Designation: D2161 – 20

Standard Practice for Conversion of Kinematic Viscosity to Saybolt Universal Viscosity or to Saybolt Furol Viscosity[1]

This standard is issued under the fixed designation D2161; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This practice[2] covers the conversion tables and equations for converting kinematic viscosity in mm^2/s at any temperature to Saybolt Universal viscosity in Saybolt Universal seconds (SUS) at the same temperature and for converting kinematic viscosity in mm^2/s at 122 °F and 210 °F (50 °C and 98.9 °C) to Saybolt Furol viscosity in Saybolt Furol seconds (SFS) at the same temperatures. Kinematic viscosity values are based on water being 1.0034 mm^2/s (cSt) at 68 °F (20 °C).

1.2 If a method other than Test Method D445 is used to generate the kinematic viscosity data, apply appropriate relative-bias correction factors as found in the precision section of that method, before performing the calculations of this practice.

NOTE 1—The equations in D2161 were originally empirically derived using data from both D445 and the Saybolt viscometer method. Therefore, it is conceivable that an error could result if the kinematic viscosities used are not bias-corrected to D445 results. It is recommended that kinematic viscosity be reported in millimetres squared per second, instead of Saybolt Universal Seconds (SUS) or Saybolt Furol Seconds (SFS). This method is being retained for the purpose of calculation of kinematic viscosities from SUS and SFS data that appear in past literature. One millimetre squared per second (mm^2/s) equals one centistoke (cSt), which is another unit commonly found in older literature.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for reference information purposes only. The SI unit of kinematic viscosity is mm^2/s.

1.3.1 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

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

D2270 Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 °C and 100 °C

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

3. Summary of Practice

3.1 The Saybolt Universal viscosity equivalent to a given kinematic viscosity varies with the temperature at which the determination is made. The basic conversion values are those given in Table 1 for 100 °F. The Saybolt Universal viscosity equivalent to a given kinematic viscosity at any temperature may be calculated as described in 4.3. Equivalent values at 210 °F are given in Table 1 for convenience.

3.2 The Saybolt Furol viscosity equivalents are tabulated in Table 3 for temperatures of 122 °F and 210 °F only.

[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.07 on Flow Properties.

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[2] This practice, together with Practice D2270, replaces Compilation of ASTM Viscosity Tables for Kinematic Viscosity Conversions.

[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**

3.3 Examples for using the tables are given in Appendix X1.

3.4 Example Historical Viscosity Extrapolation Tables to Zero Degrees Fahrenheit (SSU).[4]

4. Significance and Use

4.1 At one time the petroleum industry relied on measuring kinematic viscosity by means of the Saybolt viscometer, and expressing kinematic viscosity in units of Saybolt Universal Seconds (SUS) and Saybolt Furol Seconds (SFS). This practice is now obsolete in the petroleum industry.

4.2 This practice establishes the official equations relating SUS and SFS to the SI kinematic viscosity units, mm^2/s.

4.3 This practice allows for the conversion between SUS and SFS units and SI units of kinematic viscosity.

5. Procedure for Conversion to Saybolt Universal Viscosity

5.1 Convert kinematic viscosities between 1.81 mm^2/s and 500 mm^2/s (cSt) at 100 °F, and between 1.77 mm^2/s and 139.8 mm^2/s (cSt) at 210 °F, to equivalent Saybolt Universal seconds directly from Table 1 (see Appendix X1, Example 1).

NOTE 2—Obtain viscosities not listed, but which are within the range given in Table 1, by linear interpolation (see Appendix X1, Example 2).

5.2 Convert kinematic viscosities greater than the upper limits of Table 1 at temperatures of 100 °F and 210 °F to Saybolt Universal viscosities as follows (see Appendix X1, Example 3):

$$\text{Saybolt Universal seconds} = \text{centistokes} \times B \tag{1}$$

where $B = 4.632$ at 100 °F or 4.664 at 210 °F.

5.3 At temperatures other than 100 °F or 210 °F, convert kinematic viscosities to Saybolt Universal viscosities as follows (see Appendix X1, Example 4):

$$U_t = U_{100°F}(1 + 0.000061(t - 100)) \tag{2}$$

where:

U_t = Saybolt Universal viscosity at t °F, and
$U_{100°F}$ = Saybolt Universal viscosity at 100 °F in Saybolt Universal seconds equivalent to kinematic viscosity in centistokes at t °F, from Table 1.

