— University of Mosul —
College of Petroleum & Mining Engineering

Petroleum and Gas Chemistry
Lecture 5

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LECTURE CONTENTS

- Physical and Chemical Properties of Crude Oil and Oil Products (Viscosity)

2- Viscosity

Dynamic viscosity (η) is the force in dynes required to move a plane of 1 cm^2 area at a distance of 1 cm from another plane of 1 cm^2 area in 1 sec (is the tangential force per unit area required to move one horizontal plane with respect to another plane). In the cgs system, the unit of viscosity is the poise (gm/cm.s) or centipoise (0.01 P). Fluidity is simply the reciprocal of viscosity.

Kinematic viscosity (ν) is the dynamic viscosity in centipoises divided by the density at the same temperature:

$$\nu = \frac{\eta}{\rho}$$

Where ν is the kinematic viscosity

η is the dynamic viscosity

ρ is the density

Kinematic viscosity has the unit of stoke (cm^2/sec), although centistokes (0.01 cSt) is in more common usage.

Saybolt Method

The Saybolt universal viscosity (SUS) is the time in seconds required for the flow of 60 ml of petroleum from a container, at constant temperature, through a calibrated orifice. Another type the Saybolt furol viscosity (SFS) is determined in a similar manner, except that a larger orifice is employed.

$$\nu = \frac{a \times \text{Saybolt s} + b}{\text{Saybolt s}}$$

Where a and b are constants.

The Relation of Petroleum Viscosity and Temperature

Various studies have also been made on the effect of temperature on viscosity since the viscosity of petroleum, or a petroleum product, decreases as the temperature increases. The rate of change appears to depend primarily on the nature or composition of the petroleum, but other factors, such as volatility, may also have a minor effect. The effect of temperature on viscosity is generally represented by the equation:

$$log(v + c) = A + B\,log\,T$$

Where ν is kinematic viscosity in cS, T is temperature in ° K, and A and B are constants. This equation has been sufficient for most purposes and has come into very general use. The constants A and B vary widely with different oils, but c remains fixed at 0.6 for all oils with a viscosity over 1.5 cSt; it increases only slightly at lower viscosity (0.75 at 0.5 cSt).

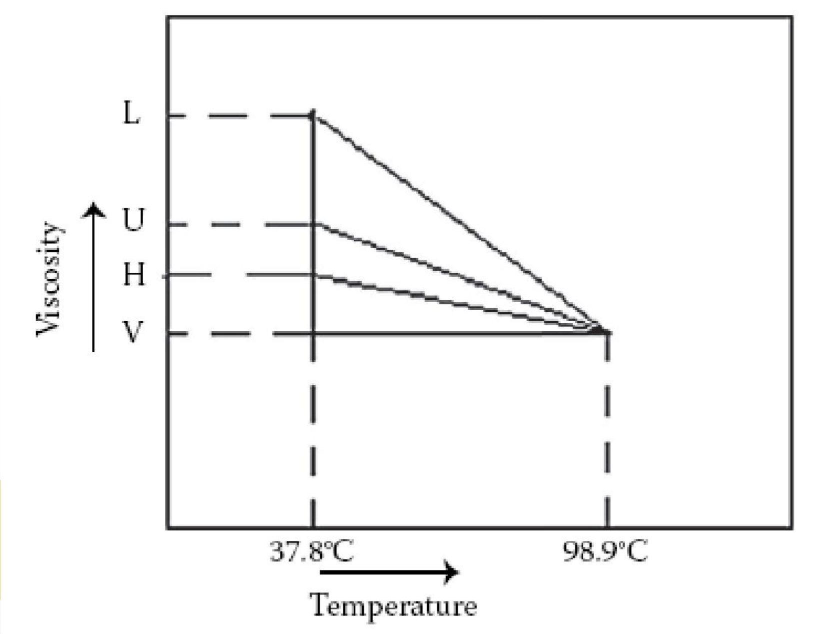
The viscosity-temperature characteristics of any oil, so plotted, thus creating a straight line, and the parameters A and B are equivalent to the intercept and slope of the line. To express the viscosity and viscosity-temperature characteristics of an oil, the slope and the viscosity at one temperature must be known; the usual practice is to select 38°C (100°F) and 99°C (210°F) as the observation temperatures.

Viscosity Index

The viscosity index (VI) is a parameter that indicates the rate of change of the oil viscosity due to a variation in temperature. This index is defined as the ratio of the difference of viscosity (U) of the lube oil to be used with respect to the viscosity (L) of petroleum (aromatic) oil having zero VI to the difference of viscosity (H) of high VI oil (paraffinic; 100 VI) to the viscosity (L) of zero VI oil for a temperature change from 38°C to 99°C. This can be written in the following way:

$$VI = 100\frac{(L - U)}{(L - H)}$$

Where L, U, and H are the viscosities of the low VI reference oil (VI = 0), the sample oil, and the high VI reference oil (VI = 100), respectively, all at a temperature of 38°C. Note that the viscosity of the sample (U) and reference oils (L and H) must be so selected that they have the same viscosity at 99°C. This can be explained graphically as below:



The relation of Petroleum Viscosity and Pressure

The viscosity of petroleum fractions increases on the application of pressure, and this increase may be very large. The pressure coefficient of viscosity correlates with the temperature coefficient, even when oils of widely different types are compared. A plot of the logarithm of the kinematic viscosity against pressure for several oils has given reasonably linear results up to 20,000 psi.

