor oil. As automobiles became more dependable and more plentiful, demands for improved roads followed, and these made the use of the family car more frequent and more enjoyable. To many motorists a highly responsive automobile was a necessary part of this pleasure driving. High performance engines and high quality, specially compounded motor oils were introduced to the motoring public to fulfill this desire. Figures 1 through 4 show some of the engine changes made in recent years to reach today's performance level.[1]

ENGINE CHANGES

One measure of the performance of an engine is the brake horsepower. This horsepower, which is the horsepower available for useful work, has shown a steady upward trend over the past several years. Figure 1 shows the increase in brake horsepower over the past 15 years. The curve for maximum horsepower available in optional engines rose rapidly until 1958. From that date onward, there was a leveling off due to limitations imposed by the size of the engine and practical problems associated with increasing the horsepower further. The curve for average brake horsepower shows the effect of both the high horsepower optional engines and the low horsepower compact car engines. The high production compacts were partially responsible for the downward turn in the curve, but in recent years the trend is upward again due, in part, to the larger

[1] Data for the 1947-1957 period were shown in Lubrication for February, 1958.

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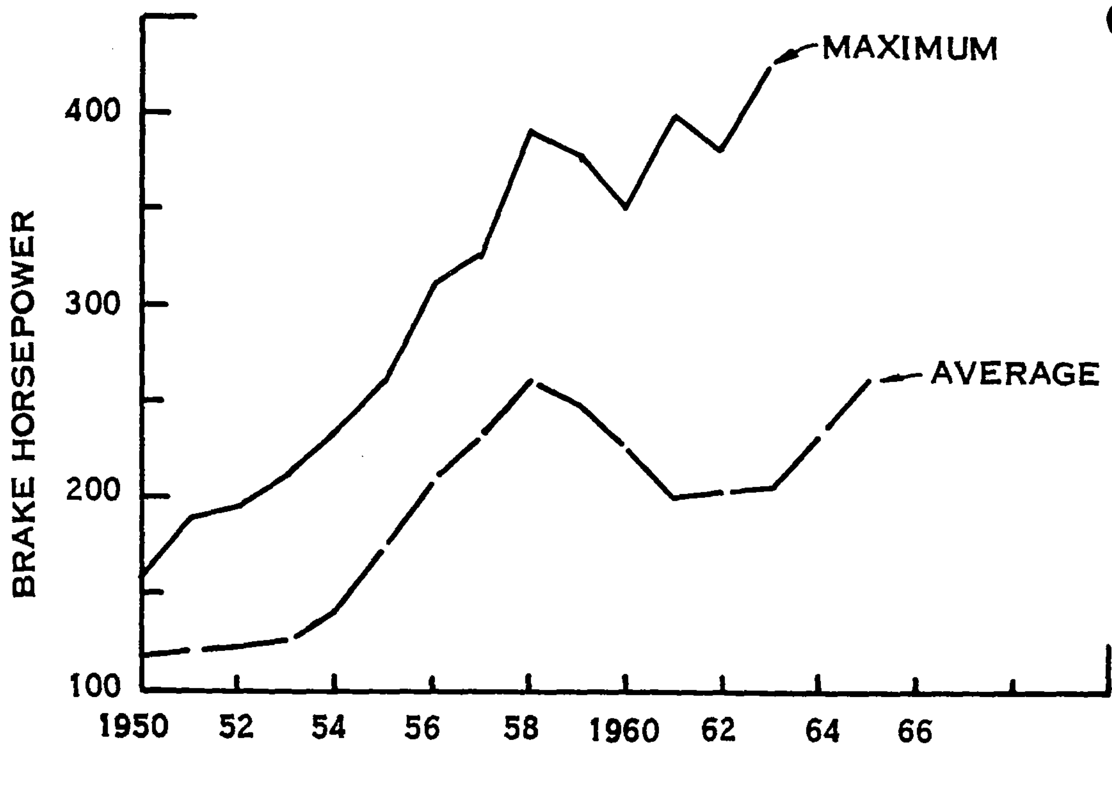

Figure 1 — Trends in passenger car brake horsepower.

engines now available in the compact cars. While the maximum brake horsepower curve was climbing, the curve for average engine revolutions per minute at maximum brake horsepower was also climbing, as shown in Figure 2. The trend in engine displacement is shown in Figure 3. The trend toward more horsepower per cubic inch of displacement is shown in Figure 4. All of these trends show that the automobile engine has been growing steadily more powerful and efficient. The use of the V-type engine made it possible to keep the physical dimensions of the engine within reasonable bounds and permit the use of low hood lines favored by automobile stylists. While many of these changes were readily apparent to the average motorist, other equally dramatic changes were taking place within the engine where the motor oil was called upon to perform ever more difficult functions. As engine clearances were reduced by improved manufacturing techniques, oil consumption was reduced. The oil in the crankcase had to last longer because frequent oil additions were not required. As engine speeds increased, oil temperatures increased: the oil had to resist oxidation. Increased engine speeds and horsepower necessitated the use of larger, heavier valves and heavier springs to close them: the oil had to prevent wear. As the use of the car increased, total fuel consumption increased and so did the amount of combustion by-products reaching the crankcase: the motor oil had to contend with these contaminants, many of which are acidic or corrosive by nature. The load on the oil was further increased by reduction in the crankcase oil capacity and extended oil drain periods. During the period between 1950 and 1965 the average capacity decreased from 5.3 quarts to slightly less than four quarts. These are but a few of the demands made on the crankcase oil by the engine. Other demands were made by the motorist. As engines became increasingly more dependable, the motorist expected his engine to start whenever he wanted it to start. The same charge of oil in the crankcase might have to function from sub-zero to hundreds of degrees above zero within a few minutes. The high quality, premium, heavy duty motor oil available from the local service station was expected to perform its many functions by the motorist whether the car was the smallest compact or the most powerful model available. The remarkable service performed by these oils is the result of the proper combination of carefully selected crudes, painstaking refining and the use of many types of specially manufactured chemical

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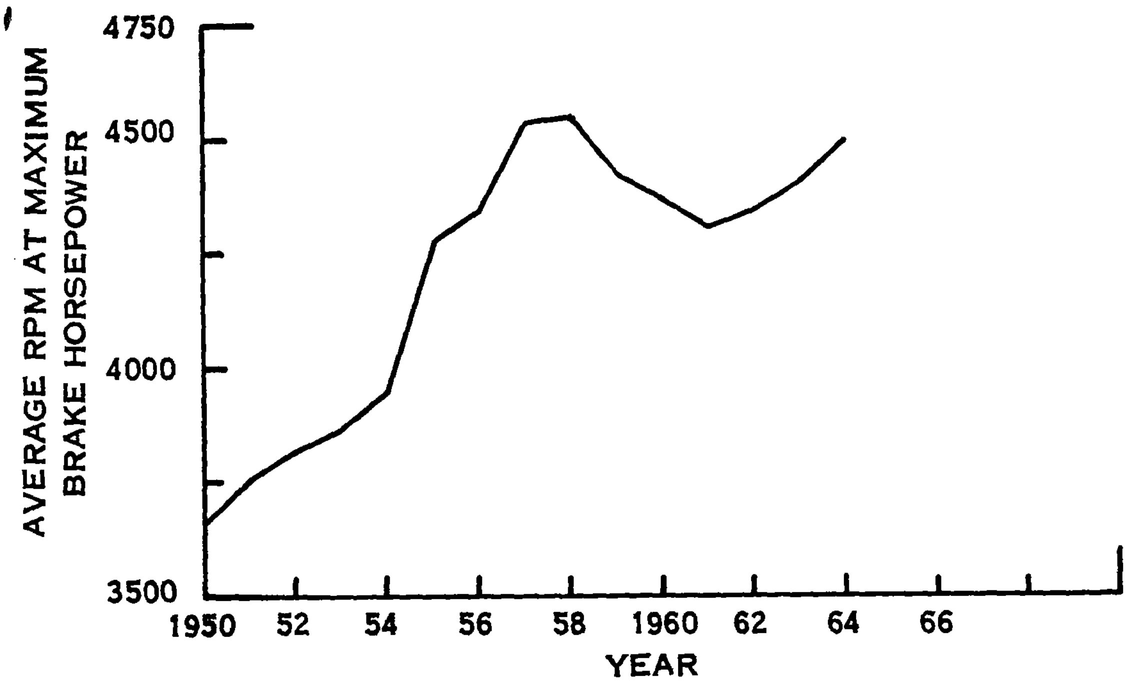

Figure 2 — Trend of average passenger car engine RPM at maximum brake horsepower.

