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Petroleum products — Calculation of viscosity index from kinematic viscosity

Produits pétroliers — Calcul de l'indice de viscosité à partir de la viscosité cinématique

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 2909 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*.

This third edition cancels and replaces the second edition (ISO 2909:1981), which has been technically revised.

Petroleum products — Calculation of viscosity index from kinematic viscosity

1 Scope

This International Standard describes two procedures for calculating the viscosity index (VI) of petroleum products and related materials, such as lubricating oils, from their kinematic viscosities at 40 °C and 100 °C.

Procedure A is applicable to petroleum products of viscosity index up to and including 100.

Procedure B is applicable to petroleum products of viscosity index 100 or greater.

NOTE The results obtained from the calculation of VI from kinematic viscosities determined at 40 °C and 100 °C are virtually the same as those obtained from the former VI system using kinematic viscosities determined at 37,78 °C and 98,89 °C.

This International Standard does not apply to petroleum products with kinematic viscosities less than 2,0 mm^2/s at 100 °C. Table 1 applies to petroleum products with kinematic viscosities between 2 mm^2/s and 70 mm^2/s at 100 °C. Equations are provided for calculating the viscosity index of petroleum products having kinematic viscosities above 70 mm^2/s at 100 °C.

NOTE In cases where kinematic viscosity data are not available at temperatures of 40 °C and 100 °C, an estimate may be made of the viscosity index by calculating the kinematic viscosity at temperatures of 40 °C 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.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3104:1994, *Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
viscosity index
VI
number used to characterize the variation of the kinematic viscosity of a petroleum product with temperature

NOTE For products of similar kinematic viscosity, the higher the viscosity index, the smaller the effect of temperature on its kinematic viscosity.

4 Principle

Kinematic viscosities at 40 °C and 100 °C are determined by a standard test method and the viscosity index is calculated from these test data using known correlations.

5 Determination

Determine the kinematic viscosity of the sample at 40 °C and 100 °C in accordance with ISO 3104.

6 Calculation

6.1 General

Calculate the viscosity index using one of the procedures given in 6.2 and 6.3.

6.2 Procedure A

6.2.1 Use procedure A for petroleum products of viscosity index up to and including 100 (see the note to 8.2).

6.2.2 If the kinematic viscosity of the petroleum product at 100 °C is in the range of 2 mm^2/s to 70 mm^2/s, extract from Table 1 the corresponding values of L and H:

where

L is the kinematic viscosity, expressed in millimetres squared per second, at 40 °C of a petroleum product of viscosity index 0 having the same kinematic viscosity at 100 °C as the petroleum product whose viscosity index is to be calculated;

H is the kinematic viscosity, expressed in millimetres squared per second, at 40 °C of a petroleum product of viscosity index 100 having the same kinematic viscosity at 100 °C as the petroleum product whose viscosity index is to be calculated.

Measured values which are not listed but which are within the range of Table 1 may be obtained by linear interpolation.

6.2.3 If the measured kinematic viscosity of the petroleum product at 100 °C is above 70 mm^2/s, calculate the values of L and H using the following equations:

$$L = 0{,}835\,3Y^2 + 14{,}67Y - 216 \quad (1)$$

$$H = 0{,}168\,4Y^2 + 11{,}85Y - 97 \quad (2)$$

where Y is the kinematic viscosity, expressed in millimetres squared per second, at 100 °C of the petroleum product whose viscosity index is to be calculated.

6.2.4 Calculate the viscosity index, VI, of the petroleum product using the following equation:

$$\mathrm{VI} = \frac{L - U}{L - H} \times 100 \quad (3)$$

where U is the kinematic viscosity, expressed in millimetres squared per second, at 40 °C of the petroleum product whose viscosity index is to be calculated.

