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AUTOMOBILE ENGINE LUBRICATING OILS

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I. Selection of Oils

The choosing of motor oils is complicated because (1) quality is determined by many factors some of which may be unknown or at least not commonly specified, (2) knowledge of the relation of the properties of oils to service performance is incomplete, and (3) the relative importance of the various properties depends very largely upon the service in which the oil is to be used.

At the present time there are many laboratory tests used for estimating the suitability of an oil for lubricating the automobile engine (Refs. 1 and 2). These have been developed mainly by the American Society for Testing Materials.

1. Viscosity

Viscosity is generally considered the most important single property of a lubricating oil since it is this property which tends to prevent metallic contact between the bearing surfaces.

Until recently the only instrument customarily used in the United States for measuring the viscosity of engine oils was the Saybolt Universal Viscometer. On this basis, viscosities were expressed in Saybolt seconds at either one or more of the standard temperatures of test: 100°F, 130°F and 210°F. During the past two years, there has been increasingly greater use of kinematic viscometers, which permit higher accuracy in viscosity measurements. Viscosity values obtained with kinematic viscometers are expressed in centistokes, and standard tables are available (Ref. 2) for converting from centistokes to Saybolt seconds, and vice versa. By the use of a suitable chart (Ref. 2), the viscosities either in kinematic or Saybolt units can be estimated at other temperatures, if the viscosities at any two temperatures are known.

The Society of Automotive Engineers has standardized a system of numbering for designating the viscosity of motor oils which has been adopted generally, so that lubricants may be purchased on this basis. The S.A.E. numbers with corresponding Saybolt viscosities (Ref. 3) are given by Table 1.

It is characteristic of all lubricating oils that the viscosity decreases with increasing temperature, the rate of change for the mineral oils used in automobile engines depending upon the refining process and upon the crude from which the oil has been refined. The change of viscosity with temperature is customarily expressed in terms of viscosity index (V.I.), an empirical scale developed by Dean & Davis. On this scale, the higher the V.I., the less is the change of viscosity with temperature. Standard tables are available (Ref. 2) for evaluating the V.I. from viscosity measurements at 100°F and at 210°F.

A fair comparison of the performance of two oils requires that their viscosities be essentially the same at the operating temperature under consideration. Therefore, since oils vary considerably in regard to V.I., when a change is made from the product of one refiner to that of another, it may be necessary to obtain from the new refiner a grade of oil having an entirely different viscosity at a given temperature of test, in order to reproduce the viscosity of the oil previously used when the engine has attained its usual operating temperature.

Table 1

S.A.E. Viscosities

S.A.E. Viscosity Number	Viscosity Range Saybolt Universal, Seconds			
	130°F		210°F	
	Min.	Max.	Min.	Max.
10	90	Less than 120		
20	120	Less than 185		
30	185	Less than 255		
40	255	-- -- --	--	Less than 80
50			80	Less than 105
60			105	Less than 125
70			125	Less than 150

The temperature of an engine will vary from that existing under starting conditions in cold weather to that which occurs when a car is driven for long periods in the summer. The viscosity of new crankcase oil will therefore vary from a maximum in winter to a minimum when the engine has reached its maximum operating temperature. The viscosity of the oil in a cold engine determines the ease with which the oil is distributed to the bearings during the first few minutes of operation. The viscosity at the average engine temperature determines to a large extent the friction losses in the engine and the factor of safety under which it operates (Ref. 4).

In general, a wide range exists between failure of the lubricating film due to a low viscosity and failure of the oil to circulate because its viscosity is too high. An engine in good mechanical condition operated for average service could probably be run successfully using an oil with a viscosity as low as 100 seconds (Saybolt Universal) or using one as high as 1000 seconds (both as determined at 100°F), or even lower or higher, the extreme limits depending upon the design of the engine. At the lower extreme the factor of safety with respect to metallic contact would be small, while at the upper, the power loss would be excessive. Proper choice lies between the two extremes and is thus a compromise between factor of safety and power loss. (Ref. 5).