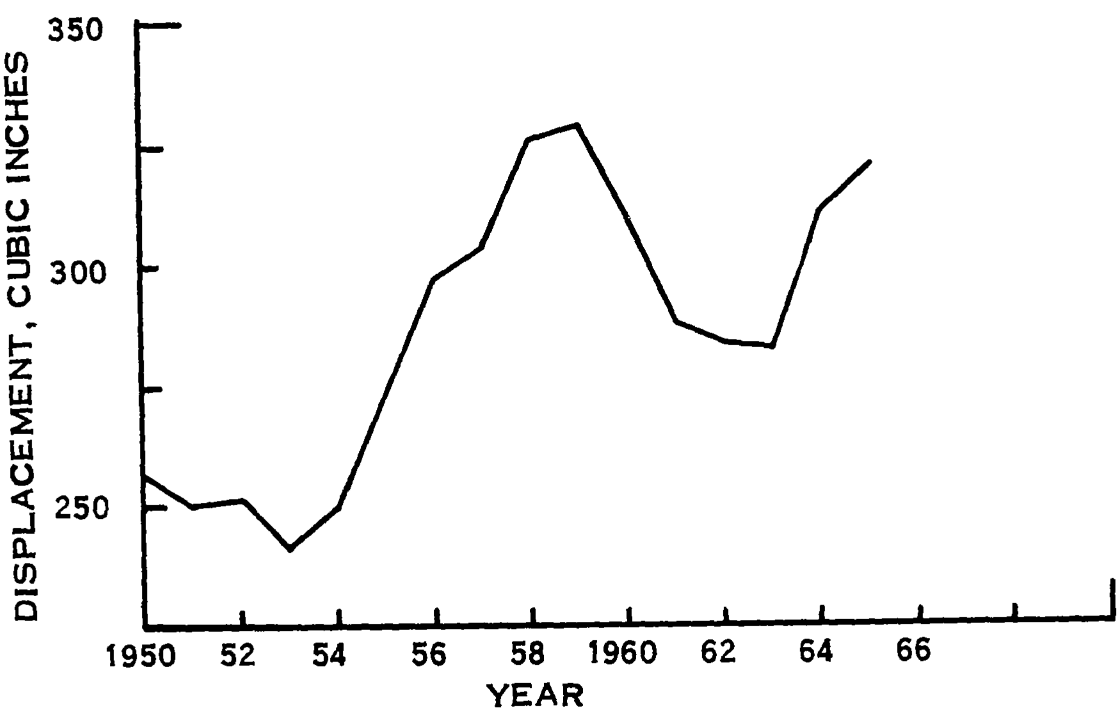

Figure 3 — Trend in passenger car engine displacement.

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TABLE I

COMMONLY USED AUTOMOTIVE ENGINE OIL ADDITIVES

ADDITIVE TYPE	TYPE COMPOUNDS COMMONLY USED	REASON FOR USE	POSSIBLE MECHANISM
Dispersants	Alkylpolyamides, alkyl P_2S_5 products, nitrogen containing methacrylate polymers, metal sulfonates, organic boron compounds.	Maintain engine cleanliness by keeping oil insoluble material in suspension.	Primarily a physical process. Dispersant is attracted to sludge particle by polar forces. Oil solubility of dispersant keeps sludge suspended.
Detergents	Term is often used interchangeably with "dispersant." "Detergent," however, implies a cleaning action in addition to a dispersing action. Since these materials exhibit only a mild cleaning action, the term "detergent" is being replaced by "dispersant."		
Viscosity Index Improvers	Methacrylate polymers, butylene polymers, polymerized olefins or isoolefins, alkylated styrene polymers, and various selected copolymers.	To lower the rate of change of viscosity with temperature.	VI improvers are less affected by temperature than oil. They raise the viscosity at 210°F. more in proportion than at 100°F. due to changes in solubility.
Oxidation Inhibitors	Zinc dithiophosphates, hindered phenols, aromatic amines.	Retard oxidative decomposition of the oil which can result in varnish, sludge and corrosion.	Decompose peroxides, inhibit free radical formation and passivate metal surfaces.
Corrosion Inhibitors	Zinc dithiophosphates, metal phenolates, basic metal sulfonates.	To prevent attack of corrosive oil contaminants on bearings and other engine parts.	Neutralization of acidic material and by the formation of a chemical film on metal surfaces.
Metal Deactivators	Zinc dithiophosphates, organic sulfides, certain organic nitrogen compounds.	Passivate catalytic metal surfaces to inhibit oxidation.	Form inactive protective film on metal surface. Form catalytically inactive complex with metal ions.
Anti-Wear, Extreme Pressure (EP), and Oiliness Film Strength Agents	Zinc dithiophosphates, organic phosphates, and acid phosphates, organic sulfur and chlorine compounds, boron-nitrogen compounds.	To reduce friction, prevent scoring and seizure. To reduce wear.	Film formed by chemical reaction on metal contacting surfaces which has lower shear strength than base metal thereby reducing friction and preventing welding and seizure of contacting surfaces when oil film is ruptured.
Rust Inhibitors	Metal sulfonates, fatty acids and amines.	Prevent rusting of ferrous engine parts during storage and from acidic moisture accumulated during cold engine operation. This is a specific type of corrosion.	Preferential adsorption of polar type surface active material on metal surfaces. This film repels attack of water. Neutralizing corrosive acids.
Pour Point Depressants	Methacrylate polymers, alkylated naphthalene or phenols.	To lower pour point of lubricants.	Wax crystals in oil coated to prevent growth and oil adsorption at reduced temperatures.
Foam Inhibitor	Silicone polymers.	To prevent the formation of stable foam.	Reduce surface tension which allows air bubbles to separate from the oil more readily.

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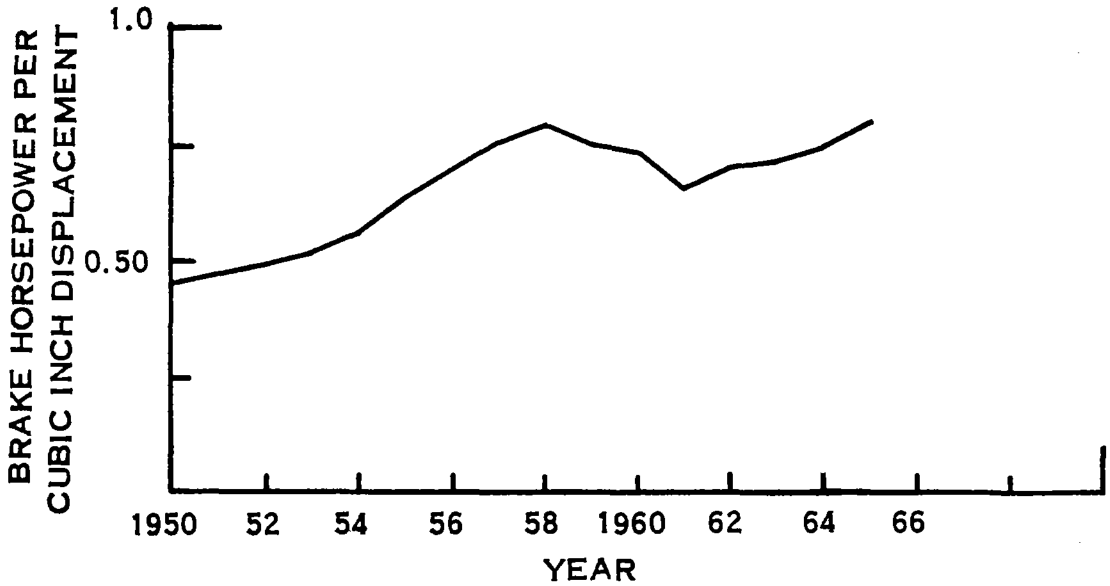

Figure 4 — Trend in passenger car engine brake horsepower per cubic inch of engine displacement.

compounds known as additives. Today's motor oil is the result of a continuing research and product development program. Oils are proven in terms of thousands of hours of engine operation and millions of miles of field testing.

MOTOR OIL FUNCTIONS

While the petroleum industry is continually improving oil quality by the use of new refining methods, the major advances in motor oils in recent years were achieved principally through the use of highly complex, synthetic chemicals called additives.[2] A brief discussion of some of the additives which have played a major part in recent advances in motor oil performance, why they are needed, and how they function are considered below. A summary of this information is shown in Table I.

Motor oils are required to carry out a number of functions to provide proper lubrication of the modern automotive engine. In addition to reducing friction and consequent wear, crankcase oils must also serve to keep the engine clean and free from rust and corrosion, to act as a coolant and sealant, and as a hydraulic oil in hydraulic valve lifters. Although the basic functions of the lubricant have not changed, the changes in the engine over the past fifteen years have made some of the tasks more difficult. The oil suppliers have, however, met the challenge. The quality oils of today are able to carry out their required functions better than ever before.