Table 1 — Measured values of L and H for kinematic viscosity

Kinematic viscosity at 100 °C mm²/s	L	H
2,00	7,994	6,394
2,10	8,640	6,894
2,20	9,309	7,410
2,30	10,00	7,944
2,40	10,71	8,496
2,50	11,45	9,063
2,60	12,21	9,647
2,70	13,00	10,25
2,80	13,80	10,87
2,90	14,63	11,50
3,00	15,49	12,15
3,10	16,36	12,82
3,20	17,26	13,51
3,30	18,18	14,21
3,40	19,12	14,93
3,50	20,09	15,66
3,60	21,08	16,42
3,70	22,09	17,19
3,80	23,13	17,97
3,90	24,19	18,77
4,00	25,32	19,56
4,10	26,50	20,37
4,20	27,75	21,21
4,30	29,07	22,05
4,40	30,48	22,92
4,50	31,96	23,81
4,60	33,52	24,71
4,70	35,13	25,63
4,80	36,79	26,57
4,90	38,50	27,53
5,00	40,23	28,49
5,10	41,99	29,46
5,20	43,76	30,43
5,30	45,53	31,40
5,40	47,31	32,37
5,50	49,09	33,34
5,60	50,87	34,32
5,70	52,64	35,29
5,80	54,42	36,26
5,90	56,20	37,23

Kinematic viscosity at 100 °C mm²/s	L	H
6,00	57,97	38,19
6,10	59,74	39,17
6,20	61,52	40,15
6,30	63,32	41,13
6,40	65,18	42,14
6,50	67,12	43,18
6,60	69,16	44,24
6,70	71,29	45,33
6,80	73,48	46,44
6,90	75,72	47,51
7,00	78,00	48,57
7,10	80,25	49,61
7,20	82,39	50,69
7,30	84,53	51,78
7,40	86,66	52,88
7,50	88,85	53,98
7,60	91,04	55,09
7,70	93,20	56,20
7,80	95,43	57,31
7,90	97,72	58,45
8,00	100,0	59,60
8,10	102,3	60,74
8,20	104,6	61,89
8,30	106,9	63,05
8,40	109,2	64,18
8,50	111,5	65,32
8,60	113,9	66,48
8,70	116,2	67,64
8,80	118,5	68,79
8,90	120,9	69,94
9,00	123,3	71,10
9,10	125,7	72,27
9,20	128,0	73,42
9,30	130,4	74,57
9,40	132,8	75,73
9,50	135,3	76,91
9,60	137,7	78,08
9,70	140,1	79,27
9,80	142,7	80,46
9,90	145,2	81,67

Table 1 — Measured values L and H for kinematic viscosity *(continued)*

Kinematic viscosity at 100 °C mm²/s	L	H
10,0	147,7	82,87
10,1	150,3	84,08
10,2	152,9	85,30
10,3	155,4	86,51
10,4	158,0	87,72
10,5	160,6	88,95
10,6	163,2	90,19
10,7	165,8	91,40
10,8	168,5	92,65
10,9	171,2	93,92
11,0	173,9	95,19
11,1	176,6	96,45
11,2	179,4	97,71
11,3	182,1	98,97
11,4	184,9	100,2
11,5	187,6	101,5
11,6	190,4	102,8
11,7	193,3	104,1
11,8	196,2	105,4
11,9	199,0	106,7
12,0	201,9	108,0
12,1	204,8	109,4
12,2	207,8	110,7
12,3	210,7	112,0
12,4	213,6	113,3
12,5	216,6	114,7
12,6	219,6	116,0
12,7	222,6	117,4
12,8	225,7	118,7
12,9	228,8	120,1
13,0	231,9	121,5
13,1	235,0	122,9
13,2	238,1	124,2
13,3	241,2	125,6
13,4	244,3	127,0
13,5	247,4	128,4
13,6	250,6	129,8
13,7	253,8	131,2
13,8	257,0	132,6
13,9	260,1	134,0

Kinematic viscosity at 100 °C mm²/s	L	H
14,0	263,3	135,4
14,1	266,6	136,8
14,2	269,8	138,2
14,3	273,0	139,6
14,4	276,3	141,0
14,5	279,6	142,4
14,6	283,0	143,9
14,7	286,4	145,3
14,8	289,7	146,8
14,9	293,0	148,2
15,0	296,5	149,7
15,1	300,0	151,2
15,2	303,4	152,6
15,3	306,9	154,1
15,4	310,3	155,6
15,5	313,9	157,0
15,6	317,5	158,6
15,7	321,1	160,1
15,8	324,6	161,6
15,9	328,3	163,1
16,0	331,9	164,6
16,1	335,5	166,1
16,2	339,2	167,7
16,3	342,9	169,2
16,4	346,6	170,7
16,5	350,3	172,3
16,6	354,1	173,8
16,7	358,0	175,4
16,8	361,7	177,0
16,9	365,6	178,6
17,0	369,4	180,2
17,1	373,3	181,7
17,2	377,1	183,3
17,3	381,0	184,9
17,4	384,9	186,5
17,5	388,9	188,1
17,6	392,7	189,7
17,7	396,7	191,3
17,8	400,7	192,9
17,9	404,6	194,6

