Tikrit University

The College of Petroleum Processes Engineering

Petroleum Systems Control Engineering Department

Petroleum Refining Processes

Fourth Class

Lecture 2

By

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Physical and Chemical Properties of Crude Oil and Oil Products

1- Density, Specific Gravity, and API Gravity

Density is defined as mass per unit volume of a fluid. Density is a state function and for a pure compound depends on both temperature and pressure and is shown by ρ. Liquid densities decrease as temperature increases but the effect of pressure on liquid densities at moderate pressures is usually negligible.

Liquid density for hydrocarbons is usually reported in terms of specific gravity (SG) or relative density defined as

$$SG = \frac{\text{density of liquid at temperature } T}{\text{density of water at temperature } T}$$

Since the standard conditions adopted by the petroleum industry are 60°F (15.5°C) and 1 atm, specific gravities of liquid hydrocarbons are normally reported at these conditions. Water density at 60°F is 0.999 or almost 1 g/cm3, thus

$$SG\ (60°F/60°F) = \frac{\text{density of liquid at } 60°F \text{ in g/cm}^3}{0.999 \text{ g/cm}^3}$$

The American Petroleum Institute (API) defined the API gravity (degrees API) to quantify the quality of petroleum products and crude oils. The API gravity is defined as

$$\text{API gravity} = \frac{141.5}{\text{SG (at } 60^{\circ}\text{F)}} - 131.5$$

Crude Oils API = 10 – 50, crude oils can generally be classified according to API as shown

Crude Category	Gravity
Light crudes	API > 38
Medium crudes	38 > API > 29
Heavy crudes	29 > API > 8.5
Very heavy crudes	API < 8.5

The definition of specific gravity for gases is somewhat different. The specific gravity of a gas is proportional to the ratio of molecular weight of gas (Mg) to the molecular weight of air (28.97)

$$SG_g = \frac{M_g}{28.97}$$

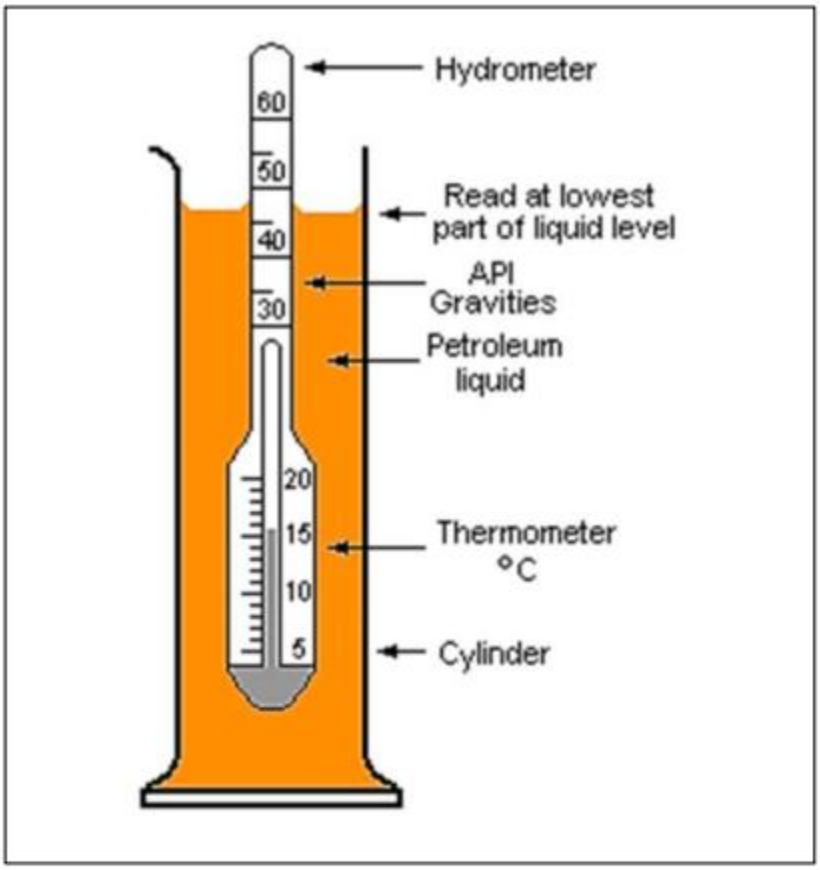
Density ASTM D 287-92, relative density (specific gravity), or API gravity of crude oil and

➢ A hydrometer (a calibrated floating device) is placed in the sample at the specified temperature.

