Designation: D2501 – 14

Standard Test Method for Calculation of Viscosity-Gravity Constant (VGC) of Petroleum Oils[1]

This standard is issued under the fixed designation D2501; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the calculation of the viscosity-gravity constant (VGC) of petroleum oils[2] having viscosities in excess of 5.5 mm^2/s at 40°C (104°F) and in excess of 0.8 mm^2/s at 100°C (212°F).

1.2 Annex A1 describes a method for calculating the VGC from Saybolt (SUS) viscosity and relative density.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3.1 The SI unit of kinematic viscosity is mm^2/s.

1.3.2 *Exception*—Fahrenheit temperature units are used in this practice because they are accepted by industry for the type of legacy conversions described in this practice.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)

D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

D1298 Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method

D2140 Practice for Calculating Carbon-Type Composition of Insulating Oils of Petroleum Origin

D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter

D7042 Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)

3. Summary of Test Method

3.1 The kinematic viscosity at 40°C (104°F) and the density at 15°C of the oil are determined. If the oil is extremely viscous, or if it is otherwise inconvenient to determine the viscosity at 40°C, the kinematic viscosity at 100°C (212°F) can be used. The viscosity-gravity constant is calculated from the measured physical properties using the appropriate equation.

4. Significance and Use

4.1 The viscosity-gravity constant (VGC) is a useful function for the approximate characterization of the viscous fractions of petroleum.[2] It is relatively insensitive to molecular weight and is related to a fluids composition as expressed in terms of certain structural elements. Values of VGC near 0.800 indicate samples of paraffinic character, while values close to 1.00 indicate a preponderance of aromatic structures. Like other indicators of hydrocarbon composition, the VGC should not be indiscriminately applied to residual oils, asphaltic materials, or samples containing appreciable quantities of nonhydrocarbons.

5. Measurement of Physical Properties

5.1 Preferably, determine the kinematic viscosity at 40°C as described in Test Method D445 or D7042. However, if the sample is extremely viscous or if it is otherwise inconvenient to measure the viscosity at 40°C, the viscosity at 100°C may be determined.

5.2 Determine the density at 15°C in accordance with Test Method D1298, D4052, or D7042. Equivalent results can be obtained by determining API Gravity at 60°F (15.56°C) in accordance with Test Method D287, and converting the result

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.04.0K on Correlative Methods.

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[2] Coats, H. B., and Hill, J. B., *Industrial and Engineering Chemistry*, Vol 20, 1928, p. 641.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

to density at 15°C by means of Table 3 of the Petroleum Measurement Tables (American Edition).[4]

NOTE 1—If it is necessary to convert a result obtained using the digital density meter to a density at another temperature, the Petroleum Measurement Tables can be used only if the glass expansion factor has been excluded.

6. Calculation of Viscosity-Gravity Constant

6.1 *From Kinematic Viscosity at 40°C and Density at 15°C*—Use the following equation to calculate the VGC from the measured properties:

NOTE 2—The original formulae[2] used Saybolt Universal Seconds and specific gravity as the input parameters. The formulae were later transformed to use kinematic viscosity in excess of 4 mm^2 at 40°C and density as input parameters and further revised to use kinematic viscosity in excess of 5.5 mm^2, all while keeping the original concepts of the formulae intact.

$$VGC = \frac{G - 0.0664 - 0.1154\,Log(V - 5.5)}{0.94 - 0.109\,Log(V - 5.5)} \quad (1)$$

where:

G = density at 15°C, g/mL, and
V = kinematic viscosity at 40°C, mm^2/s.

6.2 *From Kinematic Viscosity at 100°C and Density at 15°C*—Use the following equation to calculate the VGC:

$$VGC = \frac{G - 0.108 - 0.1255\,Log(V' - 0.8)}{0.90 - 0.097\,Log(V' - 0.8)} \quad (2)$$

where:

G = density at 15°C, g/mL, and
V' = kinematic viscosity at 100°C, mm^2/s.

7. Report

7.1 Report the calculated VGC to the nearest .002 unit.

7.2 If the viscosity at 100°C was used for the calculation, state this in the report.

8. Precision and Bias

8.1 The calculation of viscosity-gravity constant from kinematic viscosity at 40°C and density at 15°C is exact. Precision limits are not assigned to this calculation.

8.2 The precision and bias for this test method for calculating VGC are essentially as specified in Test Methods D287, D445, D1298, D4052, and D7042, and Practice D2140. The precision can be calculated as follows:

8.2.1 For viscosity measured at 40°C,

$$r_Y = \frac{1}{0.94 - 0.109\log_{10}(V - 5.5)} \cdot \sqrt{r_G^{\,2} + r_V^{\,2}\,\frac{0.00224\,(Y - 1.059)^2}{(V - 5.5)^2}} \quad (3)$$

where:

r_Y = precision of the VGC,
r_G = precision of the gravity from D287, D1298, D4052, or D7042
r_V = precision of the viscosity from D445 or D7042,
V = measured viscosity, and
Y = VGC.

