Designation: D 2270 – 93 (Reapproved 1998)

An American National Standard
British Standard 4459

Designation: 226/91 (95)

Standard Practice for Calculating Viscosity Index From Kinematic Viscosity at 40 and 100°C[1]

This standard is issued under the fixed designation D 2270; 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 is also a standard of the Institute of Petroleum issued under the fixed designation IP 226. The final number indicates the year of last revision.

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

1. Scope

1.1 This practice[2] specifies 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.[3]

1.1.1 *Procedure A*—For petroleum products of viscosity index up to and including 100.

1.1.2 *Procedure B*—For petroleum products of which the viscosity index is 100 or greater.

1.2 Table 1 given in this practice applies to petroleum products with kinematic viscosities between 2 and 70 mm ^{2}/s (cSt) at 100°C.[4] Equations are provided for calculating viscosity index for petroleum products having kinematic viscosities above 70 mm^2/s (cSt) at 100°C.

1.3 The kinematic viscosity values are determined with reference to a value of 1.0038 mm^2/s (cSt) 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 D 445, IP 71, ISO 3104, or ISO 2909.

1.4 The values stated in SI units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 341 Viscosity-Temperature Charts for Liquid Petroleum Products[5]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)[5]

D 1695 Terminology of Cellulose and Cellulose Derivatives[6]

2.2 *ISO Standards:*

ISO 2909 Petroleum products—Calculation of Viscosity Index from kinematic viscosity[7]

ISO 3104 Petroleum products—Transparent and opaque liquids—Determination of kinematic viscosity and calculation of dynamic viscosity[7]

2.3 *IP Document:*

IP 71[8]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

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.

NOTE 1—Viscosity index is also used in Terminology D 1695 in a definition unrelated to that in 3.1.1.

[1] This practice is under the jurisdiction of ASTM Committee D-2 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.

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[2] Metrication of Viscosity Index System Method D 2270 is available from ASTM Headquarters. Request RR: D02-1009.

[3] 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.

[4] 1 cSt = 1 mm^2/s = 10^{-6}m^2/s.

[5] *Annual Book of ASTM Standards*, Vol 05.01.

[6] *Annual Book of ASTM Standards*, Vol 06.03.

[7] Available from American National Standards Institute, 11 W. 42nd St., 13th Fl., New York, NY 10036.

[8] Available from Institute of Petroleum, 61 New Cavendish St., London W1M 8AR, United Kingdom.