➢ The depth to which the hydrometer sinks and comes to rest in the liquid indicates the relative weight of the liquid.

➢ The specific gravity is read directly from the calibrations on the hydrometer.

➢ The hydrometer value is converted to density at 15.6◦C or API gravity at 60◦F using standard tables



2- Viscossity

The viscosity of oil is a measure of its resistance to internal flow and an indication of its oiliness in the lubrication of surfaces. There are two types of viscosity: dynamic and kinematics viscosity.

Kinematic viscosity (υ) = dynamic viscosity (μ) / density (ρ)

The unit of dynamic viscosity is poise (0.1 Pa·s). It is more commonly expressed, particularly in ASTM standards, as centipoises (cP). While the kinematics viscosity as centiStokes – cSt (10-6 $m^2 \cdot s^{-1}$). The following equations can be used to calculate the liquid viscosities of petroleum fractions at atmospheric pressure and at temperatures of 37.8 °C(100 °F) and 98.9 °C (210 °F)

$$\log \nu_{210} = -0.463634 - 0.166532(\mathrm{API}) + 5.13447 \times 10^{-4}(\mathrm{API})^2 - 8.48995 \times 10^{-3} K(\mathrm{API}) + \frac{8.0325 \times 10^{-2} K + 1.24899(\mathrm{API}) + 0.197680(\mathrm{API})^2}{\mathrm{API} + 26.786 - 2.6296K}$$

$$\log \nu_{100} = 4.39371 - 1.94733K + 0.127690K^2 + 3.2629 \times 10^{-4}(\mathrm{API})^2 - 1.18246 \times 10^{-2} K(\mathrm{API}) + \frac{0.17161K^2 + 10.9943(\mathrm{API}) + 9.50663 \times 10^{-2}(\mathrm{API})^2 - 0.860218K(\mathrm{API})}{\mathrm{API} + 50.3642 - 4.78231K}$$

where v_{100} and v_{210} are the kinematic viscosities at 100 and 210 °F, in centistokes. The viscosity can be measured by several instruments (U-tube

Viscometer, Saybolt Universal Viscosity (SSU), thermo-viscosity, Red wood viscometer and Englar)

Thermo. = 15 + 148.5 kinematic Vis. = 46 SSU – 1183

The comparison of viscosity by different instruments is shown in Figure 1.

