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## Standard Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 and 100°C<sup>1</sup>

This standard is issued under the fixed designation D2270; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

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

### 1. Scope\*

1.1 This practice<sup>2</sup> covers the procedures for calculating the viscosity index of petroleum products, such as lubricating oils, and related materials from their kinematic viscosities at 40 and 100°C.

NOTE 1—The results obtained from the calculation of *VI* from kinematic viscosities determined at 40 and 100°C are virtually the same as those obtained from the former *VI* system using kinematic viscosities determined at 37.78 and 98.89°C.

1.2 This practice does not apply to petroleum products with kinematic viscosities less than 2.0 mm<sup>2</sup>/s at 100°C. Table 1 given in this practice applies to petroleum products with kinematic viscosities between 2 and 70 mm<sup>2</sup>/s at 100°C. Equations are provided for calculating viscosity index for petroleum products having kinematic viscosities above 70 mm<sup>2</sup>/s at 100°C.

1.2.1 In cases where kinematic viscosity data are not available at temperatures of 40 and 100°C, an estimate may be made of the viscosity index by calculating the kinematic viscosity at temperatures of 40 and 100°C from data obtained at other temperatures. Such viscosity index data may be considered as suitable for information only and not for specification purposes. See Test Method [D341](#), Annex A1.

1.3 The kinematic viscosity values are determined with reference to a value of 1.0034 mm<sup>2</sup>/s at 20.00°C for distilled water. The determination of the kinematic viscosity of a

petroleum product shall be carried out in accordance with Test Methods [D445](#), [D7042](#), [IP 71](#), or [ISO 3104](#).

1.3.1 If Viscosity Index calculated for a given sample using kinematic viscosity measurements from different test methods are in disagreement, the values calculated from Test Method [D445](#) measurements shall be accepted.

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

1.4.1 The values stated in SI units are to be regarded as the standard. For user reference, 1 mm<sup>2</sup>/s = 10<sup>-6</sup>m<sup>2</sup>/s = 1 cSt.

1.5 *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*:<sup>3</sup>

[D341 Practice for Viscosity-Temperature Charts for Liquid Petroleum Products](#)

[D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids \(and Calculation of Dynamic Viscosity\)](#)

[D1695 Terminology of Cellulose and Cellulose Derivatives](#)

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

[E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications](#)

2.2 *ISO Standards*:<sup>4</sup>

[ISO 3104 Petroleum Products—Transparent and Opaque](#)

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee [D02](#) on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee [D02.07](#) on Flow Properties.

In the IP, this practice is under the jurisdiction of the Standardization Committee and issued under the fixed designation IP 226. The final number indicates the year of last revision.

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<sup>2</sup> Supporting data (Metrication of Viscosity Index System Method D2270) have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1009.

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

<sup>4</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

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

Liquids—Determination of Kinematic Viscosity and Calculation of Dynamic Viscosity

2.3 *Energy Institute Standard*.<sup>5</sup>

**IP 71** Determination of Kinematic Viscosity and Calculation of Dynamic Viscosity

### 3. Terminology

#### 3.1 Definitions:

3.1.1 *viscosity index, n*—an arbitrary number used to characterize the variation of the kinematic viscosity of a petroleum product with temperature.

3.1.1.1 *Discussion*—For oils of similar kinematic viscosity, the higher the viscosity index the smaller the effect of temperature on its kinematic viscosity.

3.1.1.2 *Discussion*—Viscosity index is also used in Terminology **D1695** in a definition unrelated to this one.

### 4. Significance and Use

4.1 The viscosity index is a widely used and accepted measure of the variation in kinematic viscosity due to changes in the temperature of a petroleum product between 40 and 100°C.

4.2 A higher viscosity index indicates a smaller decrease in kinematic viscosity with increasing temperature of the lubricant.

4.3 The viscosity index is used in practice as a single number indicating temperature dependence of kinematic viscosity.

4.4 Viscosity Index is sometimes used to characterize base oils for purposes of establishing engine testing requirements for engine oil performance categories.<sup>6</sup>

### 5. Procedure

5.1 Determine the kinematic viscosity of the sample at 40 and 100°C in accordance with Test Method **D445**, Test Method **D7042**, **ISO 3104**, or **IP 71**.