TABLE 1 Basic Values for L and H for Kinematic Viscosity in 40–100°C System

Kinematic Viscosity at 100°C, mm^2/s (cSt)	*L*	*H*	Kinematic Viscosity at 100°C, mm^2/s (cSt)	*L*	*H*	Kinematic Viscosity at 100°C, mm^2/s (cSt)	*L*	*H*	Kinematic Viscosity at 100°C, mm^2/s (cSt)	*L*	*H*	Kinematic Viscosity at 100°C, mm^2/s (cSt)	*L*	*H*	Kinematic Viscosity at 100°C, mm^2/s (cSt)	*L*	*H*
2.00	7.994	6.394	7.00	78.00	48.57	12.0	201.9	108.0	17.0	369.4	180.2	24.0	683.9	301.8	42.5	1935	714.9
2.10	8.640	6.894	7.10	80.25	49.61	12.1	204.8	109.4	17.1	373.3	181.7	24.2	694.5	305.6	43.0	1978	728.2
2.20	9.309	7.410	7.20	82.39	50.69	12.2	207.8	110.7	17.2	377.1	183.3	24.4	704.2	309.4	43.5	2021	741.3
2.30	10.00	7.944	7.30	84.53	51.78	12.3	210.7	112.0	17.3	381.0	184.9	24.6	714.9	313.0	44.0	2064	754.4
2.40	10.71	8.496	7.40	86.66	52.88	12.4	213.6	113.3	17.4	384.9	186.5	24.8	725.7	317.0	44.5	2108	767.6
2.50	11.45	9.063	7.50	88.85	53.98	12.5	216.6	114.7	17.5	388.9	188.1	25.0	736.5	320.9	45.0	2152	780.9
2.60	12.21	9.647	7.60	91.04	55.09	12.6	219.6	116.0	17.6	392.7	189.7	25.2	747.2	324.9	45.5	2197	794.5
2.70	13.00	10.25	7.70	93.20	56.20	12.7	222.6	117.4	17.7	396.7	191.3	25.4	758.2	328.8	46.0	2243	808.2
2.80	13.80	10.87	7.80	95.43	57.31	12.8	225.7	118.7	17.8	400.7	192.9	25.6	769.3	332.7	46.5	2288	821.9
2.90	14.63	11.50	7.90	97.72	58.45	12.9	228.8	120.1	17.9	404.6	194.6	25.8	779.7	336.7	47.0	2333	835.5
3.00	15.49	12.15	8.00	100.0	59.60	13.0	231.9	121.5	18.0	408.6	196.2	26.0	790.4	340.5	47.5	2380	849.2
3.10	16.36	12.82	8.10	102.3	60.74	13.1	235.0	122.9	18.1	412.6	197.8	26.2	801.6	344.4	48.0	2426	863.0
3.20	17.26	13.51	8.20	104.6	61.89	13.2	238.1	124.2	18.2	416.7	199.4	26.4	812.8	348.4	48.5	2473	876.9
3.30	18.18	14.21	8.30	106.9	63.05	13.3	241.2	125.6	18.3	420.7	201.0	26.6	824.1	352.3	49.0	2521	890.9
3.40	19.12	14.93	8.40	109.2	64.18	13.4	244.3	127.0	18.4	424.9	202.6	26.8	835.5	356.4	49.5	2570	905.3
3.50	20.09	15.66	8.50	111.5	65.32	13.5	247.4	128.4	18.5	429.0	204.3	27.0	847.0	360.5	50.0	2618	919.6
3.60	21.08	16.42	8.60	113.9	66.48	13.6	250.6	129.8	18.6	433.2	205.9	27.2	857.5	364.6	50.5	2667	933.6
3.70	22.09	17.19	8.70	116.2	67.64	13.7	253.8	131.2	18.7	437.3	207.6	27.4	869.0	368.3	51.0	2717	948.2
3.80	23.13	17.97	8.80	118.5	68.79	13.8	257.0	132.6	18.8	441.5	209.3	27.6	880.6	372.3	51.5	2767	962.9
3.90	24.19	18.77	8.90	120.9	69.94	13.9	260.1	134.0	18.9	445.7	211.0	27.8	892.3	376.4	52.0	2817	977.5
4.00	25.32	19.56	9.00	123.3	71.10	14.0	263.3	135.4	19.0	449.9	212.7	28.0	904.1	380.6	52.5	2867	992.1
4.10	26.50	20.37	9.10	125.7	72.27	14.1	266.6	136.8	19.1	454.2	214.4	28.2	915.8	384.6	53.0	2918	1007
4.20	27.75	21.21	9.20	128.0	73.42	14.2	269.8	138.2	19.2	458.4	216.1	28.4	927.6	388.8	53.5	2969	1021
4.30	29.07	22.05	9.30	130.4	74.57	14.3	273.0	139.6	19.3	462.7	217.7	28.6	938.6	393.0	54.0	3020	1036
