A Honeywell Company

Calculation of UOP Characterization Factor and Estimation of Molecular Weight of Petroleum Oils

UOP Method 375-07

Scope

This method is for calculating the UOP Characterization Factor of petroleum oils from API gravity and distillation or viscosity data. Average molecular weight of petroleum oils is estimated from API gravity and distillation data. The UOP Characterization Factor, commonly called K, is indicative of the general origin and nature of a petroleum stock. Values of 12.5 or higher indicate a material predominantly paraffinic in nature. Highly aromatic materials have characterization factors of 10.0 or less.

References

ASTM Method D 86, "Distillation of Petroleum Products at Atmospheric Pressure," www.astm org

ASTM Method D 88, "Saybolt Viscosity," www.astm org

ASTM Method D 445, "Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)," www.astm org

ASTM Method D 1160, "Distillation of Petroleum Products at Reduced Pressure," www.astm org

ASTM Method D 1250, "Guide for the Use of Petroleum Measurement Tables," www.astm org

ASTM Method D 1298, "Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method," www.astm org

ASTM Method D 2161, "Practice for Conversion of Kinematic Viscosity to Saybolt Universal Viscosity or Saybolt Furol Viscosity," www.astm org

Smith, R. L., and Watson, K. M., *Ind. Eng. Chem.*, **29**, 1408 (1937)

Watson, K. M., Nelson E. F., and Murphy, G. B., *Ind. Eng. Chem.*, **27**, 1460 (1935)

Outline of Method

The UOP Characterization Factor, K, can be calculated using either distillation or viscosity data. The distillation data procedure calculates the K factor using data obtained from ASTM D 1298, "Density,

Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method," in combination with either ASTM D 86, " Distillation of Petroleum Products AT Atmospheric Pressure," or ASTM D 1160, "Distillation of Petroleum Products at Reduced Pressure," dependent on the sample, and the nomographs or engineering charts incorporated in the method. The viscosity data procedure calculates the K factor using data obtained from ASTM D 1298 in combination with either ASTM D 445, "Kinematic Viscosity of Transparent and Opaque Liquids (or the calculation of Dynamic Viscosity)," or ASTM D 88, " Saybolt Viscosity" and the nomographs incorporated in the method.

The Average molecular Weight is estimated using the same data as for the K factor distillation data procedure, but with a different set of nomographs.

The Appendix describes a procedure to calculate the K factor and the molecular weight using the relative density and ASTM Distillation data and equations that were derived from curve fits of the nomographs.

If the sample is beyond the scopes of these methods, other standard methods may be substituted. In some cases, this may involve additional calculations to convert the observed data to the appropriate units.

Definitions

Cubic average boiling point is the cube of the sum of the products of the volume fraction multiplied by the cube root of the boiling point of each component expressed in degrees Rankine.

Mean average boiling point is the arithmetic average of the true molal boiling point and the cubic average boiling point expressed in degrees Fahrenheit.

Molecular weight, as employed herein, is that average molecular weight of a petroleum fraction and not that of a single, pure compound.

True molal average boiling point is the sum of the products of the mol fraction multiplied by the boiling point of each component.

UOP Characterization Factor, *K*, of a petroleum oil is defined as the cube root of its cubic average boiling point, in degrees Rankine, divided by its relative density at 60ºF (15.56ºC).

Volumetric average boiling point is the arithmetic average boiling point over the range of 10% to 90% of the ASTM distillation.

Apparatus

No additional apparatus is required beyond the apparatus listed in the above methods.

Procedure

Determine the API gravity or relative density at 60ºF of the sample according to ASTM D 1298.

Perform an ASTM distillation by either ASTM D 86 or D 1160, as appropriate for the sample. Correct the data to 760 mm Hg and for material loss as specified in these methods. Convert temperatures recorded in degrees Celsius to degrees Fahrenheit.

Characterization factor may also be estimated using kinematic viscosity at 100, 122 or 210ºF (38, 50 or 99ºC). Kinematic viscosity is determined directly from ASTM D 445. Saybolt viscosity, determined by ASTM D 88, can be converted to kinematic viscosity using ASTM D 2161.

Calculations

UOP K Factor from API Gravity and ASTM Distillation

Volumetric Average Boiling Point

Calculate the volumetric average boiling point as the average of the 10, 30, 50, 70 and 90 vo1-% temperatures. Calculate the slope as °F per percent (°F/%) by subtracting the 10 vol-% temperature from the 90 vol-% temperature, and dividing the difference by 80 vol-%.

Cubic Average Boiling Point

Obtain the value of the correction to be applied to the volumetric average boiling point using Figure 1. Using the value of the slope calculated above, go to the bottom of the chart, then proceed vertically to the curve which represents the value of the volumetric average boiling point. Interpolate between curves as needed. Read the value of the vertical scale on the left side corresponding to this point to obtain the value of the correction term. *Subtract* this term from the volumetric average boiling point to calculate the cubic average boiling point.

UOP Characterization Factor, K

Determine the UOP Characterization Factor, K, using the cubic average boiling point and API gravity. Locate the cubic average boiling point on the horizontal scale at the bottom of Figure 2. Locate the API gravity on the vertical scale at the left of the graph. Find the intersection of the vertical and horizontal lines from these points. Read the number of the curve nearest to this point. This number, corrected by interpolation for the distance of the point from the nearest curve, is the characterization factor, K.

Example:

Calculate the characterization factor for a gas oil of 28.7° API at 60ºF having the following distillation properties:

ASTM Distillation (Corrected to 760 mm Hg Pressure)

Volume-%	10	30	50	70	90
Temp., ºF	598	700	755	802	874

$$\text{Volumetric average boiling point} = \frac{598 + 700 + 755 + 802 + 874}{5} = 746$$

$$\text{Slope} = \frac{874 - 598}{80} = 3.45^{\circ}\text{F/volume-\%}$$

Correction term = 5ºF from Figure 1

Cubic average boiling point = 746 − 5 = 741ºF

Characterization factor, K = 12.03 from Figure 2

UOP K Factor from API Gravity and Kinematic Viscosity

Viscosities measured at high temperatures yield more reliable values for characterization factors than viscosities measured at low temperatures. Viscosity at low temperatures is influenced by the width of boiling range as well as by relative density and characterization factor. For samples that do not yield a