



# Lubricating Oil – Types, Characteristics and Additives

An Online Continuing Education Course for Engineers

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# Lubricating Oil – Types, Characteristics and Additives

## Introduction

Most lubricating oils are obtained from distillation of crude petroleum. Due to the wide variety of petroleum constituents, it is necessary to separate petroleum into portions (fractions) with roughly the same qualities.

The refining process can be briefly described as follows:

- (1) Crudes are segregated and selected depending on the types of hydrocarbons in them.
- (2) The selected crudes are distilled to produce fractions. A fraction is a portion of the crude that falls into a specified boiling point range.
- (3) Each fraction is processed to remove undesirable components. The processing may include:
  - Solvent refining to remove undesirable compounds.
  - Solvent dewaxing to remove compounds that form crystalline materials at low temperature.
  - Catalytic hydrogenation to eliminate compounds that would easily oxidize.
  - Clay percolation to remove polar substances.
- (4) The various fractions are blended to obtain a finished product with the specified viscosity. Additives may be introduced to improve desired characteristics.

## Separation into fractions

Separation is accomplished by a two-stage process: crude distillation and residuum distillation.

### (1) Crude distillation

In the first stage the crude petroleum is mixed with water to dissolve any salt. The resulting brine is separated by settling. The remaining oil is pumped through a tubular furnace where it is partially vaporized. The components that have a low number of carbon atoms vaporize and pass into a fractionating column or tower. As the vapors rise in the column, cooling causes condensation. By controlling the temperature, the volatile components may be separated

into fractions that fall within particular boiling point ranges. In general, compounds with the lowest boiling points have the fewest carbon atoms and compounds with the highest boiling points have the greatest number of carbon atoms. This process reduces the number of compounds within each fraction and provides different qualities. The final products derived from this first-stage distillation process are raw gasoline, kerosene, and diesel fuel.

## (2) Residuum distillation

The second-stage process involves distilling the portion of the first-stage that did not volatilize. Lubricating oils are obtained from this portion, which is referred to as the residuum. To prevent formation of undesired products, the residuum is distilled under vacuum so it will boil at a lower temperature. Distillation of the residuum produces oils of several boiling point ranges. The higher the boiling point, the higher the carbon content of the oil molecules in a given range. More importantly, viscosity also varies with the boiling point and the number of carbon atoms in the oil molecules.

### **Impurity removal**

Once the oil is separated into fractions, it must be further treated to remove impurities, waxy resins, and asphalt. Oils that have been highly refined are usually referred to as premium grades to distinguish them from grades of lesser quality in the producer's line of products. However, there are no criteria to establish what constitutes premium grade.

### **Types of Oil**

Oils are generally classified as refined and synthetic. Paraffinic and naphthenic oils are refined from crude oil while synthetic oils are manufactured. Literature on lubrication frequently makes references to long-chain molecules and ring structures in connection with paraffinic and naphthenic oils, respectively. These terms refer to the arrangement of hydrogen and carbon atoms that make up the molecular structure of the oils. Discussion of the chemical structure of oils is beyond the scope of this course, but the distinguishing characteristics between these oils are noted below.

#### *Paraffinic oils*

Paraffinic oils are distinguished by a molecular structure composed of long chains of hydrocarbons, i.e., the hydrogen and carbon atoms are linked in a long linear series similar to a chain. Paraffinic oils contain paraffin wax and are the most widely used base stock for lubricating oils. In comparison with naphthenic oils, paraffinic oils have:

- Excellent stability (higher resistance to oxidation).
- Higher pour point.

- Higher viscosity index.
- Low volatility and, consequently, high flash points.
- Low specific gravities.

### *Naphthenic oils*

In contrast to paraffinic oils, naphthenic oils are distinguished by a molecular structure composed of “rings” of hydrocarbons, i.e., the hydrogen and carbon atoms are linked in a circular pattern. These oils do not contain wax and behave differently than paraffinic oils. Naphthenic oils have:

- Good stability.
- Lower pour point due to absence of wax.
- Lower viscosity indexes.
- Higher volatility (lower flash point).
- Higher specific gravities.

Naphthenic oils are generally reserved for applications with narrow temperature ranges and where a low pour point is required.

### *Synthetic oils*

Synthetic lubricants are produced from chemical synthesis rather than from the refinement of existing petroleum or vegetable oils. These oils are generally superior to petroleum (mineral) lubricants in most circumstances. Synthetic oils perform better than mineral oils in the following respects:

- Better oxidation stability or resistance.
- Better viscosity index.
- Much lower pour point, as low as  $-46^{\circ}\text{C}$ .
- Lower coefficient of friction.