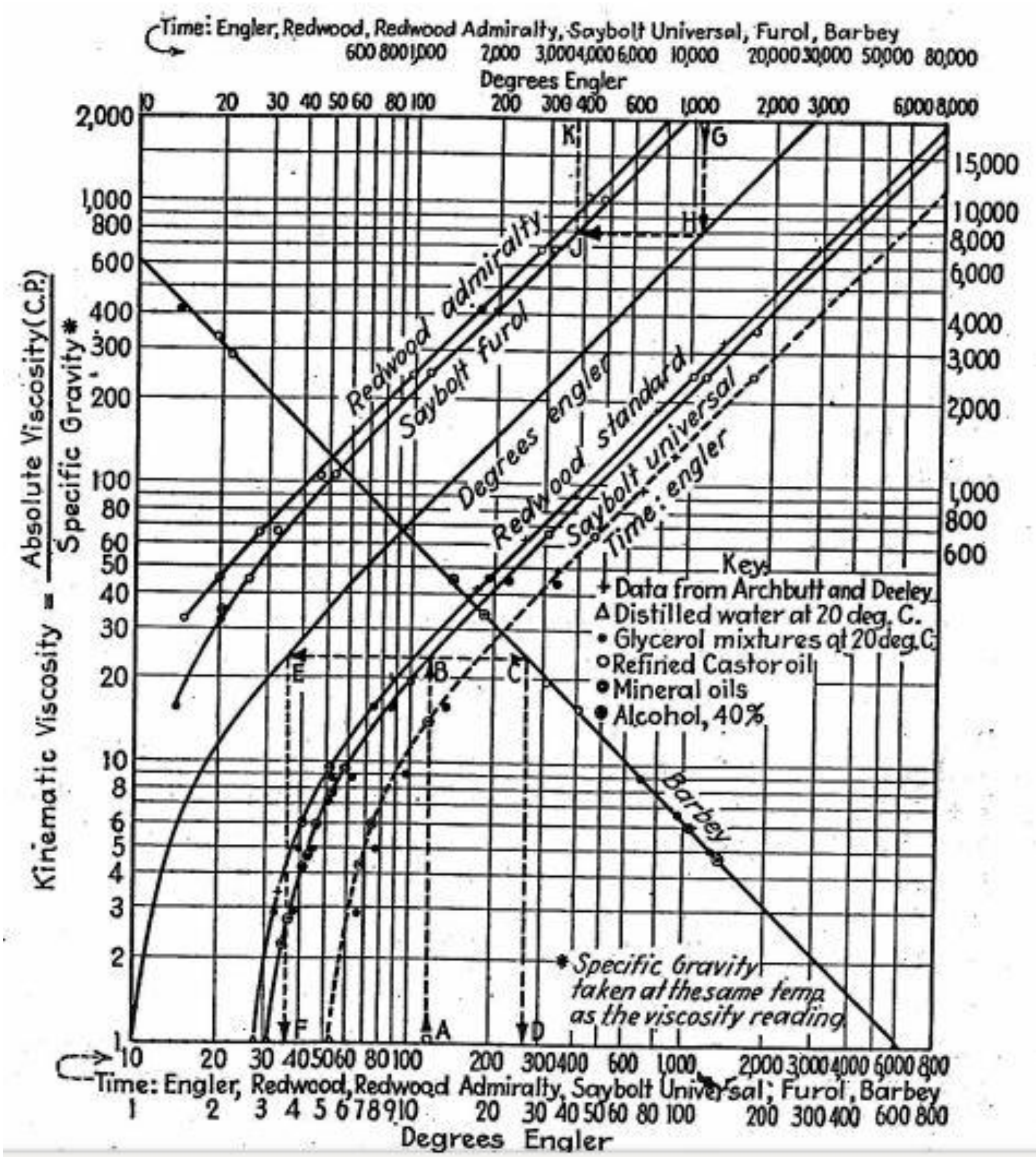


Figure1. Comparison of viscosity by different instruments (Viscosity must be at the same T).

3- Pour Point

The pour point is defined as the lowest temperature at which the sample will flow and is a rough indicator of the relative paraffinicity and aromaticity of the crude. A lower pour point means that the paraffin content is low and greater content of aromatics. To estimate the pour point of petroleum fractions from viscosity, molecular weight, and specific gravity, the following form is used for this purpose:

$$T_P = 130.47\left[SG^{2.970566}\right] \times \left[M^{(0.61235-0.47357SG)}\right] \times \left[\nu_{38(100)}^{(0.310331-0.32834SG)}\right]$$

where Tp is the pour point (ASTM D 97) in kelvin, M is the molecular weight, and v_{38} (100) is the kinematic viscosity at 37.8°C (100F) in cSt. This equation was developed with data on pour points of more than 300 petroleum fractions with molecular weights ranging from 140 to 800 and API gravities from 13 to 50 .

4- Carbon Residue, wt%

Carbon residue is determined by distillation to a coke residue in the absence of air. The carbon residue is roughly related to the asphalt content of the crude and to the quantity of the lubricating oil fraction that can be recovered. In most cases the lower the carbon residue, the more valuable the crude. This is expressed in terms of the weight percent carbon residue by either the Ramsbottom (RCR) or Conradson (CCR).