Dispersants

If an automobile engine is to operate efficiently and properly it must be kept clean. One of the major causes of contamination in present day engines is known to be low temperature, short trip driving. Operation of this type, which will be discussed in greater detail in a later section, produces engine blowby, soot, water, fuel varnishes and acids and lead salts which are the precursors of low temperature sludge. Excessive build-up of sludge can lead to the plugging of oil channels, oil pump screens, oil filters, hydraulic valve lifters and positive crankcase ventilation valves. Since it is presently virtually impossible to prevent sludge forming products from entering the crankcase, the next best thing is to prevent sludge from depositing in the engine. This is accomplished by the use of dispersant, or as they are sometimes called, detergent additives. The latter term is the older designation and is often used interchangeably with dispersant. Detergency, however, implies that the additives will clean or remove sludge and varnish deposits already formed in the engine in addition to keeping insoluble material in suspension. Since the actual mechanism is primarily one of dispersion rather than cleaning, the term "detergent" is gradually being replaced by "dispersant."

The main function of the dispersant additive is to suspend the insoluble material in the oil until it can be removed during the regular oil drain period. Although the mechanism of dispersion is not completely understood, it is generally believed to involve a physical process. Dispersant additives are usually long chain, oil-soluble polar materials. As sludge particles form in the oil, the polar portion of the dispersant molecules adsorb on their surfaces preventing agglomeration, thereby keeping them in suspension. In addition to this physical process,

[2] Magazine LUBRICATION, December 1958, "Development of a New Motor Oil."

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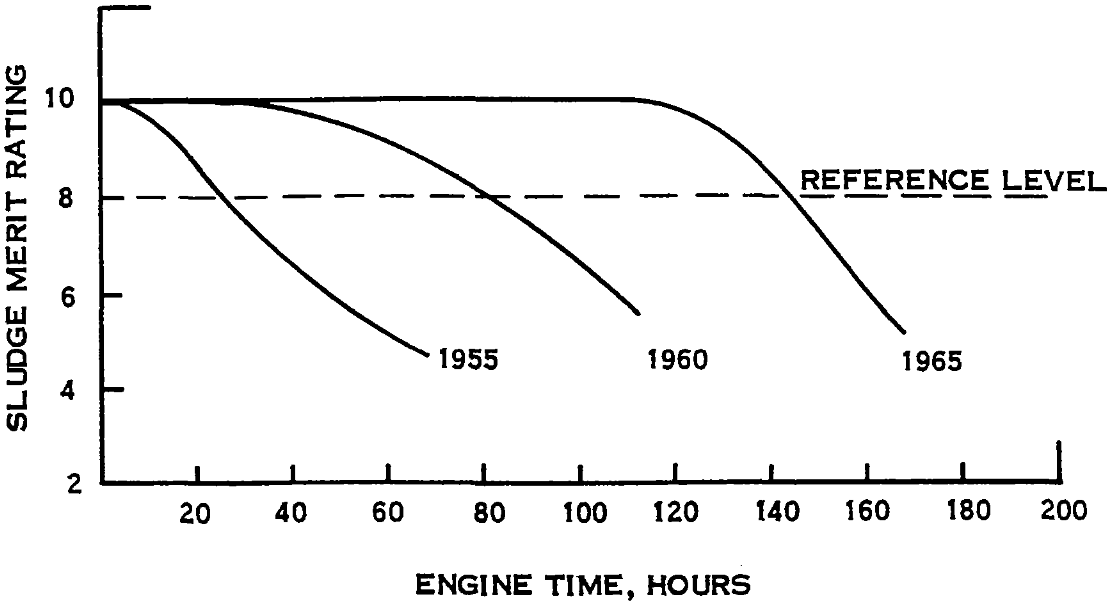

Figure 5 — Laboratory engine test data showing trends in passenger car motor oil dispersancy level.

it has also been postulated that some chemical reactions may also occur which prevent, or retard, the processes leading to sludge formation.

An example of the improvements in dispersancy which have been developed over the past few years is shown in Figure 5. As shown in this chart of laboratory engine data, premium heavy duty service station oils are now able to maintain a satisfactory engine cleanliness level (a sludge merit rating of 8) almost six times as long as the oils of ten years ago.

Motorists should be aware, however, that even the best oils cannot prevent abrasive wear from airborne grit: there is also a limit to the amount of sludge that they can keep in suspension. From the sludge prevention standpoint alone, the maximum permissible oil drain period is determined by engine operating conditions, engine mechanical condition and the dispersant-detergent qualities of the oil.

In the midst of the current confusion of oil drain recommendations, a reasonable, economical and engine-saving practice is: in winter every 30 days; in summer every 60 days; but never exceed car manufacturer's recommendations for the driving conditions prevailing.

VI Improvers

Motorists today expect satisfactory lubricant performance over a wide range of operating conditions. Starting at sub-zero temperatures may be followed by many hours of high speed driving on a turnpike. Oil drain periods may overlap seasons which can cover a variety of temperatures. Because of these factors, more and more motorists are using multigraded oils. These lubricants possess the viscosity characteristics of SAE 5W, 10W or 20W grade products at low temperatures and SAE 20, 30 or 40 grade products at the higher operating temperatures. This in effect allows the motorist to forget the seasons and to use the same grade oil all the year.

Multi-grade oils are possible through the use of polymeric additives known as VI[3] improvers. One of the explanations as to how these viscous additives function is through solubility. The polymers used for this application are borderline in solubility at the lower temperatures and, under these conditions, they curl up into small, colloidal balls. In this state they have a relatively small effect on the viscosity of the oil. At higher temperatures the solubility of the polymer increases, the molecules uncurl, and the long chains contribute to a considerable thickening of the oil. In other words, they increase oil viscosity more at high temperatures than at low temperatures and thereby decrease the effect of temperature and extend the permissible operating temperature range. Because of the convenience and outstanding performance of quality multigrade oils, these products are receiving increased acceptance by the motorist each year. An indication of the extent of this acceptance is shown in Figure 6.

Oxidation-Corrosion Inhibitors

Oxidation is the chemical reaction between the lubricant and oxygen of the air. It is accelerated by

[3] VI (viscosity index) is an empirical scale devleoped by the petroleum industry to give a single simple number to an oil's viscosity temperature characteristics: a high viscosity index indicates lesser sensitivity to temperature change. See magazine LUBRICATION, January and February 1961, "Viscosity."

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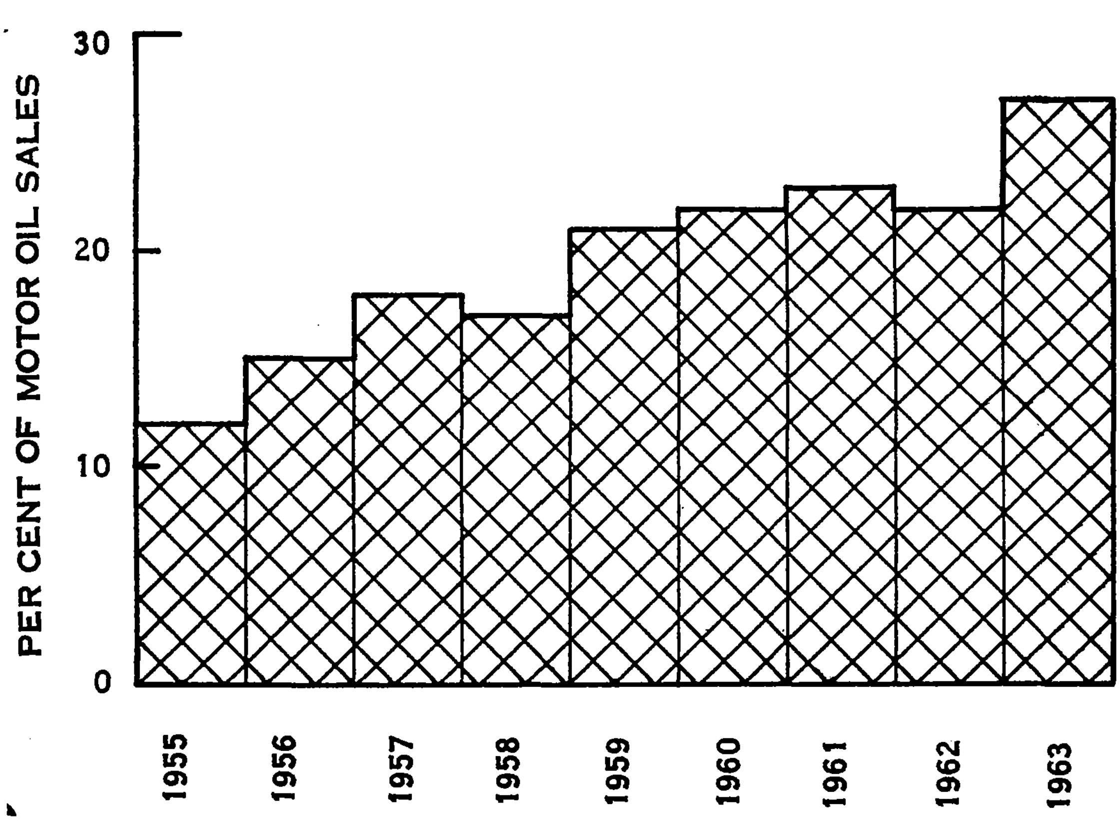

Figure 6 — Trend of service station sales of multigrade motor oils as a percentage of total motor oil sales.

high oil temperatures, vigorous mixing, and by contact with catalytic metals such as copper, iron, and lead. It can result in thickening of the oil, and in the formation of varnish, lacquer, sludge and corrosive materials which may attack corrodible bearings. Since oxidation is a degradation process which can limit the useful life of a motor oil, it is very important that it be retarded as much as possible.