The advantages offered by synthetic oils are most notable at either very low or very high temperatures. Good oxidation stability and a lower coefficient of friction permits operation at higher temperatures. The better viscosity index and lower pour points permit operation at lower temperatures.

The major disadvantage to synthetic oils is the initial cost, which is approximately three times

higher than mineral-based oils. However, the initial premium is usually recovered over the life of the product, which is about three times longer than conventional lubricants. The higher cost makes it inadvisable to use synthetics in oil systems experiencing leakage.

Plant Engineering magazine's "Exclusive Guide to Synthetic Lubricants," which is revised every three years, provides information on selecting and applying these lubricants. Factors to be considered when selecting synthetic oils include pour and flash points; demulsibility; lubricity; rust and corrosion protection; thermal and oxidation stability; antiwear properties; compatibility with seals, paints, and other oils; and compliance with testing and standard requirements. Unlike Plant Engineering magazine's "Chart of Interchangeable Lubricants," it is important to note that synthetic oils are as different from each other as they are from mineral oils. Their performance and applicability to any specific situation depends on the quality of the synthetic base-oil and additive package, and the synthetic oils listed in Plant Engineering are not necessarily interchangeable.

### *Synthetic lubricant categories*

Several major categories of synthetic lubricants are available including:

#### *Synthesized hydrocarbons*

Polyalphaolefins and dialkylated benzenes are the most common types. These lubricants provide performance characteristics closest to mineral oils and are compatible with them. Applications include engine and turbine oils, hydraulic fluids, gear and bearing oils, and compressor oils.

#### *Organic esters*

Diabasic acid and polyol esters are the most common types. The properties of these oils are easily enhanced through additives. Applications include crankcase oils and compressor lubricants.

#### *Phosphate esters*

These oils are suited for fire-resistance applications.

#### *Polyglycols*

Applications include gears, bearings, and compressors for hydrocarbon gases.

#### *Silicones*

These oils are chemically inert, nontoxic, fire-resistant, and water repellent. They also have low pour points and volatility, good low-temperature fluidity, and good oxidation and thermal stability at high temperatures.

Table 1 identifies several synthetic oils and their properties.

## Characteristics of Lubricating Oils

### Viscosity

Technically, the viscosity of an oil is a measure of the oil's resistance to shear. Viscosity is more commonly known as resistance to flow. If a lubricating oil is considered as a series of fluid layers superimposed on each other, the viscosity of the oil is a measure of the resistance to flow between the individual layers. A high viscosity implies a high resistance to flow while a low viscosity indicates a low resistance to flow. Viscosity varies inversely with temperature. Viscosity is also affected by pressure; higher pressure causes the viscosity to increase, and subsequently the load-carrying capacity of the oil also increases. This enables use of thin oils to lubricate heavy machinery. The load-carrying capacity of an oil also increases with the operating speed of the lubricated machinery is increased. Two types of viscosity are commonly employed: shear and time.

### Shear

When viscosity is expressed in terms of shear stress and shear rate, it is called dynamic viscosity. In the oil industry, it is commonly expressed in terms of kinematic viscosity, which is the absolute viscosity divided by the density of the oil. Kinematic viscosity is expressed in centistokes (cSt). Viscosity in centistokes is commonly used at two temperatures: 40 °C and 100 °C.

### Time

Another method of measuring viscosity is the time required for an oil sample to flow through a standard orifice. This viscosity is then expressed in SUS (Saybolt Universal Seconds). Kinematic viscosity is typically given at two standard temperatures: 40 °C and 100 °C. Dynamic viscosity can be expressed as centipoise (cP) or poise (P). Kinematic viscosity is expressed in SUS (SUS), depending on the actual test method used.

### Viscosity index

The viscosity index, commonly designated VI, is an arbitrary numbering scale that indicates the changes in oil viscosity with changes in temperature. Viscosity index can be classified as follows: low VI - below 35; medium VI - 35 to 80; high VI - 80 to 110; very high VI - above 110. A high viscosity index indicates small oil viscosity changes with temperature. A low viscosity index indicates high viscosity changes with temperature. Therefore, a fluid that has a high viscosity index can be expected to undergo very little change in viscosity with temperature extremes and is considered to have a stable viscosity. A fluid with a low viscosity index can be expected to undergo a significant change in viscosity as the temperature fluctuates. For a given temperature range, say -18 to 370EC ( 0 - 100 EF), the viscosity of one oil may change considerably more than another. An oil with a VI of 95 to 100 would change less than one with a VI of 80. Knowing the viscosity index of an oil is crucial when selecting a lubricant for an application, and is especially critical in extremely hot or cold climates. Failure to use an oil with the proper viscosity index when

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