Crude distilled (%) at 1100°F = 100 – 3*CCR

CCR is the Carbon residue for whole crude oil

5- Salt Content, lb/1000 bbl

If the salt content of the crude, when expressed as NaCl, is greater than 10 lb/1000 bbl, it is generally necessary to desalt the crude before processing. If the salt is not removed, severe corrosion problems may be encountered. If residua are processed catalytically, desalting is desirable at even lower salt contents of he crude. Although it is not possible to have an accurate conversion unit between lb/1000 bbl and ppm by weight because of the different densities of crude oils, 1 lb/1000 bbl is approximately 3 ppm.

6- Sulfur Content, wt%

Sulfur content and API gravity are two properties which have had the greatest influence on the value of crude oil, although nitrogen and metals contents are increasing in importance. The sulfur content is expressed as percent sulfur by weight and varies from less than 0.1% to greater than 5%. Crudes with greater than 0.5% sulfur generally require more extensive processing than those with lower sulfur content.

7- Flash point

Flash point TF, for a hydrocarbon or a fuel is the minimum temperature at which vapor pressure of the hydrocarbon is sufficient to produce the vapor needed for spontaneous ignition of the hydrocarbon with the air with the presence of an external source, i.e., spark or flame. From this definition, it is clear that hydrocarbons with higher vapor pressures (lighter compounds) have lower flash points. Generally flash point increases with an increase in boiling point. Flash point is an important parameter for safety considerations, especially during storage and transportation of volatile petroleum products (i.e., LPG, light naphtha, gasoline) in a high-temperature environment. The flash point can be estimated using the following equation:

$$T_F = 15.48 + 0.70704\, T_{10}$$

Where T10 is normal boiling point for petroleum fractions at 10 vol% distillation temperature. Both temperatures (T10 and flas point (TF) in Kelvin).

Notes:

- Flash point of petroleum fractions is the minimum temperature at which vapours arising from the oil will ignite, i.e. flash, when exposed to a flame under specified conditions.

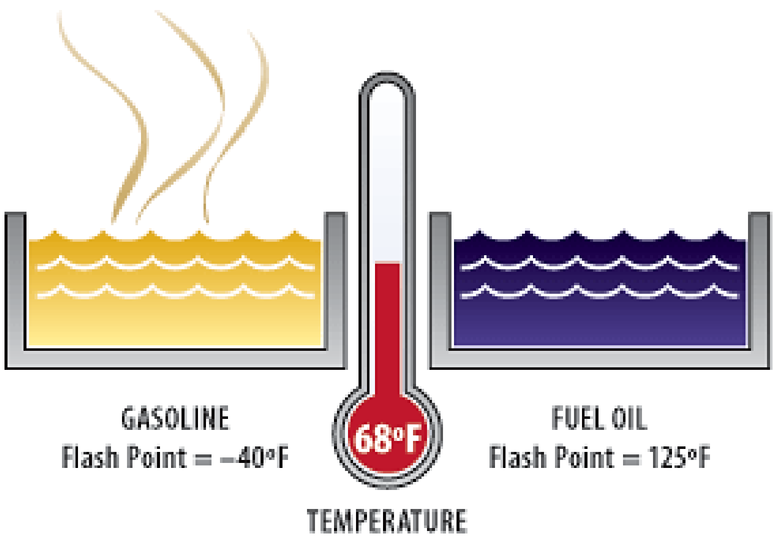
➢ The flash point indicates the maximum temperature that the fuel can be stored without serious fire hazard.

➢ Flash point is an important test for light petroleum fractions especially in high temperature environment and is directly related to the safe storage and handling of petroleum products.

➢ Flash point decreases with increasing volatility of fuel, i.e. the higher vapour pressure the lower is the flash point.

➢ Generally for crude oils with RVP greater than 0.2 bar the flash point is less than 20°C.

➢ High flash point means higher temperature is required for the fuel to flash. The fuel therefore does not ignite easily and is safe.



There are several methods of determining flash points of petroleum fractions.

• **The Closed Tag method (Abel) (ASTM D56)** is used for petroleum stocks with flash points below 80°C (175 °F).

• **The Pensky-Martens method (close cup) (ASTM D93)** is used for all petroleum products except waxes, solvents, and asphalts.