Although the composition of motor oil hydrocarbons is complex and varied, studies of the oxidation of other less complex systems have led to a good understanding of the reactions involved and how they can be controlled.[4] It is presently believed that the first products formed in oxidation are organic peroxides as in reactions (1) and (2) below. These peroxides are unstable and on decomposition form free radicals which can cause a chain reaction. This chain reaction, which is referred to as autocatalytic oxidation, causes the oil to oxidize rapidly once the reaction has started (3). The reaction resulting from the decomposition of the hydroperoxide (4) can end in the formation of products such as water, alcohols, aldehydes and corrosive organic acids.

$$(1)\quad \underset{\text{(Hydrocarbon)}}{RH} + \underset{\text{(oxygen)}}{O_2} \longrightarrow \underset{\text{(free radical)}}{R'} + \underset{\text{(peroxide)}}{HO_2'}$$

$$(2)\quad \underset{\text{(Free radical)}}{R'} + \underset{\text{(oxygen)}}{O_2} \longrightarrow \underset{\text{(peroxide)}}{ROO'}$$

$$(3)\quad \underset{\text{(Peroxide)}}{ROO'} + \underset{\text{(hydrocarbon)}}{RH} \longrightarrow \underset{\text{(hydroperoxide)}}{ROOH} + \underset{\text{(free radical)}}{R'}$$

$$(4)\quad \underset{\text{(Hydroperoxide)}}{ROOH} \longrightarrow RO' + OH'$$

Though oxygen can't be removed from the system, the oxidation of motor oils is controlled by the use of additives called antioxidants. These chemicals may function through several processes. The additive may act as a metal deactivator on metals present which might catalyze the reaction, it may act as a free radical inhibitor, or as a peroxide decomposer. Aromatic amines or phenols have been found to function as inhibitors. Peroxide decomposers are usually sulfur containing compounds such as the commonly used dithiophosphates. The metal deactivators (or "catalyst poisons" as they are sometimes called) are generally organic sulfides, phosphites or thiophosphates. An oxidation inhibitor may, of course, function in more than one way, or several may be used in combination to provide protection under various kinds of service.

[4] Magazine LUBRICATION, December 1963 and January 1964, "Oil Stability Bench Tests."

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Anti-Wear Additives

One of the primary functions of a motor oil is to reduce wear. Wear should be limited as much as possible since it can result in poor performance and high oil consumption.

Wear may be caused by a number of different processes such as corrosion from the action of chemicals on the metal surfaces, metal to metal contact, and abrasion from dust or other wear particles.[5]

Corrosive wear is aggravated by any process which can lead to the formation of acidic materials in the oil. Short trip, stop-and-go driving which results in the condensation of moisture and corrosive blowby materials in the crankcase is particularly severe in this respect. Control is gained both through the use of alkaline additives which can chemically neutralize the acidic contaminants and by the formation of protective films on the metal. Because much of the inhibitor activity is the result of a chemical reaction, the additive material is actually depleted and no longer available for further protection. This depletion of additives is one of the major reasons for not extending the oil drain period beyond the time recommended.

Ideally, mechanical wear is prevented by hydrodynamic lubrication in which a film of oil completely separates the moving engine parts. Problems in lubrication occur when the oil film is reduced to molecular dimensions under certain conditions such as increased load and reduced speed. Metal to metal contact occurs if the oil film ruptures. This condition is known as quasi-hydrodynamic or boundary lubrication and may occur at the valve lifter-cam interfaces, valve tips, piston rings, timing gears, and other engine parts. Wear may take the form of a polishing action where the loss of metal is gradual or it may result in the actual welding and tearing away of metal particles. Since wear of this type is a surface phenomena it may be controlled by the use of additives which, by adsorption or reaction with the metal surface, change the frictional and anti-weld properties of the metals. Chemicals of this type are called anti-wear or E.P. (extreme pressure) additives. While there are many compounds containing phosphorus, sulfur or chlorine which show anti-wear or E.P. activity, the additives which have found the widest acceptance in automotive engine oils are the several zinc dithiophosphates.

The use of additives to prevent mechanical wear requires a considerable knowledge of the conditions and metallurgy involved, since chemicals which are sufficiently active to react with the metal surfaces may also cause corrosion unless used judiciously.

Rust Inhibitors

The importance of effective rust inhibitors has increased during the past several years because of the aggravating conditions of short trip, low temperature driving, combined with longer oil drain periods. Rust is the corrosion of ferrous engine parts resulting from the chemical or electrochemical action of oxygen and water from the air and water and acidic combustion products from the fuel. Rusting may occur on cylinder walls and other engine parts during periods of idleness. It may also occur in these and other areas such as push rods, valve lifter plungers and oil pump relief valves during engine operation.

Uninhibited mineral oils provide only very limited protection against rust: the severe conditions experienced in today's engines require the use of special anti-rust additives. Most of the additives used for this purpose are long chain, highly polar chemicals. The inhibitor molecules are adsorbed on the metal parts in closely packed mono-layers with the polar portion oriented toward the metal surface and the non-polar or hydrocarbon portion away from the metal. This forms a hydrophobic barrier which resists displacement by water and thereby protects the metal surfaces from rust.

Since rust can result in considerable engine wear and the malfunction of closely machined mechanisms like hydraulic valve lifters, research in developing even more effective additives for this purpose is a continuing effort by knowledgeable oil suppliers.

Pour Point Depressants

The pour point of an oil is the temperature at which the oil will no longer flow when cooled under certain carefully controlled conditions. Failure to pour may result from either excessive thickening of the oil, or because of the formation of wax crystals. Although wax in motor oils is in itself not harmful, the uninhibited formation of wax crystals at low temperatures can seriously alter the flow properties of oils thereby affecting low temperature lubrication. This is due to the growth and adherence of the wax crystals into lattice or gel-like structures which trap the liquid oil. The pour point is controlled to a certain degree by the selection of the crude stock and by refining. It is at this point that the actual wax content of the oil is controlled. This approach, however, is limited by the desirability of using certain stocks for motor oils, and by the economics of the dewaxing process. When it is necessary to reduce the pour point of wax type oils below the level obtained by the dewaxing process, this can be accomplished by the use of additives termed pour point depressants.[6] Materials which have been found effective for reducing the pour point are methacrylate polymers, alkylated naphthalene and alkylated phenols. These additives act by coating the wax

[5] Magazine LUBRICATION, December 1956, "Fundamentals of Wear."

[6] Magazine LUBRICATION, December 1961, "Lubricating Oil Processing Development."

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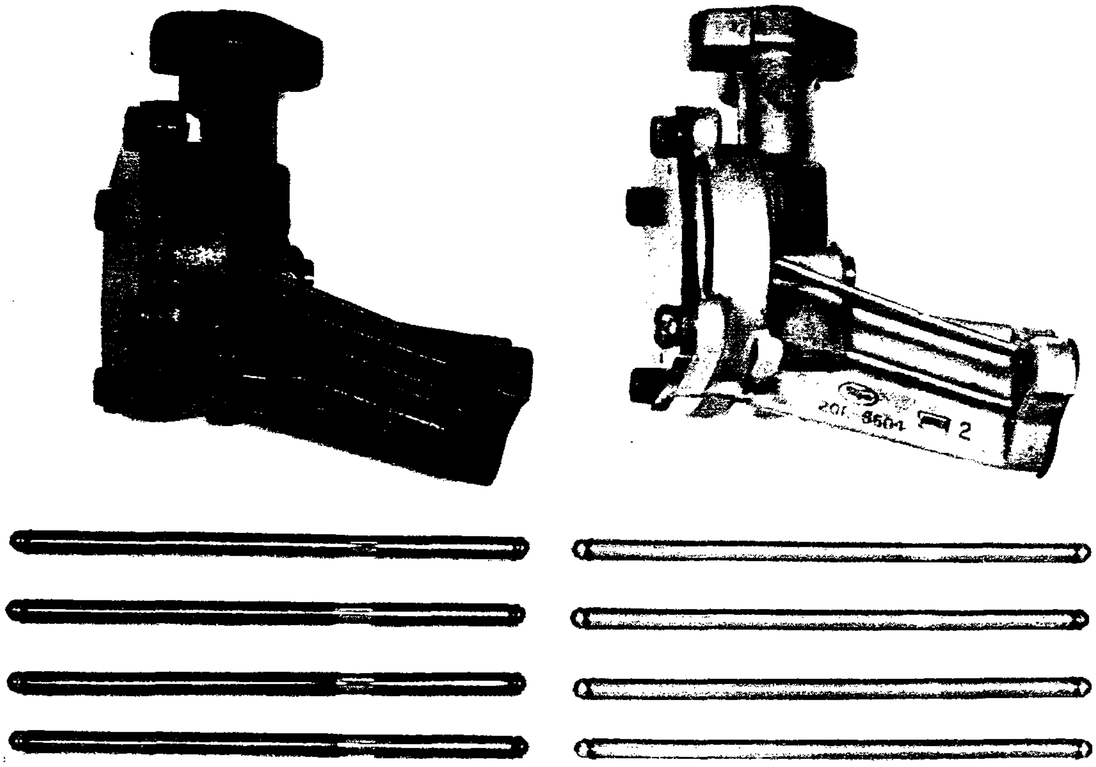

Figure 7 — Oil pumps and push rods from identical cars operated 12,000 miles under high speed, high temperature conditions with Oil "A" (reader's left) or Oil B (reader's right).

crystals as they are formed thereby checking their growth and preventing their adherence into a matrix structure.