Table 1 — Measured values L and H for kinematic viscosity *(continued)*

Kinematic viscosity at 100 °C mm²/s	L	H
18,0	408,6	196,2
18,1	412,6	197,8
18,2	416,7	199,4
18,3	420,7	201,0
18,4	424,9	202,6
18,5	429,0	204,3
18,6	433,2	205,9
18,7	437,3	207,6
18,8	441,5	209,3
18,9	445,7	211,0
19,0	449,9	212,7
19,1	454,2	214,4
19,2	458,4	216,1
19,3	462,7	217,7
19,4	467,0	219,4
19,5	471,3	221,1
19,6	475,7	222,8
19,7	479,7	224,5
19,8	483,9	226,2
19,9	488,6	227,8
20,0	493,2	229,5
20,2	501,9	233,0
20,4	510,8	236,4
20,6	519,9	240,1
20,8	528,8	243,5
21,0	538,4	247,1
21,2	547,5	250,7
21,4	556,7	254,2
21,6	566,4	257,8
21,8	575,6	261,5
22,0	585,2	264,9
22,2	595,0	268,6
22,4	604,3	272,3
22,6	614,2	275,8
22,8	624,1	279,6
23,0	633,6	283,3
23,2	643,4	286,8
23,4	653,8	290,5
23,6	663,3	294,4
23,8	673,7	297,9

Kinematic viscosity at 100 °C mm²/s	L	H
24,0	683,9	301,8
24,2	694,5	305,6
24,4	704,8	309,4
24,6	714,9	313,2
24,8	725,7	317,0
25,0	736,5	320,9
25,2	747,2	324,9
25,4	758,2	328,8
25,6	768,8	332,7
25,8	779,7	336,7
26,0	790,4	340,5
26,2	801,6	344,4
26,4	812,8	348,4
26,6	824,1	352,3
26,8	835,5	356,4
27,0	847,0	360,5
27,2	857,5	364,6
27,4	869,0	368,3
27,6	880,6	372,3
27,8	892,3	376,4
28,0	904,1	380,6
28,2	915,8	384,6
28,4	927,6	388,8
28,6	938,6	393,0
28,8	951,2	396,6
29,0	963,4	401,1
29,2	975,4	405,3
29,4	987,1	409,5
29,6	998,9	413,5
29,8	1 011	417,6
30,0	1 024	421,7
30,5	1 055	432,4
31,0	1 086	443,2
31,5	1 119	454,0
32,0	1 151	464,9
32,5	1 184	475,9
33,0	1 217	487,0
33,5	1 251	498,1
34,0	1 286	509,6
34,5	1 321	521,1

Table 1 — Measured values L and H for kinematic viscosity *(continued)*

Kinematic viscosity at 100 °C mm²/s	L	H
35,0	1 356	532,5
35,5	1 391	544,0
36,0	1 427	555,6
36,5	1 464	567,1
37,0	1 501	579,3
37,5	1 538	591,3
38,0	1 575	603,1
38,5	1 613	615,0
39,0	1 651	627,1
39,5	1 691	639,2
40,0	1 730	651,8
40,5	1 770	664,2
41,0	1 810	676,6
41,5	1 851	689,1
42,0	1 892	701,9
42,5	1 935	714,9
43,0	1 978	728,2
43,5	2 021	741,3
44,0	2 064	754,4
44,5	2 108	767,6
45,0	2 152	780,9
45,5	2 197	794,5
46,0	2 243	808,2
46,5	2 288	821,9
47,0	2 333	835,5
47,5	2 380	849,2
48,0	2 426	863,0
48,5	2 473	876,9
49,0	2 521	890,9
49,5	2 570	905,3
50,0	2 618	919,6
50,5	2 667	933,6
51,0	2 717	948,2
51,5	2 767	962,9
52,0	2 817	977,5
52,5	2 867	992,1
53,0	2 918	1 007
53,5	2 969	1 021
54,0	3 020	1 036
54,5	3 073	1 051