Selection of a suitable viscosity for a given service is often difficult for a user of oils. It is generally desirable to follow the recommendations of the manufacturer of the equipment to be lubricated, sometimes stamped on the crankcase filler cap, or the recommendation of a reputable oil refiner.

2. Pour Point

The pour point, or the lowest temperature at which an oil will flow under certain standardized conditions, is often used as an indication of the characteristics of an oil under starting conditions.

It has been shown (Ref. 6) that the torque required to start an engine and the rate at which an oil will flow are not related to pour point. However, at crankcase temperatures below the pour point, the oil will have a tendency to "channel" in the crankcase where it is being drawn into the pump. This "channeling" effect may prevent circulation of the oil through the system.

3. Carbon Residue and Oxidation

Due to their instability under service conditions, all motor oils undergo changes during use. The changes occurring are: (1) cracking, or decomposition of the oil into lighter compounds and a carbonaceous residue, and (2) oxidation, or combination with oxygen to form organic acids and products of an asphaltic nature, called asphaltenes.

In the automobile engine cracking probably takes place only in the combustion chamber, the carbonaceous residue going to make up a large part of the so-called "carbon" found there. The Conradson carbon residue test has been used as an indication of the relative tendencies to form carbon deposits with different oils. On the other hand, experimental work (Ref. 7) suggests that a distillation test for volatility may also be significant as regards the amount of carbon deposit to be expected.

The oxidation of an oil takes place chiefly in the crank-case, being accelerated at high operating temperatures. The asphaltenes so formed cause discoloration of the oil, and some increase in viscosity. Asphaltenes in solution may not be harmful, but if formed in excess, they are precipitated, and form a binder that aggregates the dust, metallic particles and finely divided carbon which works down from the combustion chamber. Since these aggregates tend to clog small passages, they may cause failure of the oil supply.

The tendency of an oil to form asphaltenes may be measured by some form of oxidation test. The Indiana method (Ref. 8), which involves heating of the oil at 340°F with aeration, is widely used for this purpose. Recent work indicates that the change in viscosity and in carbon residue during the oxidation test are also of importance in evaluating the stability of an oil. The Navy work factor test (Ref. 9) has attained the most recognition along this line.

All oils when oxidized tend to form organic acids to an extent dependent upon the characteristics of the oil and upon the temperature at which oxidation takes place. The neutralization number of an oxidized oil is a measure of the total acidity and does not differentiate between the acids which are non-corrosive and those which tend to cause bearing corrosion. For this purpose, a bearing corrosion test should be employed.

4. Color, Flash Point and Specific Gravity

Light colored and highly transparent oils are obtained by certain refining processes. The color of an oil is of little value to the consumer for judging its value as an engine lubricant but should assist in the detection of dirt or other foreign material. There is no known relation between color and service performance.

Tests which may be of value for identification purposes but which mean little as specification items are flash point and specific gravity. The flash point has been found of limited value as an indication of volatility and hence of oil consumption.

5. Source of the Crude Oil

In the early days, oils were classified as paraffin base, naphthene base or mixed base depending upon the type of crude oil from which they were refined. Probably the most important differences between these types of oils were (a) the change of viscosity with temperature was less for the paraffin than for the naphthene base oils, and (b) carbon formation in the cylinders was usually higher with the paraffin base oils. Oils refined from mixed base crudes by the old conventional methods had intermediate properties.

In recent years, there has been a marked development in methods for the refining of crude oils, and solvent refining is now employed extensively by the petroleum industry. By these new methods, it is possible to produce from a given crude lubricating oils widely different in properties from those produced by the older conventional methods from this crude (Ref. 10). In fact, oils of the same significant characteristics may be produced from a wide variety of crudes. In view of these developments, the old distinction between paraffin base and naphthene base oils has lost most of its significance, and more attention is now paid to the properties of the refined oil than to the type or source of crude.