#### 5.2 Calculation:

5.2.1 If the kinematic viscosity of the sample at 100°C is less than or equal to 70 mm<sup>2</sup>/s, extract from **Table 1** the corresponding values for *L* and *H*. Measured values that are not listed, but are within the range of **Table 1**, may be obtained by linear interpolation. The viscosity index is not defined and shall not be reported for oils with kinematic viscosity of less than 2.0 mm<sup>2</sup>/s at 100°C.

5.2.2 If the kinematic viscosity is greater than 70 mm<sup>2</sup>/s at 100°C, calculate the values of *L* and *H* as follows:

$$L = 0.8353 Y^2 + 14.67 Y - 216 \quad (1)$$

$$H = 0.1684 Y^2 + 11.85 Y - 97 \quad (2)$$

where:

*L* = kinematic viscosity at 40°C of an oil of 0 viscosity index having the same kinematic viscosity at 100°C as the oil whose viscosity index is to be calculated, mm<sup>2</sup>/s,

*Y* = kinematic viscosity at 100°C of the oil whose viscosity index is to be calculated, mm<sup>2</sup>/s, and

*H* = kinematic viscosity at 40°C of an oil of 100 viscosity index having the same kinematic viscosity at 100°C as the oil whose viscosity index is to be calculated, mm<sup>2</sup>/s.

5.2.3 If *U* > *H*, calculate the viscosity index, *VI*, of the oil as follows:

$$VI = [(L - U)/(L - H)] \times 100 \quad (3)$$

where:

*U* = kinematic viscosity at 40°C of the oil whose viscosity index is to be calculated, mm<sup>2</sup>/s.

5.2.3.1 *Calculation Example*—Measured kinematic viscosity at 40°C of the oil whose viscosity index is to be calculated = 73.30 mm<sup>2</sup>/s; kinematic viscosity at 100°C of the oil whose viscosity index is to be calculated = 8.86 mm<sup>2</sup>/s.

From **Table 1** (by interpolation) *L* = 119.94

From **Table 1** (by interpolation) *H* = 69.48

Substituting in Eq 3 and rounding to the nearest whole number:

$$VI = [(119.94 - 73.30)/(119.94 - 69.48)] \times 100 = 92.43 \quad (4)$$

$$VI = 92 \quad (5)$$

5.2.4 If *U* < *H*, calculate the viscosity index, *VI*, of the oil as follows:

$$VI = [((\text{antilog } N) - 1)/0.00715] + 100 \quad (6)$$

where:

$$N = (\log H - \log U) / \log Y \quad (7)$$

or

$$Y^N = H/U \quad (8)$$

5.2.4.1 *Calculation Example*—Measured kinematic viscosity at 40°C of the oil whose viscosity index is to be calculated = 22.83 mm<sup>2</sup>/s; kinematic viscosity at 100°C of the oil whose viscosity index is to be calculated = 5.05 mm<sup>2</sup>/s:

From **Table 1** (by interpolation) *H* = 28.975

Substituting by Eq 7 (by logarithms):

$$N = \left[ \frac{\log(28.975) - \log(22.83)}{\log(5.05)} \right] = 0.14719 \quad (9)$$

Substituting in Eq 6 and rounding to the nearest whole number:

$$\begin{aligned} VI &= \left[ \frac{\text{anti log}(0.14719) - 1}{0.00715} \right] + 100 \\ &= \left[ \frac{1.40343 - 1}{0.00715} \right] + 100 \\ &= \left[ \frac{0.40343}{0.00715} \right] + 100 \\ &= 156.4235 \end{aligned} \quad (10)$$

$$VI = 156$$

5.2.4.2 *Calculation Example*—Measured kinematic viscosity at 40°C of the oil whose viscosity index is to be calculated = 53.47 mm<sup>2</sup>/s; kinematic viscosity at 100°C of the oil

<sup>5</sup> Available from Energy Institute, 61 New Cavendish St., London, WIG 7AR, U.K.

