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AUTOMOBILE ENGINE LUBRICATING OILS

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, 14). 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 all 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 a 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 Min.	130 °F Max.	210°F Min.	210°F 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.

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.

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. 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 extents of the probable carbon deposits with different oils. Recent work (Ref. 7) suggests that a distillation test for volatility may be a better indication of 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 out, 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.8) is at present believed to be the most reproducible and rapid. The precise relation between this test and oxidation of oils in the crankcase has not been definitely established.

The acidity, emulsion and demulsibility of tests, the latter two not generally being included in motor oil specifications, are also used as an indication of the oxidizing tendency of oils. In addition, acidity may be a measure of the tendency of an oil to corrode, although the acidity of well refined oil is nearly always, if not invariably, of organic origin, and hence is so weak that it causes no appreciable corrosion.

4. Color, Flash Point and Specific Gravity.

Light colored and highly transparent oils are obtained by certain refining processes. Since the same treatment of oils from different crudes will not give the same color or degree of transparency, 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 very 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 asphalt base crude. Oils from mixed base crudes or blended from the stocks of the two general types are also common. Selection of an oil from a particular base of crude oil may be necessary for certain abnormal types of service and the following summary of the characteristics of paraffin and asphalt base oils when compared on the basis of equal viscosity at the test temperature should serve as a criterion in such a selection.

Paraffin vs. Asphalt Base Oils

(a) The change of viscosity with temperature is less for the paraffin than for the asphalt base oils.

(b) The specific gravities of the paraffin base oils are lower, that is, gravities A.P.I. are higher.

(c) The carbon residue value is higher for the paraffin base.

(d) Carbon formation in the cylinder is usually higher with the paraffin base oils.

(e) The pour point is higher with the paraffin base oils unless dewaxed, in which case it may be lower.

(f) The flash point is higher for the paraffin base oils.

(g) Oils refined from mixed base crudes have characteristics intermediate between the paraffin and asphalt base lubricants.

6. Specifications

Specifications are frequently used in the purchase of oils in large quantities (Refs. 2, 9). In this way

a more uniform product is obtained and in many cases the cost of the oil purchased on specifications 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 whose viscosities 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	.22	.45	.60
Oxidation No.	30	25	20

II. Contamination in Use.

In current automotive equipment, operating on present day fuels, and not equipped with special 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.

1. Dilution.

It is common knowledge that crankcase oil frequently loses its viscosity in service (Ref.10). This is caused by dilution of the oil with the less volatile constituents from the fuel. In general, the amount of this 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 dilutions in summer have been found to vary between 5 and 20 percent, on the average, whereas in winter the amount increases to from 20 to 50 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 forced crankcase ventilation the resulting vapors are removed and dilution is thus reduced. It should also be borne in mind that dilution can be avoided 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*

Viscosities at 100°F, Seconds,	Saybolt Universal Viscometer							
	Paraffin Base				Asphalt 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 after 100 or 200 miles of driving. 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. 11). 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. 12). 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 to form corrosive acids. Forced crankcase ventilation has been found of considerable value in removing water vapor before it condenses.

4. Removal

Periodic draining of the crankcase may be necessary in order to remove diluted oil and accumulated dust, metallic particles and oxidation products. The frequently recommended practice of draining every 500 miles is designed to afford an ample margin of safety in the absence of special devices for reducing the amount of foreign material in the oil. The efficiency of the devices used depends upon their construction and maintenance. Suitable designs adequately cared for should make it possible to operate 2,000 miles or more between oil changes.

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