4.40	30.48	22.92	9.40	132.8	75.73	14.4	276.3	141.0	19.4	467.0	219.4	28.8	951.2	396.6	54.5	3073	1051
4.50	31.96	23.81	9.50	135.3	76.91	14.5	279.6	142.4	19.5	471.3	221.1	29.0	963.4	401.1	55.0	3126	1066
4.60	33.52	24.71	9.60	137.7	78.08	14.6	283.0	143.9	19.6	475.7	222.8	29.2	975.4	405.3	55.5	3180	1082
4.70	35.13	25.63	9.70	140.1	79.27	14.7	286.4	145.3	19.7	479.7	224.5	29.4	987.1	409.5	56.0	3233	1097
4.80	36.79	26.57	9.80	142.7	80.46	14.8	289.7	146.8	19.8	483.9	226.2	29.6	998.9	413.5	56.5	3286	1112
4.90	38.50	27.53	9.90	145.2	81.67	14.9	293.0	148.2	19.9	488.6	227.7	29.8	1011	417.6	57.0	3340	1127
5.00	40.23	28.49	10.0	147.7	82.87	15.0	296.5	149.7	20.0	493.2	229.5	30.0	1023	421.7	57.5	3396	1143
5.10	41.99	29.46	10.1	150.3	84.08	15.1	300.0	151.2	20.2	501.5	233.0	30.5	1055	432.4	58.0	3452	1159
5.20	43.76	30.43	10.2	152.9	85.30	15.2	303.4	152.6	20.4	510.8	236.4	31.0	1086	443.2	58.5	3507	1175
5.30	45.53	31.40	10.3	155.4	86.51	15.3	306.9	154.1	20.6	519.9	240.1	31.5	1119	454.0	59.0	3563	1190
5.40	47.31	32.37	10.4	158.0	87.72	15.4	310.3	155.6	20.8	528.8	243.5	32.0	1151	464.9	59.5	3619	1206
5.50	49.09	33.34	10.5	160.6	88.95	15.5	313.9	157.0	21.0	538.4	247.1	32.5	1184	475.9	60.0	3676	1222
5.60	50.87	34.32	10.6	163.2	90.19	15.6	317.5	158.6	21.2	547.5	250.7	33.0	1217	487.0	60.5	3734	1238
5.70	52.64	35.29	10.7	165.8	91.40	15.7	321.1	160.1	21.4	556.7	254.2	33.5	1251	498.1	61.0	3792	1254
5.80	54.42	36.26	10.8	168.5	92.65	15.8	324.6	161.6	21.6	566.4	257.8	34.0	1286	509.6	61.5	3850	1270
5.90	56.20	37.23	10.9	171.2	93.92	15.9	328.3	163.1	21.8	575.6	261.5	34.5	1321	521.1	62.0	3908	1286
6.00	57.97	38.19	11.0	173.9	95.19	16.0	331.9	164.6	22.0	585.2	264.9	35.0	1356	532.5	62.5	3966	1303
6.10	59.74	39.17	11.1	176.6	96.45	16.1	335.5	166.1	22.2	595.0	268.6	35.5	1391	544.0	63.0	4026	1319
6.20	61.52	40.15	11.2	179.4	97.71	16.2	339.2	167.7	22.4	604.3	272.3	36.0	1427	555.6	63.5	4087	1336
6.30	63.32	41.13	11.3	182.1	98.97	16.3	342.9	169.2	22.6	614.2	275.8	36.5	1464	567.1	64.0	4147	1352
6.40	65.18	42.14	11.4	184.9	100.2	16.4	346.6	170.7	22.8	624.1	279.6	37.0	1501	579.3	64.5	4207	1369
6.50	67.12	43.18	11.5	187.6	101.5	16.5	350.3	172.3	23.0	633.6	283.3	37.5	1538	591.3	65.0	4268	1386
6.60	69.16	44.24	11.6	190.4	102.8	16.6	354.1	173.8	23.2	643.4	286.8	38.0	1575	603.1	65.5	4329	1402
6.70	71.29	45.33	11.7	193.3	104.1	16.7	358.0	175.4	23.4	653.8	290.5	38.5	1613	615.0	66.0	4392	1419
6.80	73.48	46.44	11.8	196.2	105.4	16.8	361.7	177.0	23.6	663.3	294.4	39.0	1651	627.1	66.5	4455	1436
6.90	75.72	47.51	11.9	199.0	106.7	16.9	365.6	178.6	23.8	673.7	297.9	39.5	1691	639.2	67.0	4517	1454
												40.0	1730	651.8	67.5	4580	1471
												40.5	1770	664.2	68.0	4645	1488
												41.0	1810	676.6	68.5	4709	1506
												41.5	1851	689.1	69.0	4773	1523
												42.0	1892	701.9	69.5	4839	1541
															70.0	4905	1558