• **The Cleveland Open Cup method (ASTM D 92)** is used for petroleum fractions with flash points above 80°C (175°F) excluding fuel oil.

• This method usually gives flash points 3-6°C higher than the above two methods.

The main reason for the requirement of flash point test is to:

➢ Assess the fire hazards of a liquid hydrocarbon with regard to its flammability and then classify the liquid into a group.

➢ This classification is then used to warn of a risk and to enable the correct precautions to be taken when using, storing or transporting the liquid.

➢ The lower the flash point temperature, the greater the risk.

8- Fire Point

Fire point of petroleum fractions is the lowest temperature at which vapors arising from the oil will ignite, i.e. fire, when exposed to a spark or flame under specified conditions. Therefore, the fire point of a fuel indicates the maximum temperature that it must not reach it to prevent the combustion of the petroleum fractions.

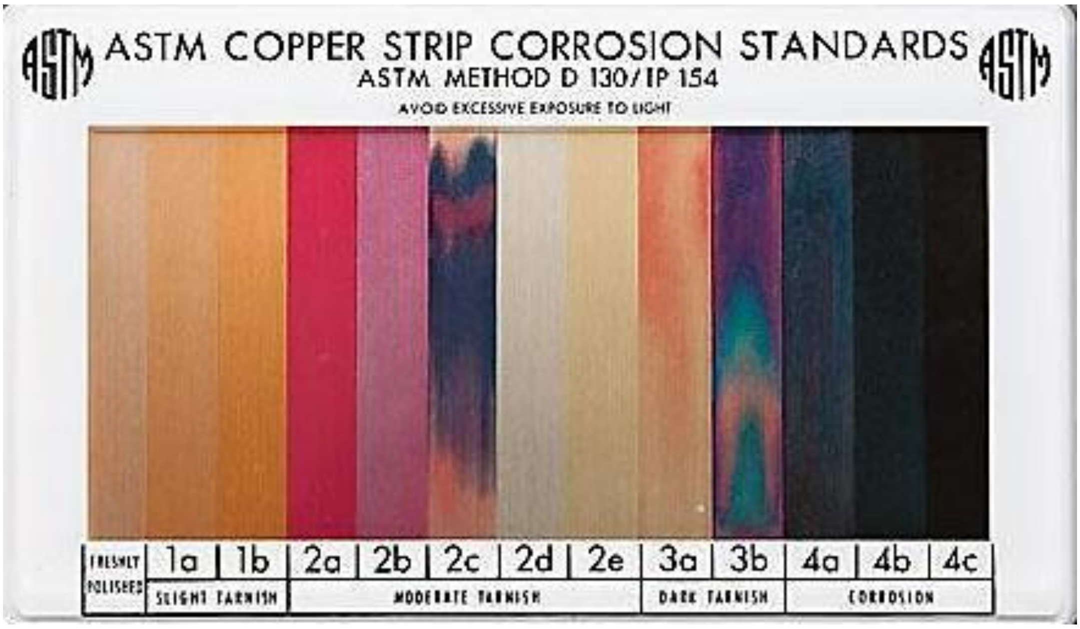
9- Copper strip corrosion test

➢ Measures the corrosivity of light and mid distillates due to presence of sulphur compounds.

➢ ASTM D130 for Petroleum products (gasoline, aviation fuel, kerosene, diesel, fuel oil, natural gasoline).

➢ A polished copper strip is immersed in the sample for three hours at 50°C (122°F). The strip is then removed and tested for discoloration and corrosion of a copper strip under standard test conditions.

➢ Classification number ranges from 1 to 4 after a comparison with the ASTM D130 copper strip corrosion standard is given as below.



class	Designation	Description
1	Slight Tarnish	a) Light orange, almost same as the finely polished strip b) Dark orange
2	Moderate Tarnish	a) Claret red b) Lavender c) Multi colored d) Silvery e) Brassy or gold
3	Dark Tarnish	a) Magenta overcast on brassy strip b) Multi colored with red and green showing no gray
4	Corrosion	a) Transparent black, dark gray, or brown b) Graphite or lusterless black c) Glassy or black