<sup>6</sup> API 1509, “*Engine Oil Licensing and Certification System*,” 16e, American Petroleum Institute, April 2007.



whose viscosity index is to be calculated = 7.80 mm<sup>2</sup>/s:

From **Table 1**,  $H = 57.31$

Substituting in **Eq 8** (by logarithms):

$$N = [(\log 57.31 - \log 53.47)/\log 7.80] = 0.03376 \quad (11)$$

Substituting in **Eq 7** and rounding to the nearest whole number:

$$\begin{aligned} VI &= [(\text{antilog } 0.03376) - 1]/0.00715 + 100 \quad (12) \\ &= [(1.08084 - 1)/0.00715] + 100 = 111 \end{aligned}$$

5.2.5 If  $U = H$ , the viscosity index, VI, of the oil equals 100.

5.3 **ASTM DS 39b**,<sup>7</sup> is based on the above calculation and may be used instead of **5.2** through **5.2.5**.

## 6. Report

6.1 Report the viscosity index to the nearest whole number, using the Rounding Method of **E29**. When the number is

<sup>7</sup> ASTM DS 39b, *Viscosity Index Tables for Celsius Temperatures*, ASTM International.

exactly halfway between the nearest two whole numbers, round to the nearest even number. For example, 116.5 shall be reported as 116.

6.2 The test report shall contain at least the following information:

6.2.1 A reference to this standard,

6.2.2 The type and complete identification of the product tested,

6.2.3 The result of the test,

6.2.4 The test method used for the kinematic viscosity measurements,

6.2.5 Any deviation, by agreement or otherwise, from the procedure specified, and

6.2.6 The date of the test.

## 7. Keywords

7.1 kinematic viscosity; viscosity index

## APPENDIXES

### (Nonmandatory Information)

#### X1. VISCOSITY INDEX CALCULATIONS FROM KINEMATIC VISCOSITIES AT NON-STANDARD TEMPERATURES

X1.1 In certain cases, it is of interest to obtain the  $VI$  of an oil when conditions prevent the use of the standard temperatures of 40 and 100°C. An estimate may be made by calculating the kinematic viscosity at 40 and 100°C from data obtained at other temperatures. Reference should be made to Test Method **D341** for the suitable equations. The kinematic viscosity data

used should preferably be taken from temperatures near the standard values and as widely separated as possible.

X1.2 Viscosity index values of an oil calculated from non-standard data as discussed above should be considered as suitable for information only and not desirable for specification purposes.

#### X2. ANOTHER COMPUTATIONAL METHOD

X2.1 The exact computational method for the calculation of viscosity index is defined in Section **5** of this practice. However, computation by computer or programmable calculator may be desired. This appendix describes one widely used method.

X2.1.1 In case of conflict between results using this method and the method in Section **5**, the method in Section **5** shall be accepted.

X2.2 The calculation of viscosity index requires:

X2.2.1 Input of kinematic viscosity data at 40 and 100°C.

X2.2.2 Calculation of  $L$  and  $H$  corresponding to the kinematic viscosity at 100°C.

X2.2.3 Calculation of the viscosity index using equations in Section **5** of this practice.

X2.3 Values of  $L$  and  $H$  can be determined using computer software and the coefficients and equations stored in **Table X2.1**. In this set of sixteen equations, the errors in individual values of  $L$  and  $H$  so calculated are believed not to exceed

0.1 %. For a given value of  $Y$ , select the pair of equations whose range includes this value of  $Y$  and calculate directly the values of  $L$  and  $H$ .

X2.4 With the given values of  $Y$  and  $U$  and the calculated values of  $L$  and  $H$  corresponding to  $Y$  from **Table X2.1**, the viscosity index is calculated directly using:

X2.4.1 (Eq 3) where  $U \geq H$  or

X2.4.2 (Eq 6) and (Eq 7) where  $U \leq H$  as is described in Section **5** of this practice.

X2.5 An example of these methods is as follows:  
given kinematic viscosity at 40°C = 73.50 mm<sup>2</sup>/s,  
and kinematic viscosity at 100°C = 8.860 mm<sup>2</sup>/s.