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.

5. Procedure A—For Oils of Viscosity Index Up to and Including 100

5.1 *Calculation*:

5.1.1 If the kinematic viscosity of the oils at 100°C is less than or equal to 70 mm^2/s (cSt), 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 may not be reported for oils of kinematic viscosity of less than 2.0 mm^2/s (cSt) at 100°C.

5.1.2 If the kinematic viscosity is above 70 mm^2/s (cSt) 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^2/s (cSt),

Y = kinematic viscosity at 100°C of the oil whose viscosity index is to be calculated, mm^2/s (cSt), 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^2/s (cSt).

5.1.3 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^2/s (cSt).

5.1.4 *Calculation Example*:

Measured kinematic viscosity at 40°C of the oil whose viscosity index is to be calculated = 73.30 mm^2/s (cSt) kinematic viscosity at 100°C of the oil whose viscosity index is to be calculated = 8.86 mm^2/s (cSt)

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 *ASTM DS 39b*[9] *Viscosity Index Tables for Celsius Temperatures* is based on the above calculation and may be used instead of 5.1-5.1.4.

6. Procedure B—For Oils of Viscosity Index of 100 and Greater

6.1 *Calculation*:

6.1.1 If the kinematic viscosity of the oil at 100°C is less than or equal to 70 mm^2/s (cSt), extract the corresponding value for H from Table 1. Measured values that are not listed, but are within the range of Table 1, can be obtained by linear interpolation. The viscosity index is not defined and may not be reported for oils of kinematic viscosity of less than 2.0 mm^2/s (cSt) at 100°C.

6.1.2 If the measured kinematic viscosity at 100°C is greater than 70 mm^2/s (cSt), calculate the value of H as follows:

$$H = 0.1684\, Y^2 + 11.85\, Y - 97 \quad (6)$$

where:

Y = kinematic viscosity at 100°C of the oil whose kinematic viscosity is to be calculated, mm^2/s (cSt), 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^2/s (cSt).

6.1.3 Calculate the viscosity index, *VI*, of the oil as follows:

$$VI = [((\text{antilog } N) - 1)/0.00715] + 100 \quad (7)$$

where:

$$N = (\log H - \log U)/\log Y, \quad (8)$$

or

$$Y^N = H/U \quad (9)$$

where:

U = kinematic viscosity at 40°C of the oil whose viscosity index is to be calculated mm^2/s (cSt).

6.1.4 *Calculation Example*:

(1) Measured kinematic viscosity at 40°C of the oil whose viscosity index is to be calculated = 22.83 mm^2/s (cSt) kinematic viscosity at 100°C of the oil whose viscosity index is to be calculated = 5.05 mm^2/s (cSt)

From Table 1 (by interpolation) H = 28.97

Substituting by Eq 8 (by logarithms):

$$N = [(\log 28.97 - \log 22.83)/\log 5.05] = 0.14708 \quad (10)$$

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

$$VI = [((\text{antilog } 0.14708) - 1)/0.00715] + 100 \quad (11)$$

$$= [(1.40307 - 1)/0.00715] + 100 = 156.37$$

$$VI = 156$$

(2) Measured kinematic viscosity at 40°C of the oil whose viscosity index is to be calculated = 53.47 mm^2/s (cSt) kinematic viscosity at 100°C of the oil whose viscosity index is to be calculated = 7.80 mm^2/s (cSt)

From Table 1, H = 57.31

Substituting in Eq 8 (by logarithms):

[9] Available from ASTM Headquarters.

$$N = [(\log 57.31 - \log 53.47)/\log 7.80] = 0.03376 \quad (12)$$

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

$$VI = [((\text{antilog } 0.03376) - 1)/0.00715] + 100 \quad (13)$$
$$= [(1.08084 - 1)/0.00715] + 100 = 111$$

6.2 *ASTM DS 39b*[6]*—Viscosity Index Tables for Celsius Temperatures* is based on the above calculation and may be used instead of 6.1 through 6.1.4.

7. Report

7.1 Report the viscosity index to the nearest whole number. When the number is exactly halfway between the nearest two whole numbers, round to the nearest even number.

7.2 Calculated viscosity index numbers can differ depending on the kinematic viscosity data as determined. When duplicate kinematic viscosity data are available, it is recommended that viscosity index values calculated therefrom be considered acceptable only when the kinematic viscosity data meet the acceptability limits in Test Method D 445 of 0.35 % for repeatability and 0.70 % for reproducibility. It is also recommended that the viscosity index calculated and reported be that based on the means of the appropriate kinematic viscosity values. If the kinematic viscosity data do not meet acceptability limits in Test Method D 445, the data should be examined and redetermined.

8. Precision and Bias

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

8.2 The accuracy of the calculated viscosity index is dependent only on the accuracy of the original viscosity determination. Test Method D 445 has a stated repeatability limit of 0.35 % and a reproducibility limit of 0.70 %.

8.3 See Appendix X1 for a discussion of the precision that can be attributed to the viscosity index.

8.4 *Bias*—The calculation of viscosity index from kinematic viscosities at 40 and 100°C is exact, and no bias can be assigned to this calculation.

9. Keywords

9.1 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°C and 100°C from data obtained at other temperatures. Reference should be made to Viscosity-Temperature Charts D 341 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.