Foam Inhibitors

When a complex liquid such as a motor oil is churned with air in an automotive engine oil pump, or splashed against the crankcase by the crankshaft, foam is likely to result. The persistence of the foam is enhanced by the additives used and is more stable in the more viscous oils than in the lighter grades. If uncontrolled, foam may become a real hindrance to proper lubrication and interfere with the proper performance of hydraulic valve lifters. While there are many types of compounds which have been suggested as foam inhibitors, the additives commonly used in motor oils are silicone fluids. Foam inhibitors of this type are extremely effective compounds with dosages of only a few parts per million providing satisfactory protection.

Foam inhibitors act by reducing surface tension which allows air bubbles to separate from the oil more readily. Additives which are effective foam inhibitors are usually insoluble in the oil and have a lower surface tension than the oil.

OPERATING CONDITIONS

It should be recognized that many of the above phenomena such as sludge formation, rusting, oxidation, and wear occur to some degree during all types of engine operation. There are, however, certain operating conditions that are known to accentuate or accelerate some of these phenomena over others. A discussion of two broad categories of operating conditions described as high temperature and low temperature operation is presented below.

High Temperature Operation

Only a few years ago long trip, high speed, high temperature operation was considered severe service. In many respects it was severe considering the limited power available and the fact that some engines were operating near maximum capability. Today's engines, however, are seldom required to develop more than a fraction of the output of which they are capable, consequently the average motorist has a comfortable power reserve for passing and hill climbing. The combination of steady throttle, high temperature, high speed operation and a quality crankcase lubricant has reduced this vacation type driving to the mild service category. The mild rating can only be applied to the steady high temperature operation of the modern engine with the modern high quality lubricant. Lesser lubricants are inadequate for this service. Figure 7 shows oil

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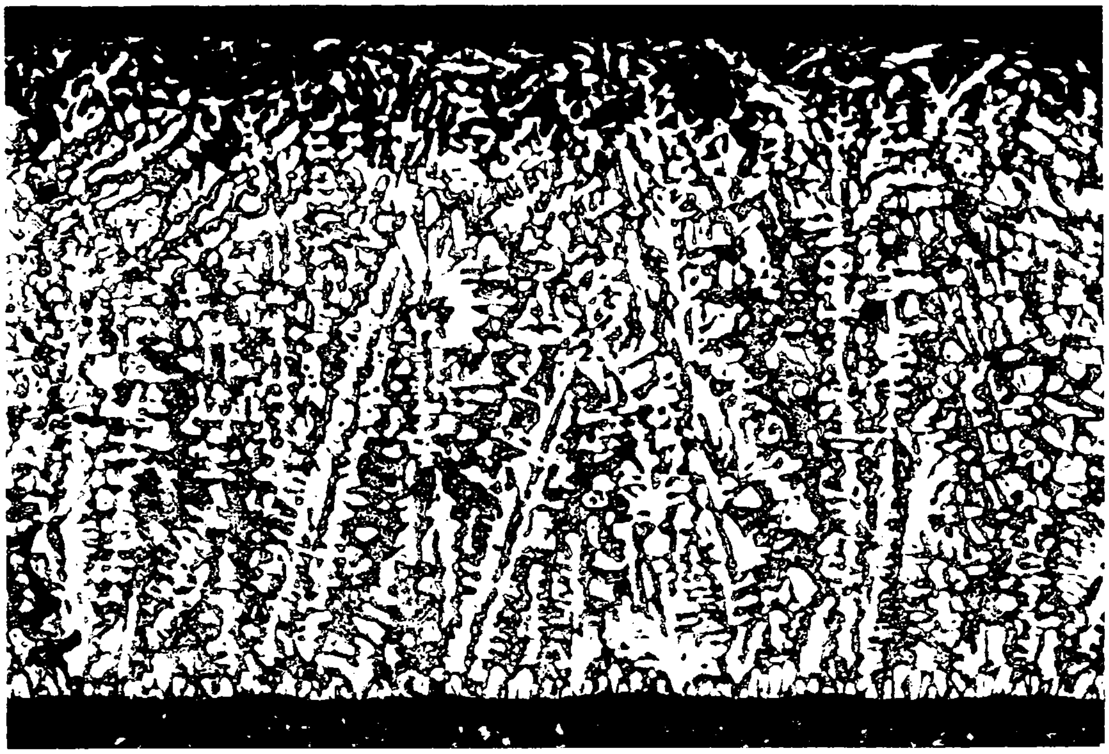

Figure 8 — Photomicrograph of cross section of a cast copper-lead bearing showing corrosive removal of gray-colored lead from the bearing surface (at top) to form black voids in the white copper matrix. Small portion of steel bearing backing shows at the bottom. Magnification, 130X.

pumps and push rods from identical cars operated under these high speed, high temperature conditions. Only the crankcase lubricants were different. Oil A would have been considered an outstanding lubricant by all standards only 5 years ago. Oil B is considered outstanding by today's standards. The difference in varnish deposits on these two oil pumps shows the improvement effected by new additives. Other effects of high speed, high temperature driving may be measured in terms of wear and bearing corrosion[7] in engines equipped with corrodible bearings. High temperature wear in the modern engine occurs primarily in the valve train which consists of camshaft, valve lifters, push rods, rocker arms and valves, and can actually be seen as well as measured in many engines. As discussed earlier in this article, certain types of additives, zinc dithiophosphates for example, are very effective in controlling valve train wear as shown in Table II. These data are from a standard laboratory engine procedure designed to measure wear. Oil A was fully compounded with heavy duty oil additives except that it contained no anti-wear additive. The wear measurements show the catastrophic wear observed with this oil. Oil B contained the same heavy duty oil additives plus about 0.50 per cent of an anti-wear additive. Wear is negligible. While this test demonstrates that some of these additives are remarkably effective, caution should be used in extrapolating too far from data of this type. There is no known anti-wear additive that can compensate for all of the possible factors contributing to wear. Misalignment, metallurgy, surface finish, loading, driving habits and many other conditions can affect wear and may render the most effective additive incapable of performing its intended function.

[7] Magazine LUBRICATION, July 1964, "Plain Bearing Failures."

TABLE II

Effect of Anti-Wear Additive on Cam and Lifter Wear

	Oil A	Oil B
Cam plus Lifter Wear, inches		
Maximum	0.1660	0.0044
Average	0.0358	0.0036
Number Scuffed		
Cam Noses	16	0
Lifter Crowns	4	0

In recent years the use of copper-lead bearings has increased because of their high load-carrying capacity. Copper is a poor bearing material and lead is too weak structurally to be used alone. However in a mixture (not alloy) of the two, the copper structure or matrix contributes the necessary mechanical strength while the lead provides a good

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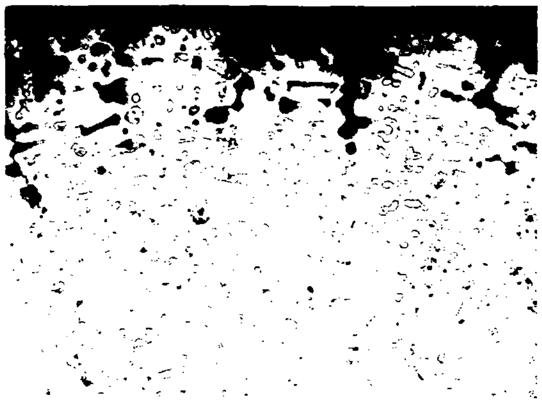

Figure 9 — Another example of lead corrosion in another cast copper-lead structure which left an irregular bearing surface (at top). Magnification, 200X.

low-friction bearing surface. The surface of many of these bearings is protected with a plating or "flashing" of corrosion resistant lead-tin alloy. Unprotected bearings are susceptible to corrosion. This corrosion is a condition which is also amenable to correction by proper choice of additives. High crankcase oil temperatures rapidly oxidize certain constituents present in the crankcase from both fuel and lubricant sources to corrosive chemicals which remove either lead or copper or both from unprotected bearings. When this metal removal becomes excessive, the bearing is no longer able to carry the load imposed on it and failure results. The consequences of this bearing failure can include any number of conditions from a bearing knock to virtual destruction of the engine. Bearing corrosion can be controlled within limits imposed by the type of additive used, structure and composition of the bearing materials and operating conditions, including oil drain period. The latter can be particularly important because some of the mechanisms of corrosion control consume the additive or render the additive incapable of providing further protection.