NOTE 3—The multipliers for Saybolt Universal seconds in Eq 2 are given as Factor A in Table 2 for a range of temperatures.

5.4 Since the relationship between Saybolt and kinematic viscosities is linear above 75 mm^2/s (cSt), kinematic viscosities above this limit may be converted to Saybolt Universal viscosities at any temperature between 0 °F and 350 °F by use of Eq 1 (4.2), selecting the proper factor for B from Table 2 (see Appendix X1, Example 5).

6. Procedure for Conversion to Saybolt Furol Viscosity

6.1 Convert kinematic viscosities between 48 mm^2/s to 1300 mm^2/s (cSt) at 122 °F, and between 50 mm^2/s and 1300 mm^2/s (cSt) at 210 °F, to equivalent Saybolt Furol seconds directly from Table 3 (see Appendix X1, Examples 6 and 7).

NOTE 4—Viscosities not listed, but which are within the range given in Table 3, may be obtained by linear interpolation (see Appendix X1, Example 8).

6.2 Convert kinematic viscosities above 1300 cSt to equivalent Saybolt Furol seconds by use of the following equations (see Appendix X1, Example 9):

$$\text{Saybolt Furol seconds at } 122°F = 0.4717 \times \text{mm}^2/\text{s (cSt) at } 122°F \tag{3}$$

$$\text{Saybolt Furol seconds at } 210°F = 0.4792 \times \text{mm}^2/\text{s (cSt) at } 210°F \tag{4}$$

7. Procedure for Computer Calculation

7.1 Table 1 and Table 3 were computed by fitting a smooth curve to the original experimental data points. The derived equations are given as follows for the convenience of those who wish to use a computer for conversion rather than refer to the tables:

$$U_{100°F} = 4.6324\nu + \frac{1.0 + 0.03264\nu}{(3930.2 + 262.7\nu + 23.97\nu^2 + 1.646\nu^3) \times 10^{-5}} \tag{5}$$

$$U_t = [1.0 + 0.000061(t - 100)] \cdot \left[4.6324\nu + \frac{1.0 + 0.03264\nu}{(3930.2 + 262.7\nu + 23.97\nu^2 + 1.646\nu^3) \times 10^{-5}}\right] \tag{6}$$

$$F_{122°F} = 0.4717\nu + \left[\frac{13924}{(\nu^2 - 72.59\nu + 6816)}\right] \tag{7}$$

$$F_{210°F} = 0.4792\nu + \left[\frac{5610}{(\nu^2 + 2130)}\right] \tag{8}$$

where:

ν = kinematic viscosity, mm^2/s (cSt) at t°F,
$F_{122°F}$ = Saybolt Furol viscosity at 122 °F in Saybolt Furol seconds equivalent to kinematic viscosity, mm^2/s (cSt) at 122 °F, and
$F_{210°F}$ = Saybolt Furol viscosity at 210 °F in Saybolt Furol seconds equivalent to kinematic viscosity, mm^2/s (cSt) at 210 °F.

7.2 Eq 5 and Eq 6 and Table 1 are limited to values of Saybolt Universal of 32.0 s and above.

7.3 Eq 7 and Eq 8 and Table 3 are limited to values of Saybolt Furol of 25.1 s and above.

8. Supplementary Conversion Equivalents

8.1 The following units and equivalents are frequently used in connection with viscosity conversions:

poise	=	cgs unit of absolute viscosity.
centipoise	=	0.01 poise.
stokes	=	cgs unit of kinematic viscosity.
centistokes	=	0.01 stokes.
centipoise	=	centistokes × density (at temperature under consideration).

[4] Originally an adjunct produced in 1998. Supporting documentation has been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-2014. Contact ASTM Customer Service at service@astm.org.

9. Report

9.1 Saybolt Universal and Saybolt Furol viscosities should be reported to the nearest 0.1 s for values below 200 s and to the nearest whole second for values of 200 s and higher.

10. Keywords

10.1 kinematic viscosity; Saybolt furol; Saybolt universal