X1.3 *Precision Attributed to Viscosity Index:*

X1.3.1 It is sometimes important to know the precision that can be attributed to the viscosity index values, especially so as to not place undue importance on small differences between a calculated value of the viscosity index on the same material determined within a laboratory on different days, and also those determined between laboratories.

X1.3.2 Viscosity index repeatability and reproducibility were given in the precision section of this test method. These calculations[10,11] are based on the assumption that the overall kinematic viscosity determinations would be within the precision of Test Method D 445.

X1.3.3 The data on which Fig. X1.1 is based are calculated on the "worst case" assumption in the precision section of this test method, and show a greater variation in the viscosity index than had been shown in the D2270 – 77 precision section. Thus, for example, two laboratories can report on the same sample of oil the following data:

	Laboratory	
	No. 1	No. 2
Kinematic viscosity at 100°C (mm^2/s)	12.95	13.04
Kinematic viscosity at 40°C (mm^2/s)	145.0	144.0
Viscosity index (unrounded)	77.91	80.25
Viscosity index (rounded)	78	80

These data are within the precision of Test Method D 445, and demonstrate at 13 cSt at 100°C the maximum difference in the *VI*.

X1.3.4 For Fig. X1.1 the repeatability of viscosity index is one-half of the value for the reproducibility of viscosity index.

X1.3.5 If the calculated viscosity indexes are rounded to whole numbers before comparison, this may cause their difference to exceed the precision limits to be attributed to the

[10] Marmin, A. J., and Sommelet, Peter, "Viscosity Index Repeatability and Reproducibility," *Journal of Materials*, ASTM, June 1972, p. 206.

[11] Bayle, G. G., "Latitudes of Viscosity Index Values," *Journal of Testing and Evaluation*, ASTM, Vol 5, No. 3, May 1977, pp. 154–160.

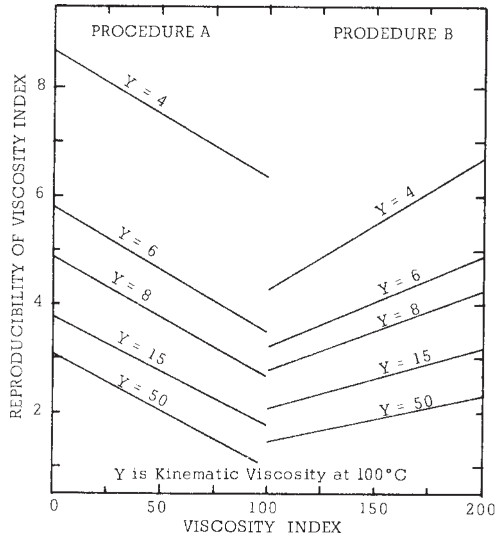

FIG. X1.1 Reproducibility of Viscosity Index

viscosity index without the experimental kinematic viscosities being mutually inconsistent. In case of doubt, therefore, it is advisable to compare viscosity index data before rounding (that is, to include the first decimal place when making the comparison).

X2. OTHER COMPUTATIONAL METHODS

X2.1 The exact computational method for the calculation of viscosity index is defined in Sections 5 and 6 of this test method. However, computation by computer or programmable calculator may be desired. This appendix describes three methods.

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 Sections 5 and 6 of this test method.

X2.3 Values of *L* and *H* can be determined as follows:

X2.3.1 The complete table of *L* and *H* can be stored in computer memory. Values of *L* and *H* calculated using linear interpolation will be exactly the same as those calculated in this test method. This table requires a relatively large section of computer memory, but ensures exact calculation of *L*, *H*, and viscosity index.

X2.3.2 A limited few entries in Table 1 may be stored in the computer memory. To calculate *L* corresponding to the given value *Y* of kinematic viscosity at 100°C, select the data pair from Table X2.1 that is nearest the given kinematic viscosity value. Select also the data pair above and below this data pair. Using these three data pairs, calculate the coefficients *a*, *b*, and *c* in the equation:

$$L = a\,Y^2 + b\,Y + c \quad \text{(X2.1)}$$

In a similar manner calculate the coefficients to the equation:

$$H = d\,Y^2 + e\,Y + f \quad \text{(X2.2)}$$

The 32 sets of data in Table X2.1 have been selected from Table 1, and represent a balance between the minimum number of sets of data items and acceptable accuracy of the quadratic