Examples of copper-lead bearing corrosion are shown in Figures 8 through 10 which present magnified cross-sections of the bearing surfaces. The upper part of Figure 8 shows a copper-lead bearing surface from which some of the grey-colored lead has been removed to leave black voids. The copper matrix (the white areas) has not yet been crushed although this would be expected momentarily with the bearing in continued service. The upper part of Figure 9 shows a lower magnification of another

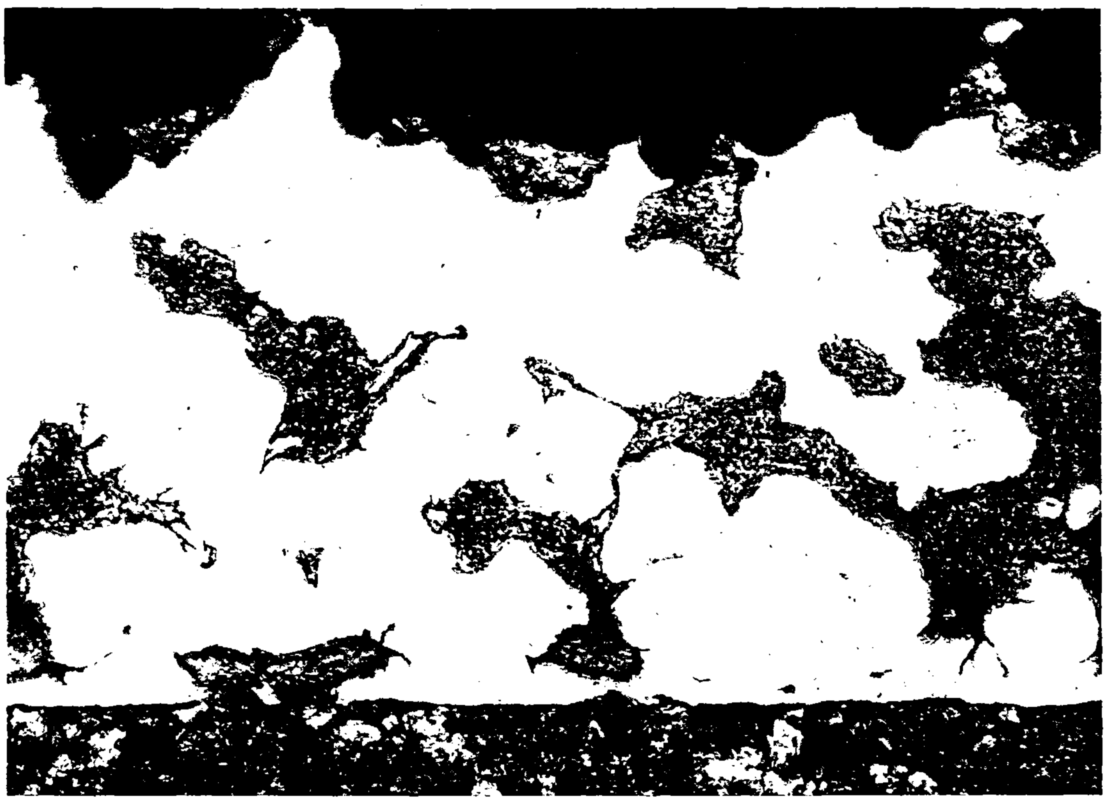

Figure 10 — Photomicrograph of cross section of a sintered (powder-metallurgy) copper-lead structure showing corrosive pitting of the white copper in the bearing surface (at top). Note that gray-colored lead on the bearing surface has not been corroded though some parts have broken away when the stronger supporting copper was removed by corrosion. Magnification, 240X.

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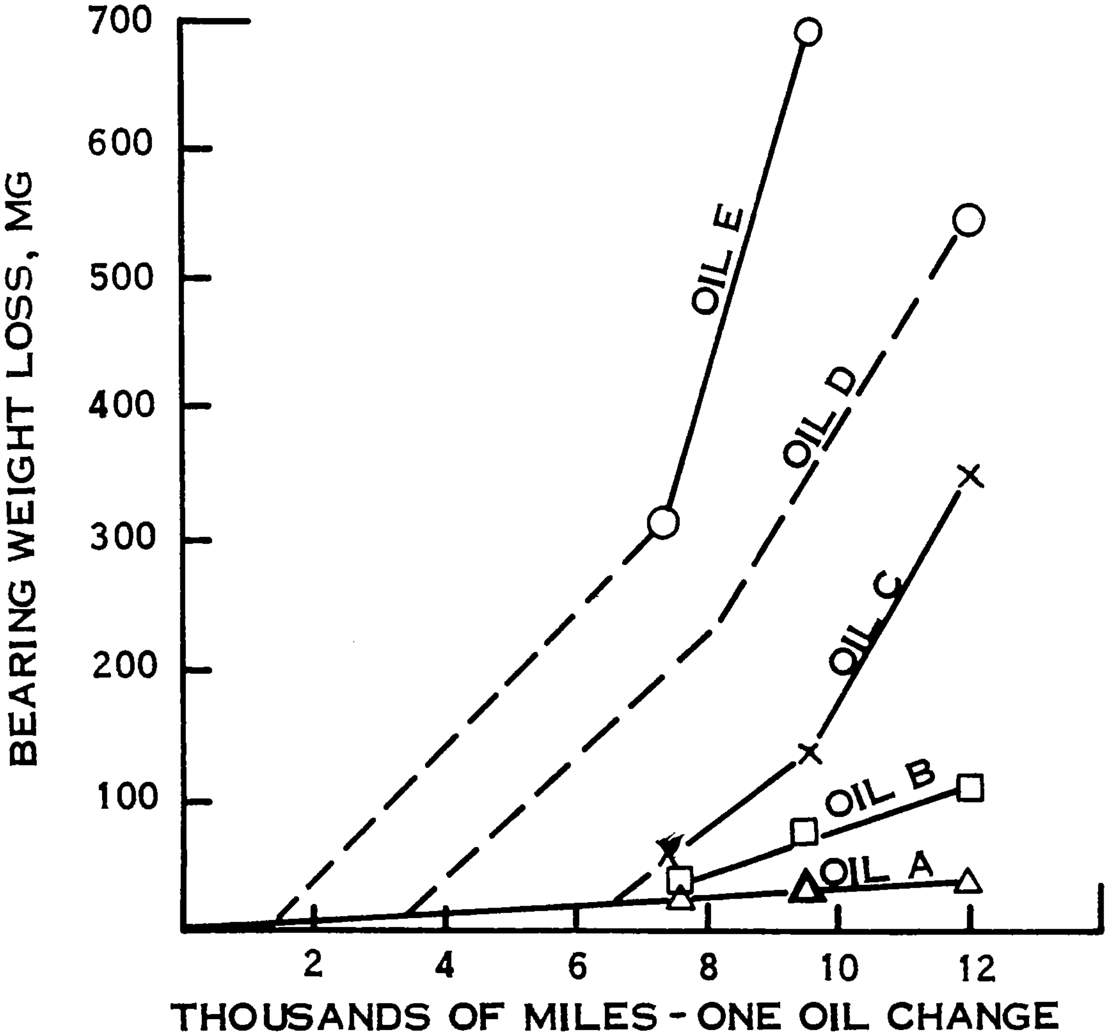

Figure 11 — Effect of type and concentration of corrosion inhibitor on copper-lead bearing weight loss.

bearing structure with the lead removed and incipient collapse of the copper matrix. Figure 10 shows another type of corroded bearing in which the white-colored copper at the bearing surface has been corroded while some of the grey-colored lead has broken away because of lack of support.

The data shown in Figure 11 were obtained during extensive road tests and nicely illustrate the distinction between normal bearing wear and bearing corrosion. The line shown for Oil A is actually a representation of bearing weight loss due to normal wear in this particular test because no corrosion was evident by microscopic examination. The other curves show that there is a period of normal wear with each oil followed by an abrupt increase in bearing weight loss as corrosion occurs. All oils contained heavy duty type additives and differed primarily in either the concentration or type of corrosion inhibitor used. Oil D was an outstanding oil of a few years ago. Oil A is a modern, high quality lubricant. In this particular road test, run under high temperature, high speed, steady throttle conditions, the extent of corrosion in Oil D was sufficient to produce audible bearing knock. The trained technicians driving these cars recognized this knock when it first became evident. However a less informed motorist might have driven the car until a major engine repair was required. Proper engine maintenance and careful attention to oil drain recommendations make this type of failure relatively rare. The men who developed the modern engines and the modern lubricants have the benefit of millions of miles of service testing behind their recommendations. These recommendations are made to protect and preserve the engine for the motorist with a minimum of inconvenience and are sound advice.