X2.5.1 As described in **X2.3**, the equations stored in memory which include  $Y = 8.860$  are:

$$L = 0.41858 Y^2 + 16.1558 Y - 56.040 \quad (X2.1)$$

$$H = 0.05794 Y^2 + 10.5156 Y - 28.240 \quad (X2.2)$$

X2.5.1.1 From the given value of  $Y = 8.860$  mm<sup>2</sup>/s:

**TABLE X2.1 Coefficients of Quadratic Equations**

Y min	Y max	a	b	c	d	e	f
2.0	3.8	1.14673	1.7576	-0.109	0.84155	1.5521	-0.077
3.8	4.4	3.38095	-15.4952	33.196	0.78571	1.7929	-0.183
4.4	5.0	2.5000	-7.2143	13.812	0.82143	1.5679	0.119
5.0	6.4	0.10100	16.6350	-45.469	0.04985	9.1613	-18.557
6.4	7.0	3.35714	-23.5643	78.466	0.22619	7.7369	-16.656
7.0	7.7	0.01191	21.4750	-72.870	0.79762	-0.7321	14.610
7.7	9.0	0.41858	16.1558	-56.040	0.05794	10.5156	-28.240
9.0	12	0.88779	7.5527	-16.600	0.26665	6.7015	-10.810
12	15	0.76720	10.7972	-38.180	0.20073	8.4658	-22.490
15	18	0.97305	5.3135	-2.200	0.28889	5.9741	-4.930
18	22	0.97256	5.2500	-0.980	0.24504	7.4160	-16.730
22	28	0.91413	7.4759	-21.820	0.20323	9.1267	-34.230
28	40	0.87031	9.7157	-50.770	0.18411	10.1015	-46.750
40	55	0.84703	12.6752	-133.310	0.17029	11.4866	-80.620
55	70	0.85921	11.1009	-83.19	0.17130	11.3680	-76.940
70	Up	0.83531	14.6731	-216.246	0.16841	11.8493	-96.947

$$L = a Y^2 + b Y + c$$

$$H = d Y^2 + e Y + f$$

$$L = 119.9588 \quad (X2.3)$$

$$H = 69.4765 \quad (X2.4)$$

X2.5.2 Since  $U \geq H$ :

$$\text{Viscosity index} = [(L - U)/(L - H)] \times 100 \quad (X2.5)$$

X2.5.2.1 For the data in X2.5.1:

$$VI = \frac{119.9588 - 73.50}{119.9588 - 69.4765} \times 100 = 92.030 = 92 \quad (X2.6)$$

### X3. PRECISION OF VISCOSITY INDEX

#### X3.1 Precision and Bias<sup>8</sup>

X3.1.1 The calculation of viscosity index from kinematic viscosities at 40°C and 100°C is exact, and no precision limits can be assigned to this calculation.

NOTE X3.1—This precision value was obtained by statistical examination of interlaboratory results from approximately 40 base oil samples (base oils without additive package) in the range from 79 to 164 VI and between 2.4 and 80 mm<sup>2</sup>/s kinematic viscosity at 100°C for D445 and 12 base oil samples (base oils with additive package) in the range from 93 to 150 Vi and between 3.5 and 40 mm<sup>2</sup>/s kinematic viscosity at 100°C for Test Method D7042.

X3.1.2 The precision of a viscosity index value for an unknown sample depends on the precision of the two independent kinematic viscosity values from which it is derived. For petroleum base stocks within the limits of viscosity at 100°C

listed below and within the limits of viscosity index listed below, the precision of viscosity index has been determined by examination of multiple data sets.

X3.1.3 *Reproducibility (R)*—The difference between two single and independent results obtained by different operators working in different laboratories on nominally identical test material would, in the long run, in the normal and correct operation of this practice, exceed the values in Table X3.1 only in one case in twenty.

**TABLE X3.1 Precision of Viscosity**

Method to Measure Kinematic Viscosity	Range of Applicability		
	Kinematic Viscosity at 100°C	Viscosity Index	Reproducibility (R)
D445	2.4 to 80	79 to 164	2
D7042	3.5 to 40	93 to 150	2
Other		Not determined	

<sup>8</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1707.

**SUMMARY OF CHANGES**

Subcommittee D02.07 has identified the location of selected changes to this standard since the last issue (D2270–04) that may impact the use of this standard.

- |                                                                                                                           |                                                                                                  |
|---------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| (1) Combined Procedure A (for $VI < 100$ ) and Procedure B (for $VI > 100$ ) into one procedure with better logical flow. | kinematic viscosities for VI calculation.                                                        |
| (2) Updated and corrected precision.                                                                                      | (4) Designated “table” as the referee method in case of disagreement with the “equation” method. |
| (3) Allowed the use of Test Method <b>D7042</b> to measure                                                                | (5) Updated SI units to conform to ASTM guidelines.                                              |

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