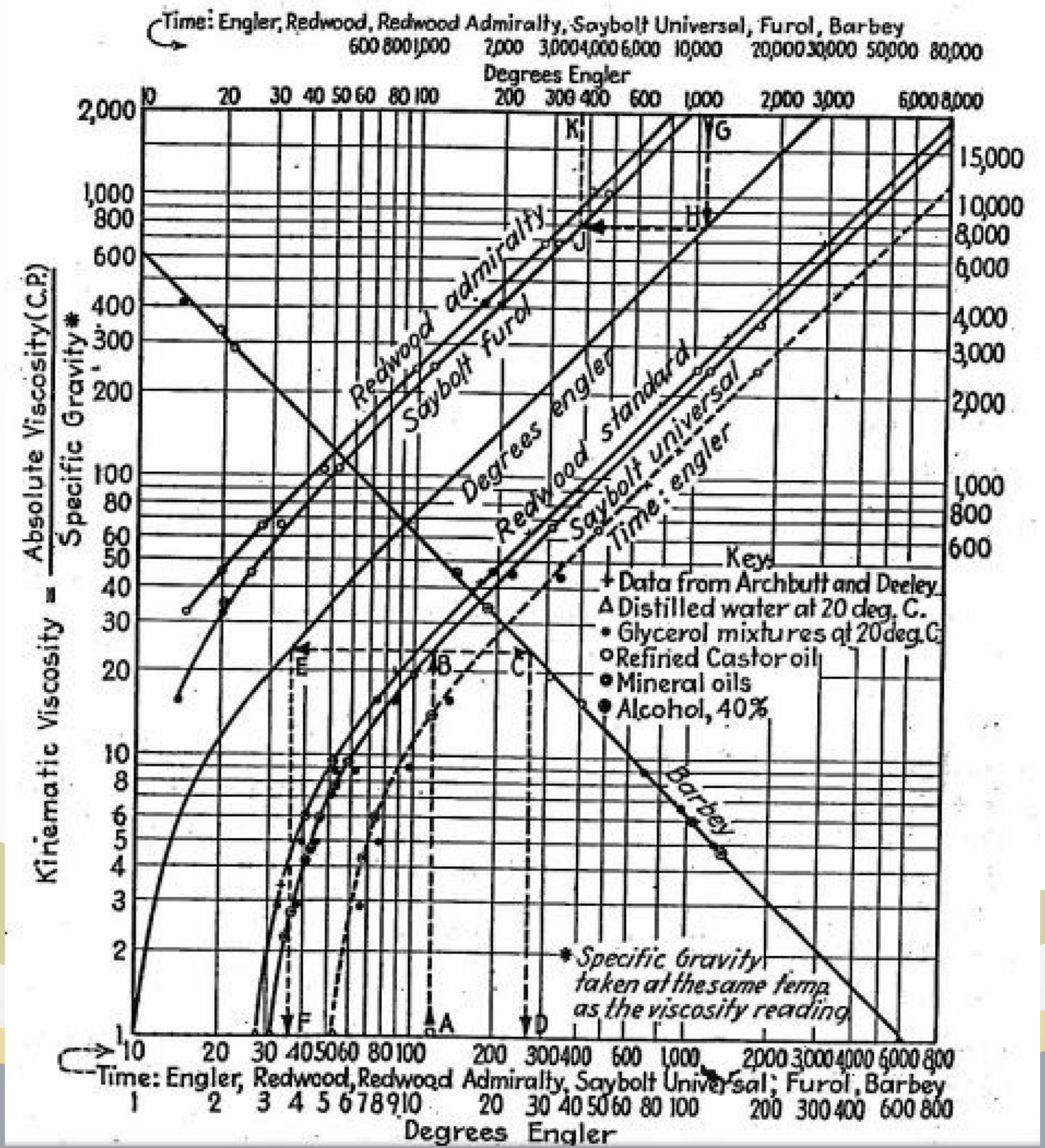
$$\nu_p = \nu_o c^p$$

Where ν_p is the viscosity at pressure p

ν_o is the viscosity at atmospheric pressure

c is constant

At higher pressures, the viscosity decreases with increasing temperature, as at atmospheric pressure; in fact, viscosity changes of small magnitude are usually proportional to density changes, whether these are caused by pressure or by temperature.


Time: Engler, Redwood, Redwood Admiralty, Saybolt Universal, Furol, Barbey
Degrees Engler
Kinematic Viscosity = Absolute Viscosity (C.P.) / Specific Gravity*
Redwood admiralty
Saybolt furol
Degrees engler
Redwood standard
Saybolt universal
Time: engler
Barbey
Key:
+ Data from Archbutt and Deeley
Δ Distilled water at 20 deg. C.
• Glycerol mixtures at 20 deg. C.
○ Refined Castor oil
● Mineral oils
● Alcohol, 40%
* Specific Gravity taken at the same temp. as the viscosity reading
Time: Engler, Redwood, Redwood Admiralty, Saybolt Universal; Furol, Barbey
Degrees Engler