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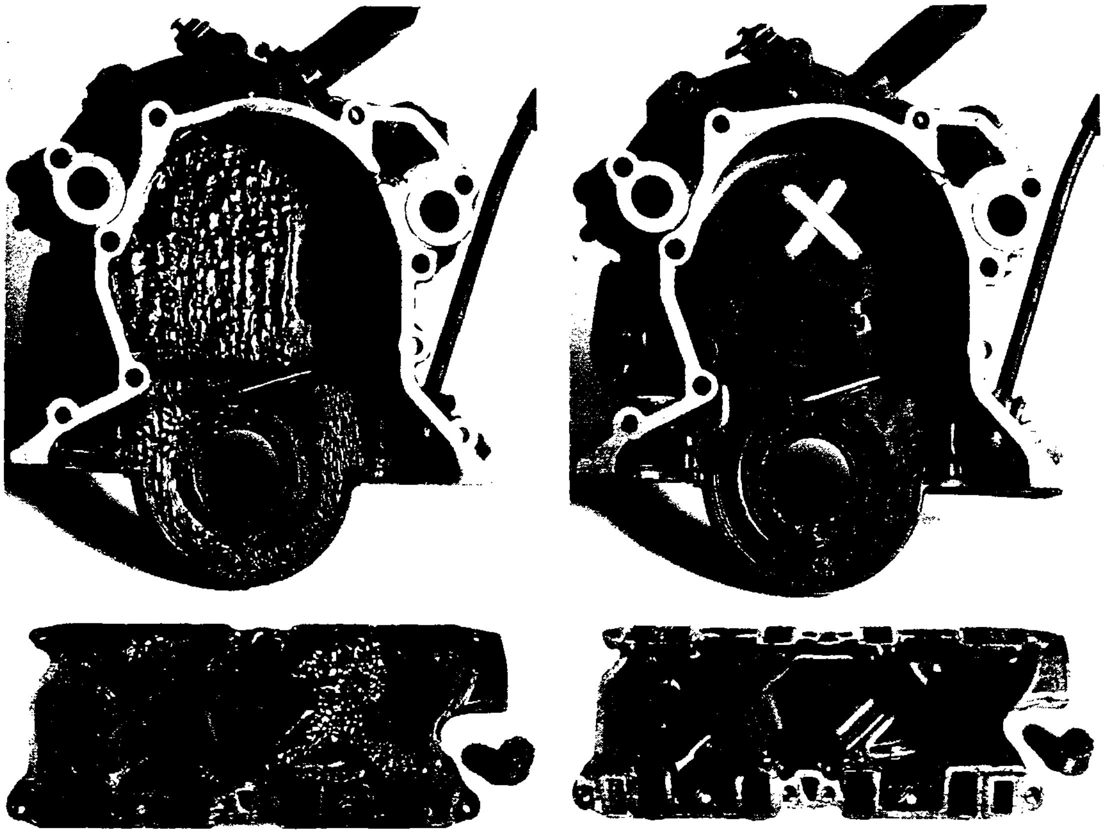

Figure 12 — Comparison between timing gear covers (upper) and valve chest covers (lower) after 10,500 miles of low temperature operation with an older type conventional oil (left) and a modern highly dispersive oil (right).

Low Temperature Operation

Urban and suburban driving greatly increase the formation of the engine blowby products responsible for sludge formation at such a rate that this stop and start, short trip driving is considered very severe service. The service is so severe, in fact, that taxi fleets are used extensively to evaluate new motor oil formulations. Unless the oil has exceptional protectivity, the consequences of this type of driving can be even more costly than those of the high speed, high temperature driving discussed above. While today's high quality lubricants are far more durable than earlier oils, they too must be changed at intervals related to the type of service imposed on the engine. An oil which will provide 60 days of safe lubrication under one type of service may have to be changed every week in a more demanding service. Failure to observe proper oil drain periods is an invitation to expensive engine repair. Sludge and rust which result from the short trip operation, (and this may account for up to 85 per cent of the usage of the average family car) are formed within the engine where they are never seen until trouble occurs.

Sludge resulting from short trip, partially warmed up, stop and go type driving collects on internal engine surfaces, including the oil pump screen and oil filter unless prevented by a quality oil. This sludge, and the other contaminants in the oil, can lead to major engine damage if oil passages are blocked or restricted. The effects of restricted oil flow include high wear, burned out bearings and scuffed or seized pistons and rocker arm shafts. Fortunately for today's motorist, some of the most pronounced, and quite recent advances in motor oil formulation have been in the ability to prevent the deposition of this low temperature sludge. There are a number of different types of additives that are effective for this service. While the mechanisms by which they function may not be the same in each case, the basic principle is to keep the particles so dispersed that they do not agglomerate and deposit within the engine. If sensible oil drain schedules are observed, the potential sludge forming materials are drained from the engine before the additives become ineffective. A relatively clean, efficient engine is the immediate benefit. A longer lasting, more dependable engine is the long term benefit.

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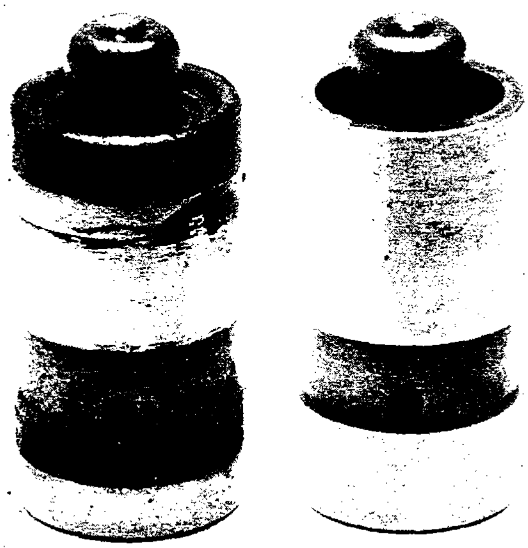

Figure 13 — Effect of different quality rust inhibitors on valve lifters used in low temperature operation.

Figure 12 shows the reduction in sludge deposition that is possible with a modern highly dispersive motor oil formulation. The heavily sludged engine components on the reader's left were removed from a relatively new car which had operated only a few thousand miles on a driving schedule which provided for about 85 per cent short trip, partially warmed up, stop and go driving and 15 per cent parkway type driving. The oil used was considered a top quality lubricant less than 5 years ago. The cleaner engine components on the reader's right were removed from a car of the same make and model, operated on the same driving schedule but using a modern highly-dispersant motor oil formulation. Oil drain periods were deliberately extended to 10,500 miles because this was a closely supervised, laboratory controlled test. With the shorter drain periods recommended by many oil suppliers, even lighter deposits would have been observed with the highly dispersant oil.

Some of the most critical internal engine surfaces to protect against rust are those of the hydraulic valve lifter plungers. Valve lifters are closely machined with clearances of one to two ten thousandths of an inch between their plungers and barrels. When clean and functioning properly, the average motorist is virtually unaware of their existence. When one or more of these closely fitted plungers sticks because of rust, dirt or varnish deposits, the noise is usually sufficient to require immediate correction. If rust is the offender and several of the lifters have to be replaced, the event can be expensive. Valve lifters can be kept relatively free from rust and functioning properly by the use of high quality motor oil containing an effective rust inhibitor coupled with sensible drain periods. An example of the protection afforded by one such product is shown on the reader's right in Figure 13. Both lifters have operated the same length of time in the same model car, but on different oils. The plunger on the right is in nearly new condition. Because the proper functioning of hydraulic valve lifters is so important to the operation of the modern engine, some automotive manufacturers chrome plate the plunger surface to assure that rust will not form there. This plating however, does not prevent the formation of varnish deposits which can be controlled only by the use of a highly dispersant oil and by proper oil drain practice.

For many years low temperature ring wear was a problem which was also associated with partially warmed up engine operation. Under these operating conditions products of incomplete fuel combustion combine with water to form acidic materials which attack iron piston rings. While most of the metal removal from rings is actually the result of this corrosion rather than wear, some wear also results. The pits formed by corrosion produce a rough surface which is difficult to lubricate and subject to wear. The combination of chrome plated or otherwise treated rings now used by most automobile manufacturers and alkaline (acid-neutralizing) additives used by most oil suppliers has greatly reduced this source of difficulty in the modern, well maintained engine.

MOTOR OIL CLASSIFICATION

Motor oils are now classed both by viscosity and by their performance under various service conditions.

Viscosity

The use of the proper viscosity of motor oil is essential to satisfactory engine performance. The lubricant must be viscous enough at elevated temperatures to provide a protective oil film between moving parts, yet must also have sufficient fluidity at lower temperatures to allow quick starting and adequate lubrication during the warm up period. Because of the importance of viscosity, this property is one of the primary means of classifying motor oils.

