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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 (Ref. 1). These have been developed mainly by the American Society for Testing Materials (Refs. 2 and 3).

### 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.

The instrument customarily used in the United States for measuring the viscosity of engine oils is the Saybolt Universal Viscometer. Viscosities are expressed in Saybolt seconds at either one or all of the standard temperatures of test: 100°F, 130°F and 210°F. By the use of a suitable chart the viscosities at other temperatures can be estimated if the viscosities at any two temperatures are known (Ref. 4).

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. 5) 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 crude from which the oil has been refined and in special cases upon the method of treatment. For this reason, a fair comparison of the performance of two oils cannot be made unless it is known that their viscosities are the same at the operating temperature under consideration. For instance, 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 225 | | |
| 40 | 255 | -- -- -- | -- | Less than 75 |
| 50 | | | 75 | 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 engine may be cranked, as well as the facility 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. 6).

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. 7).

Selection of a suitable viscosity for a given service is often difficult for a user of oils. It is generally desirable to follow 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 temperature at which an oil ceases to 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. 8) 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 extents of the probable carbon deposits with different oils. On the other hand, experimental work (Ref. 9) 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 crankcase, 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 Sligh oxidation test developed at the Bureau of Standards (Ref. 10) is frequently used. The precise relation between this test and oxidation of oil in the crankcase has not been definitely established. Recent work (Ref. 11) suggests that oxidation in the presence of air at 340°F may be a more significant test.

The acidity, emulsion, and demulsibility tests, the last two not generally being included in motor oil specifications, are also used as an indication of the oxidation of oils. In addition, high acidity may cause corrosion although the acidity of well refined oil is nearly always of organic origin, and hence may be so weak that it will not cause appreciable corrosion.

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

There are two distinct types of crude oil from which petroleum lubricating oils may be derived, the paraffin base crude and the naphthene base crude. Probably the most important differences between these two types of oil are (a) the change of viscosity with temperature is less for the paraffin than for the naphthene base oils, and (b) carbon formation in the cylinders is usually higher with the paraffin base oils. Many crude oils have properties intermediate between those of the two extreme types, and lubricating oils refined in the ordinary manner from these mixed base crudes also have intermediate properties.

In recent years there has been a marked development in methods for the refining of crude oils. Hydrogenation, chemical treatment, and solvent extraction methods make it possible to produce, from a given crude, lubricating oils widely different in properties from those produced by the older methods from this crude (Ref. 12). In fact, by suitable refining methods, it is now possible to produce oils of the same significant characteristics from a wide variety of crudes. In view of these recent developments, the old distinction between paraffin base and naphthene base oils is losing much of its significance, and more attention is being paid to the properties of the refined oil than to the source of crude.

6. Specifications are frequently used in the purchase of oils in large quantities (Refs. 13, 14). 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.

In Table 2 below are given the properties of three oils, the viscosities of which correspond to S.A.E. grades in common use. The values listed are the average of oils sold by several representative refiners:

Table 2

Properties of Typical Oils

| Property | S.A.E. Number 20 | 30 | 40 |
|---|---|---|---|
| Flash point, °F | 405 | 425 | 440 |
| Viscosity, Saybolt sec. at 100°F | 308 | 554 | 760 |
| Viscosity, Saybolt sec. at 130°F | 137 | 227 | 296 |
| Viscosity, Saybolt sec. at 210°F | 49 | 59 | 69 |
| A.S.T.M. Color No. | 5 | 6 | 7.5 |
| Pour Point, °F | 15 | 20 | 30 |
| Carbon residue, percent | 0.22 | 0.45 | 0.60 |
| Oxidation No. | 30 | 25 | 20 |

## II. Contamination in Use

In current automotive equipment, operating on present-day fuels, and not equipped with effective oil and air cleaning devices, the lubricating oil is often rendered unfit for use by what may be called 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. 15).

### 1. Dilution

It is common knowledge that crankcase oil frequently decreases in viscosity during service (Ref. 16). 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 seldom exceeds 10 percent, whereas in winter the amount may increase to 20 or 30 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 from using a rich carburetor setting.

The effect of dilution on the viscosity of an oil is approximately as given in the following table:

Table 3

Effect of Dilution on Viscosity*

| Condition of Oil | Viscosities at 100°F, Seconds, Saybolt Universal Viscometer | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Paraffin base | | | | Naphthene base | | | |
| New Oil | 300 | 600 | 1000 | 4000 | 300 | 600 | 1000 | 4000 |
| 10 Percent Dilution | 151 | 261 | 376 | 1123 | 103 | 189 | 291 | 811 |
| 20 Percent Dilution | 105 | 162 | 254 | 573 | 85 | 102 | 170 | 409 |
| 40 Percent Dilution | 64 | 77 | 85 | 151 | 50 | 58 | 68 | 110 |

*Computed from data given in Bureau of Standards Technologic Paper 164 "Saybolt Viscosities of Blends".

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 equilibrium 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. 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. Road Dust

Another harmful contaminant is road dust, which may be highly abrasive (Ref. 17). 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. 18). 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 before it condenses.

## 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. 15, 19). 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 250 miles, then in 6000 miles of operation, 84 quarts will be used if changed every 500 miles. On the other hand, if the oil is changed every 1000 miles, 54 quarts will be used; whereas extending the period of changing to 1500 miles would require the use of 44 quarts. The difference between changes at 500-mile and 1000-mile intervals is 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 between changes at 1000 miles and at 1500 miles, in the particular case chosen, is so small that any increased risk in extending from 1000 to 1500 miles between changes would hardly be justified. While the above example is fairly typical, there are variations in different types of equipment and service.

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 knownsafe 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 testingthe 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 mechanical condition of the engine, (2) the conditions of operation, and (3) the properties of the oil.

### 1. Mechanical Condition of Engine (Refs. 20, 21)

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 deposits on the rings causing them to stick in the piston ring grooves is one of the more common causes of high oil consumption. Piston ring design may also have an important bearing on the rate at which the oil is consumed. Marked differences in oil consumption may be found with different engines, due to differences in design features.

### 2. Engine Operating Conditions (Ref. 20)

Probably the most important factor affecting oil consumption is the engine speed. In some cases, the oil consumption may increase ten times in raising the average car speed from 30 to 60 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. 20)

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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