8.2.2 For viscosity measured at 100°C,

$$r_Y = \frac{1}{0.90 - 0.097\,\log_{10}(V - 0.8)} \cdot \sqrt{r_G^{\,2} + r_V^{\,2}\,\frac{0.00177(Y - 1.294)^2}{(V - 0.8)^2}} \quad (4)$$

8.3 The VGC calculated from the viscosity at 100°C can differ slightly from that calculated from the viscosity at 40°C. A statistical evaluation of VGC data derived from equivalent viscosities at both 100°F and 210°F suggests that in the range from about 0.80 to 0.95 VGC, the expected average difference will be approximately 0.003 units. Whenever possible, it is preferable to determine the VGC using Eq 1.

8.4 *Bias*—The procedure in Test Method D2501 for calculation of viscosity-gravity constant has no bias because the value of viscosity-gravity constant can be defined only in terms of a test method.

8.5 The term viscosity-gravity constant is also used in Practice D2140, for determining carbon-type composition of insulating oils of petroleum origin. The equations used are different from those in this test method; the bias between the two test methods is unknown.

9. Keywords

9.1 aromatic; density; kinematic viscosity; paraffinic

[4] Published jointly by, and available from, ASTM Headquarters and Energy Institute, 61 New Cavendish St., London W1M 8AP. Companion volumes—the British Edition and the Metric Edition—are also available. These tables supersede all other similar tables previously published by either of these societies and the National Bureau of Standards Circular C-410 and the supplement to Circular C-410.

ANNEX

(Mandatory Information)

A1. CALCULATION OF VISCOSITY-GRAVITY CONSTANT FROM SAYBOLT VISCOSITY AND RELATIVE DENSITY (SPECIFIC GRAVITY)

A1.1 The calculation of viscosity-gravity constant (VGC) can also be calculated from viscosity in units of Saybolt seconds universal (SUS) and relative density (specific gravity).

A1.2 From Saybolt Viscosity at 100°F and Relative Density (Specific Gravity) 60/60°F

A1.2.1 Use the following equation to calculate the VGC from the measured properties:

$$VGC = \frac{10G - 1.0752\ \log(V - 38)}{10 - \log(V - 38)} \quad \text{(A1.1)}$$

where:

G = relative density (specific gravity) at 60/60°F, and
V = Saybolt Universal viscosity at 100°F.

A1.3 From Saybolt Viscosity at 210°F and Relative Density (Specific Gravity) 60/60°F

A1.3.1 Use the following equation to calculate the VGC:

$$VGC = \frac{G - 0.1244\ \log(V_1 - 31)}{0.9255 - 0.0979\ \log(V_1 - 31)} - 0.0839 \quad \text{(A1.2)}$$

where:

G = relative density (specific gravity) at 60/60°F, and
V_1 = Saybolt Universal viscosity at 210°F.

A1.4 The viscosity-gravity constant calculated from the Saybolt viscosity at 210°F can differ slightly from that calculated from the 100°F viscosity. A statistical evaluation of VGC data derived from both the 100°F and 210°F viscosities suggests that in the range from about 0.80 to 0.5 VGC, the expected average difference will be approximately 0.003 units. Whenever possible, it is preferable to determine the VGC using Eq A1.1.

APPENDIX

X1. REVISION HISTORY

X1.1 This current revision includes a change in Eq 1 and Eq 2 in Section 6, Calculation of Viscosity-Gravity Constant.

X1.1.1 During a revision change from D2501-87 and D2501-91 there was a change in units from SUS (Saybolt Universal Seconds) to the SI unit of viscosity mm^2/s (cSt). This unit change necessitated a modification of the Scope (1.1) from "in excess of 40 Saybolt Universal Seconds (SUS) at 100°F (37.79°C)" to "in excess of 4 cSt. = 4×10^{-6} m^{-2} /s at 40°C (104°F)." This change created a mathematical error of trying to take the log of a negative number in Eq 1 (in Section 6, Calculation of Viscosity-Gravity Constant) for V (Kinematic Viscosities) less than 5.5 cSt (mm^2/s) and the Scope value in excess of 4 cSt. (mm^2/s). Consensus input to this discrepancy was to change the Scope from "in excess of 4 cSt. = 4×10^{-6} m^{-2}/s at 40°C" to "5.5 mm^2/s at 40°C (104°F) and in excess of 0.8 mm^2/s at 100°C (212°F)." This change was made in the D2501-11 revision.

X1.2 Expected Average Differences in Section 8.3

X1.2.1 Section 8.3 (Precision and Bias) discusses the "statistical evaluation of VGC data derived from equivalent viscosities at both 100°F and 210°F suggests that in the range from about 0.80 to 0.95 VGC, the expected average difference will be approximately 0.003 units." Because no evaluation has been performed in SI units, the retention of the English units (°F) is retained.

SUMMARY OF CHANGES

Subcommittee D02.04 has identified the location of selected changes to this standard since the last issue (D2501 – 11) that may impact the use of this standard. (Approved June 1, 2014.)

(1) Test Method D7042 added as alternative to Test Method D445 or Test Method D4052.