6. Additives

The use of additives to introduce new properties into the oil or to enhance the characteristics already possessed by a lubricating oil has been increasing during the past few years. Probably the most extensively used additives are the pour point depressors, which have the effect of lowering the pour point of the oil and giving it better low temperature characteristics. There has also been some use of viscosity index improvers which raise the viscosity index and thereby improve both the low temperature and the high temperature characteristics.

From a technical standpoint, one of the most important types of additives for use in present-day motor car engines is the rust preventive type. Although rust-preventive additives have not been commonly employed in automobile engine oils, their use would materially reduce wear, particularly during intermittent low-temperature operation, where wear may be excessive due to rusting of the piston rings and cylinder walls. Some use has been made of wear-reducing additives which act primarily not through rust prevention, but by increasing the film strength, and thereby reducing the extent of metal to metal contact between the piston rings and the cylinder walls.

Miscellaneous additives have been employed to reduce varnish formation on piston rings, to reduce the tendency towards ring sticking, and to increase the stability of the oil with resultant decrease in the amount of sludge formed in the engine. More extensive use has been made of corrosion inhibitors which help to prevent corrosion with the newer bearing materials, such as occurs with some types of oils during continued high speed operation with high crankcase oil temperature.

7. Specifications

Specifications are frequently used in the purchase of oils in large quantities (Refs. 9, 11). In this way a more uniform product is obtained, and in many cases the cost of the oil purchased on specification is less than the cost of branded oils showing the same results when given the usual laboratory tests.

II. Contamination in Use

In current automotive equipment operating on present day fuels, the lubricating oil is rendered unfit for use by external contaminants and by contaminants resulting from chemical changes which take place in the oil. If the engine is not equipped with effective oil and air cleaning devices, the lubricating oil is often rendered unfit for use by the external contaminants long before it deteriorates badly due to its inherent instability. External contamination is a function, broadly speaking, of operating conditions, and hence lubrication failures due to such causes are not properly chargeable to the oil (Ref. 12).

1. Dilution

It is common knowledge that crankcase oil frequently decreases in viscosity during service (Ref. 13). This is caused by dilution of the oil with the less volatile constituents from the fuel. In general, the amount of dilution is governed by the engine temperature. When the cylinder walls and crankcase are cold, especially when starting, the amount of fuel reaching the crankcase is relatively high. This is shown by the fact that dilution in summer is usually negligible, whereas in winter the amount may increase to 10 or 20 percent. Thermostats and radiator shutters, both of which assist in producing high operating temperature, are for this reason of considerable value, especially in winter. It has also been shown that a high temperature in the crankcase will tend to evaporate the diluent from the oil. By the use of crankcase ventilation, the resulting vapors are removed and dilution is thus reduced. It should also be borne in mind that dilution can be minimized by refraining from excessive use of the choke and by avoiding over-rich carburetor settings.

As a result of the loss in viscosity, diluted oil works past the piston more readily, causing increased oil consumption, excessive carbon formation and fouling of the spark plugs. As the diluted oil will not maintain a lubricating film under as high bearing pressures as will the oil of higher viscosity, excessive wear and even seizure of bearings may ensue.

Fortunately, dilution does not generally increase indefinitely in amount, but tends rather to attain an equilibrium which on the average may be reached in about 200 miles of driving. The equilibrium dilution in any engine will vary with the operating conditions and with the atmospheric temperature. Extensive slow driving or intermittent operation for short periods of time will lead to an equilibirum dilution much higher than if the car is operated for long periods of time at relatively high speed. Likewise lower dilutions are found in warm weather than in cold weather. In this connection, a long period of high speed driving after intermittent operation will tend to evaporate some of the diluent and the oil consumption may appear to be excessive. As a general rule, the viscosity of the oil recommended by reputable refiners is such that average dilutions do not make the oil too thin for safe operation.

2. <u>Road Dust</u>

Another harmful contaminant is road dust, which may be highly abrasive (Ref. 14). The harmful effects of dust are greater with low viscosity (e.g. diluted) oil, since the thickness of the oil film is less in such cases. Either an air cleaner on the carburetor air intake or a filter in the oil circulating system will materially reduce the amount of dirt in the crankcase oil, and in this way help to avoid excessive wear of the bearing surfaces from this source.