TABLE X2.1 Data Pairs for Quadratic Interpolation of *L* and *H*

Kinematic Viscosity at 100°C, mm²/s (cSt)	*L*	*H*	Kinematic Viscosity at 100°C, mm²/s (cSt)	*L*	*H*
2.0	7.994	6.394	12	201.9	108.0
2.9	14.63	11.50	13.5	247.4	128.4
3.8	23.13	17.97	15	296.5	149.7
4.1	26.50	20.37	16.5	350.3	172.3
4.4	30.48	22.92	18	408.6	196.2
4.7	35.13	25.63	20	493.2	229.5
5.0	40.23	28.49	24	683.9	301.8
5.7	52.64	35.29	28	904.1	380.6
6.4	65.18	42.14	34	1286	509.6
6.7	71.29	45.33	40	1730	651.8
7.0	78.00	48.57	47.5	2380	849.2
7.4	86.66	52.88	55	3126	1066
7.8	95.43	57.31	62.5	3966	1303
8.4	109.2	64.18	70	4905	1558
9.0	123.3	71.10	100	9604	2772
10.5	160.6	88.95	130	15810	4290

interpolation calculations for L and H. Other choices for Table X2.1 can be made to fit the computer memory available and the required accuracy of the calculation of L and H.

X2.3.3 The data in Table 1 can also be fit to a series of quadratic equations. The range of each equation must be consistent with acceptable accuracy for all values of L and H within its range. One set of sixteen equations is given in Table X2.2; 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 X2.2, the viscosity index is calculated directly using

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

X2.4.2 (Eq 7) and (Eq 8) where $U \leq H$ as is described in Section 6 of this test method.

X2.5 An example of these methods is as follows:
given kinematic viscosity at 40°C = 73.50 mm^2/s (cSt)
and kinematic viscosity at 100°C = 8.86 mm^2/s (cSt).

X2.5.1 Using the method described in X2.3.1 to calculate L and H, the "look-up" table stored in computer memory.

Kinematic Viscosity, mm^2/s at 100°C	L	H
8.8	118.5	68.79
8.9	120.9	69.94

linear interpolation gives

$$L = 119.94 \quad (X2.3)$$

$$H = 69.48$$

X2.5.2 Using Table X2.1 as described in X2.3.2, the three sets of data selected from computer memory are

Kinematic Viscosity at 100°C	L	H
8.4	109.2	64.18
9.0	123.3	71.10
10.5	160.6	88.95

from which are calculated

$$L = 0.65079\, Y^2 + 12.1762\, Y - 39.00 \quad (X2.4)$$

$$H = 0.17460\, Y^2 + 8.4952\, Y - 19.50 \quad (X2.5)$$

for the range of Y between 8.4 and 9.0. For $Y = 8.86$

$$L = 119.9681 \quad (X2.6)$$

$$H = 69.4741 \quad (X2.7)$$

X2.5.3 As described in X2.3.3, the equations stored in memory which include $Y = 8.86$ are

$$L = 0.41858\, Y^2 + 16.1558\, Y - 56.040 \quad (X2.8)$$

$$H = 0.05794\, Y^2 + 10.5156\, Y - 28.240 \quad (X2.9)$$

(a) From the given value of $Y = 8.86$ mm^2/s (cSt)

$$L = 119.9588 \quad (X2.10)$$

$$H = 69.4765 \quad (X2.11)$$

X2.5.4 Since $U \geq H$

$$\text{Viscosity index} = [(L - U)/(L - H)] \times 100 \quad (X2.12)$$

(a) For the data in X2.5.1

$$VI = \frac{119.94 - 73.50}{119.94 - 69.48} \times 100 = 92.033 = 92 \quad (X2.13)$$

(b) For the data in X2.5.2

$$VI = \frac{119.9681 - 73.50}{119.9681 - 69.4741} \times 100 = 92.027 = 92 \quad (X2.14)$$

(c) For the data in X2.5.3

$$VI = \frac{119.9588 - 73.50}{119.9588 - 69.4765} \times 100 = 92.030 = 92 \quad (X2.15)$$

TABLE X2.2 Coefficients of Quadratic Equations (Eq 1 and Eq 2)

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

$L = a\,Y^2 + b\,Y + c$
$H = d\,Y^2 + e\,Y + f$