Viscosity is a measure of the resistance of a liquid to flow. This resistance is due to the internal friction of the liquid molecules moving past each other. Since temperature is a measure of molecular motion, this factor is the most important variable affecting viscosity and must always be controlled and reported in conjunction with viscosity measurements.[8]

While there are many ways of measuring viscosity, it is usually carried out in the modern petroleum laboratory by timing the flow of a given volume of oil through a precisely calibrated capillary. Determi-

[8] Magazine LUBRICATION, January and February 1961, "Viscosity."

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nations are usually made at temperatures of 210°F. and 100°F.: viscosities at other temperatures can then be established by plotting the determined values on a standard ASTM viscosity-temperature chart and interpolating or extrapolating to the temperature desired.

The system presently used to classify motor oils by viscosity was developed by the Society of Automotive Engineers (SAE) and a simplified version is shown in Table III. The SAE grade numbers in this table which are not followed by the letter W are obtained from determined viscosity measurements at 210°F. Numbers containing a W (for "winter") are obtained on the basis of an extrapolated viscosity at 0°F. Multigrade or "hyphenated" oils like the 5W-20, 10W-30, 20W-40 and 20-20W meet the viscosity requirements of both the stated grades. These grade numbers serve as an important guide for the motorist in the selection of the proper viscosity oil for various temperature and service conditions.

Until recent years the extrapolated viscosity at 0°F. was used to indicate how a lubricant would function at low temperatures in the crankcase. There is considerable evidence now, however, that the extrapolated viscosity at 0°F. is not a reliable indication of the low temperature flow properties of multigrade oils which contain relatively large amounts of polymeric VI improvers. For this reason, and because of the importance of valid low temperature viscosity measurements and their relationship to engine cranking, efforts are being made to provide a new basis for the SAE "W" viscosity grades. Because the fundamental problem involves engine performance, one approach has been to develop a technique for measuring the low temperature cranking performance of oils using a multicylinder engine under controlled laboratory (cold room) conditions. It is obvious, however, that the use of a multicylinder engine would not be suitable for routine measurements of low temperature flow properties. To meet the need for a relatively simple laboratory procedure which would correlate with engine performance, studies have been carried out on laboratory viscometers which might provide correlation with the engine.

Although direct measurements at 0°F. can be made by using a capillary type viscometer, the high molecular weight polymers used in the multigrade oils give these products non-Newtonian properties which makes viscosity measurements of this type unsatisfactory. This is because the viscosity of non-Newtonian oils is dependent not only on the temperature of the oil but also on the rate of shear and other variables. A number of investigations have been carried out using viscometers such as the Forced Ball, Brookfield, and Ferranti-Shirley. Indications are at present that the Ferranti-Shirley and Forced Ball measurements, with suitable empirical corrections, correlate quite well with engine cold cranking data. Further development of viscometric techniques is now being carried out to improve the precision of the measurements before changing the present SAE classification system.

TABLE III
SAE MOTOR OIL VISCOSITY GRADE CLASSIFICATION SYSTEM

SAE Viscosity Grade Number	Viscosity, Saybolt Universal Seconds At 0°F. Minimum	At 0°F. Maximum	At 210°F. Minimum	At 210°F. Maximum
5W		4,000	39	
10W	6,000	12,000		
or		12,000	40	
20W	12,000	48,000		
or		48,000	45	
20			45	58
30			58	70
40			70	85
50			85	110

Performance

The SAE classification system covers requirements which are affected by viscosity only. A system based on the requirements of engines determined by design and severity of service is a second method for classifying motor oils. In 1947 motor oils were generally divided into Regular, Premium, and Heavy Duty types with no definitions or standards to distinguish among them. Developments since that time in both lubricants and engines have been so great that the old ratings were no longer adequate. To meet the newer requirements a system was developed based on service classifications. This system, which was proposed by the American Petroleum Institute in 1952, has been continually reviewed and, when necessary, modified.

The present system describes, by letter symbols, general service operating conditions. The symbols used and a description of the service conditions they cover are as follows:

Service ML: This designation covers the least severe service conditions. ML conditions would involve operating at moderate speeds and loads most of the time. It also includes the operation of engines which may be insensitive to sludge, deposit formation, bearing corrosion, wear or fuel characteristics.

Service MM: This designation includes moderate to severe operating conditions with some problems of high temperature deposits and bearing corrosion. Service MM does not include low temperature stop-and-go driving.

Service MS: This classification covers the most severe operating conditions. It includes stop-and-go type driving where sludge formation and corrosive

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wear are problems, and also operation under high temperature heavy load conditions where oxidation, ring sticking and scuffing are problems. Service MS indicates that an oil will provide protection under all operating conditions.

These definitions are quite broad and subject to wide differences in interpretation. To make the important MS classification more definitive a series of engine tests have been developed by General Motors, Chrysler and Ford which are designed to produce, under controlled conditions, severe performance demands of the type a motorist might experience under the most adverse circumstances. Briefly these MS test sequences are as follows; the Oldsmobile Sequence[9] IIa, IIIa includes both low temperature and high temperature operating cycles. The objectives of this test are to evaluate scuffing, wear, rusting, deposits, and bearing corrosion. The Chrysler MS Sequence IV evaluates high temperature wear characteristics of areas such as the camshaft lobes and lifters. The Lincoln MS Sequence V evaluates motor oils with respect to their ability to reduce sludge, oil ring clogging, oil screen plugging and varnish formed by low and medium temperature operating conditions.

The importance of the above MS engine tests is reflected in the fact that the packages for the vast majority of top quality service station motor oils carry some statement to indicate that the products meet or exceed these requirements. Typical statements are: "Excels All Car Manufacturer's Service Requirements;" "Surpasses Car Makers' Requirements for API Service MS," "Exceeds Automobile Manufacturer's MS Sequence Test Requirements," "Surpasses Car Builder's Most Severe (MS) Service Tests," "Surpasses Car Maker's Limits in the ASTM Engine Test Sequences," "Surpasses the Engine Test Requirements of All Car Manufacturers," "Meets All Automotive Manufacturer's Recommendations," and "Exceeds Car Manufacturer's Engine Sequence Tests." The effort and expense necessary to establish these critical service standards make evident the great interest the automotive manfacturers and petroleum companies have in providing the motorist with the best possible products for his car.

OIL DRAIN PERIODS

It has been stated that motor oils never wear out. Why then is it necessary to drain motor oil? The primary reason a motor oil must be drained is to get rid of contaminants. Sludge, water, wear particles, dirt, and by-products of fuel and oil oxidation are continually forming or being introduced into the crankcase. Although oil filters help, there is a limit to both their capacity and their effectiveness, particularly with the newer highly-dispersant oils. Since even the finest oils have a limit to the amount of material they can hold in suspension, they must be drained periodically to remove the contaminants and keep the engine clean. In addition to the dispersant capacity factor there is also a problem of additive depletion during service. For positive protection these additives must be replenished periodically. This, of course, is accomplished when the motor oil is changed. The real problem is not "why" but "when" to change the oil.

Since there is no simple test a motorist can perform to determine when the oil must be drained, it is necessary for him to rely on the recommendations of the automotive manufacturers and oil companies. Their judgment is based on years of experience coupled with an intimate knowledge of engine performance characteristics and the capability of lubricants under various operating conditions. During the past few years many automotive companies, recognizing the advances made in motor oil development, have extended their recommended drain periods from 2,000 miles or 60 days to 4,000 and 6,000 miles or 60 days. The American Petroleum Institute (API) has also recognized these improvements, but have preferred to use time rather than mileage as the principal guide. They now recommend oil changes at least every 60 days compared with the 30 days in winter or 60 days in summer previously used.

Almost every major oil company now markets an "extended drain period oil"; however, they may or may not be labeled or recommended as such. These products, which are usually multigrade oils, easily surpass the MS test requirements. They are in fact so superior that some engine manufacturers have suggested that consideration be given to adding a new service category more severe than the present MS tests. Some of these products are specifically labeled for extended drain purposes. Other companies offering similar quality products emphasize service conditions rather than mileage and therefore specify time as the major criterion with the additional stipulation that the automotive manufacturer's mileage recommendations not be exceeded.

SUMMARY

Owning and driving one of today's automobiles can be a source of great satisfaction. The dependability and performance of these vehicles has been achieved through a continuing program of research and development. The high quality, premium grade motor oil that lubricates and protects these engines is the product of a similar extensive program. When used as recommended, today's motor oils will provide a high level of protection against corrosion and engine deposits and aid in realizing long engine life.

[9] The original Oldsmobile MS-I, II, III procedure has been revised and is now designated IIa, IIIa.

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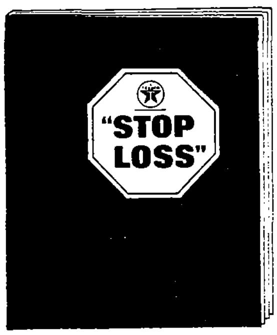
excessive downtime
high parts inventory
high lube inventory
rising maintenance costs
rising production costs

Rx:



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