3. Water

Still a third contaminant, particularly in cold weather, is the water which is formed in the combustion of gasoline in the proportion of about one gallon of water for each gallon of gasoline burned (Ref. 15). The greater part of this water passes out with the exhaust gases in the form of vapor, but some vapor may blow by the pistons into the crankcase. In cold weather this will condense and may form emulsions with the oil, which have the appearance and consistency of heavy greases, or it may collect and freeze in such parts of the lubrication system as will prevent circulation of the oil. Water may also cause serious corrosion, particularly in combination with the oxides of sulphur from the combustion chamber, with which it forms corrosive acids. Crankcase ventilation has been found of considerable value in removing water vapor.

Most of the wear which takes place in the average engine is caused by rusting of the cylinder walls and piston rings, which commences almost immediately after the engine is stopped. During cold weather operation, the wear caused by rusting is much higher than during warm weather. Wear from this cause is also much higher for intermittent service operation, such as taxicabs and delivery trucks, than for longer periods of operation where the oil tends to warm up sufficiently to permit vaporization of most of the water in it. As pointed out previously, rust preventive additives may be expected to reduce wear caused by rusting.

4. Acids

The acids which form in the lubricating oil in service and cause corrosion are of two general types. The first type comes from the fuel and consists of the products of combustion of the sulfur compounds in the fuel and of the ethyl fluid used to increase the octane number. In the presence of water in the crankcase oil, the oxides of sulfur blown past the rings from the combustion chamber form acids which are very corrosive to steel. Fortunately, the use of crankcase breathers and ventilators helps to remove both the oxides of sulfur and the water vapor before they condense in the oil, and sulfur corrosion is not very extensive. The acidic compounds from combustion of the ethyl fluid are of concern mainly in that they accelerate the rusting of the piston rings and cylinder walls. Again, this is most noticeable in cold weather intermittent operation.

During use, the lubricating oil tends to oxidize and may form weak organic acids which are non-corrosive towards steel, but which may cause corrosion of lead-bronze or cadmium-silver bearings. Normally, this only occurs with some types of oils in engines operated for long periods of time at high crankcase oil temperatures, and, as pointed out previously, additives can be used in the oil which will minimize the danger of bearing corrosion. Likewise, most oil filters during the useful life of the filtering element will maintain the oil acidity at values below that at which bearing corrosion is usually encountered.

5. Carbon and Asphaltenes

Considerable carbon may contaminate the oil in the crankcase as the result of blow-by from the combustion chamber. Also, during use the oil may oxidize and polymerize to form asphaltenes to such an extent that they may precipitate from the oil. In the presence of water, especially during cold weather operation, the asphaltenes may form very thick emulsions which in extreme cases may affect the oil circulation through the engine. Also, the asphaltenes tend to combine with the blow-by carbon, road dust and metallic particles to form aggregates which may increase the tendency toward ring sticking and towards clogging of oil control ring grooves. Most of the present-day lubricating oils for automobile engines are very stable against formation of insoluble materials caused by decomposition of the oil. Further, efficient oil filters will remove the blow-by carbon and the insoluble decomposition products of the oil, and maintain the oil clear over long periods of time.

III. Changing Crankcase Oil

Periodic draining of the crankcase is recommended in order to remove diluted oil and accumulated dust, metallic particles and oxidation products (Refs. 12, 16). The gradual accumulation in the oil of these contaminants renders the crankcase oil gradually less safe and effective as a lubricant. The frequency of changing depends on the several factors mentioned, and upon the efficiency of any filters or devices used to reduce the amount of foreign material in the oil. It is well to remember that the cost of repairing damages resulting from a lubrication failure usually is large compared with the cost of oil. Changes, therefore, should not be delayed too long. For example, if a car holding 6 quarts of oil in the crankcase uses 1 quart of oil every 500 miles, then in 12,000 miles of operation, 84 quarts will be used if changed every 1000 miles at an average cost of $25.20, assuming the average price of oil is 30 cents per quart. On the other hand, if the oil is changed every 2000 miles, 54 quarts will be used at an average cost of $16.20; whereas extending the period of change to 3000 miles would require the use of 44 quarts at an average cost of $13.20. The difference between changes at 1000-mile and 2000-mile intervals may be sufficient to merit real consideration, if the type of equipment and of service permits this increase in distance between oil changes. However, the 10-quart difference in oil consumption, or $3 increase in oil cost for 12,000 miles of operation, between changes at 2000 miles and at 3000 miles, in the particular case chosen, is so small that any increased risk in extending from 2000 to 3000 miles between changes would hardly be justified. While the above example is fairly typical, there are variations in different types of equipment and service. With efficient oil filters, changed as soon as the oil begins to darken, longer periods between oil changes can be employed than when operating without a filter. However, even in this case, there appears to be little gain economically in extending the oil drain period excessively.

In the case of the individual car owner, it is considered advisable to accept the recommendation of the car manufacturer regarding the mileage between changes, which can be assumed as well on the safe side. With an organization owning a large fleet of cars, trucks, or buses, and keeping an accurate cost record of operation, the situation is somewhat different. Inspection of the equipment is made periodically and facilities are available for testing the crankcase oil. Under these conditions, the period between draining the oil can be gradually raised from a known safe lower limit until the optimum mileage between changes is found for the particular equipment involved. This optimum mileage represents a balance between oil costs and repair costs. Such a procedure is obviously impossible for the average car owner, because of lack of adequate facilities for making inspections of equipment and testing the oil. In general, the difference in the optimum mileage between oil changes found by some of the larger fleet owners and the mileage recommended by the car manufacturers represents a very small fraction of the cost of operating a car.

IV. Oil Consumption

The motorist is accustomed to refilling the gasoline tank and accepts that as a necessary consequence of driving an automobile. On the other hand, he feels that there is something wrong if he has to add lubricating oil from time to time. The fact remains, however, that unless there is some oil consumption, the engine is not being adequately lubricated. The extent of oil consumption depends upon (1) the mecahnical condition of the engine, (2) the conditions of operation, and (3) the properties of the oil.

1. Mechanical Condition of Engine (Refs. 17, 18)

In general, the oil consumption will decrease slowly with a new engine due to a better seating of the piston rings on the cylinder walls, and will then tend to increase with further running, as the result of increased wear. Much of the oil consumption is caused by oil getting past the piston rings into the combustion chamber. Hence, anything which can be done to obtain a tight seal between the rings and the cylinder walls will reduce oil consumption. Accumulation of carbon in the slits of the oil control rings is one of the more common causes of high oil consumption. Also, accumulation of carbon in the ring grooves causing the rings to stick, may markedly increase the oil consumption. Piston ring design may have an important bearing on the rate at which oil is consumed, and marked differences may be found with different engines, due to differences in design features and in condition.

2. Engine Operating Conditions (Ref. 17)

Probably the most important factor affecting oil consumption is the engine speed. In some cases, the oil consumption at 60 miles per hour may be several times that obtained at an average car speed of 30 miles per hour, and more extreme cases are not infrequent. Large variations in the effect of speed on oil consumption will be found with different engines.

3. Oil Characteristics (Ref. 17)

The two major oil characteristics which have an effect on oil consumption are viscosity and volatility. In general, the higher the viscosity of the oil, the less will be the oil consumption. On the other hand, as previously pointed out in this Circular, the higher the viscosity of the oil, the higher will be the engine friction and the more difficult will it be to start the engine in cold weather. Also the fuel consumption will tend to increase with increase in the viscosity of the oil.

It may happen that two oils will have the same viscosity, but have quite different volatilities. In this case, greater oil consumption will be obtained when using the oil of greater volatility, since some oil is always lost by evaporation at the high operating temperatures. In general, the lower the viscosity, the higher is the volatility.

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