Kinematic viscosity at 100 °C mm²/s	L	H
55,0	3 126	1 066
55,5	3 180	1 082
56,0	3 233	1 097
56,5	3 286	1 112
57,0	3 340	1 127
57,5	3 396	1 143
58,0	3 452	1 159
58,5	3 507	1 175
59,0	3 563	1 190
59,5	3 619	1 206
60,0	3 676	1 222
60,5	3 734	1 238
61,0	3 792	1 254
61,5	3 850	1 270
62,0	3 908	1 286
62,5	3 966	1 303
63,0	4 026	1 319
63,5	4 087	1 336
64,0	4 147	1 352
64,5	4 207	1 369
65,0	4 268	1 386
65,5	4 329	1 402
66,0	4 392	1 419
66,5	4 455	1 436
67,0	4 517	1 454
67,5	4 580	1 471
68,0	4 645	1 488
68,5	4 709	1 506
69,0	4 773	1 523
69,5	4 839	1 541
70,0	4 905	1 558

6.2.5 The calculation method using Table 1 is indicated by the example shown below:

	Measured oil properties
Kinematic viscosity at 40 °C, mm^2/s	73,30
Kinematic viscosity at 100 °C, mm^2/s	8,860

From Table 1 by interpolation, $L = 119{,}94$

From Table 1 by interpolation, $H = 69{,}48$

$$VI = \frac{119{,}94 - 73{,}30}{119{,}94 - 69{,}48} \times 100$$

$$VI = 92{,}43$$

$$VI = 92$$

6.3 Procedure B

6.3.1 Use procedure B for petroleum products of viscosity index 100 or greater (see the note to 8.2).

6.3.2 If the kinematic viscosity of the petroleum product at 100 °C is in the range 2 mm^2/s to 70 mm^2/s, extract the corresponding value of H from Table 1. Measured values which are not listed, but which are within the range of Table 1, may be obtained by linear interpolation.

6.3.3 If the measured kinematic viscosity of the petroleum product at 100 °C is greater than 70 mm^2/s, calculate the value of H using equation (2) (see 6.2.3 for the definition of Y)

$$H = 0{,}168\,4Y^2 + 11{,}85Y - 97 \qquad (2)$$

6.3.4 Calculate the viscosity index, VI, of the petroleum product using the following equation:

$$VI = \frac{\left(10^n\right) - 1}{0{,}007\,15} + 100 \qquad (4)$$

where

$$n = \frac{\log_{10} H - \log_{10} U}{\log_{10} Y}$$

U is the kinematic viscosity, expressed in millimetres squared per second, at 40 °C of the petroleum product whose viscosity index is to be calculated;

Y is the kinematic viscosity, expressed in millimetres squared per second, at 100 °C of the petroleum product whose viscosity index is to be calculated.

6.3.5 The method is illustrated by the example shown below:

	Measured oil properties
Kinematic viscosity at 40 °C, mm^2/s	22,83
Kinematic viscosity at 100 °C, mm^2/s	5,050

From Table 1 by interpolation, $H = 28,97$

By substitution:

$$n = \frac{\log_{10} 28,97 - \log_{10} 22,83}{\log_{10} 5,05}$$

$$= 0,147\,08$$

$$VI = \frac{\left(10^{0,147\,08}\right) - 1}{0,007\,15} + 100$$

$$VI = 156,37$$

$$VI = 156$$

7 Expression of results

Report the result to the nearest whole number. When the result is exactly halfway between the nearest two whole numbers, round it to the nearest even number. For example, 115,5 should be reported as 116.

8 Precision

8.1 The calculation of viscosity index from measured kinematic viscosities at 40 °C and 100 °C is exact.

8.2 The precision of a viscosity-index value depends on the precision of the two independent kinematic viscosity values from which it is derived. The results of two viscosity-index calculations shall be considered suspect if the values of the kinematic viscosities differ by more than the amounts quoted for repeatability or reproducibility as given in ISO 3104. The precision levels given in Tables 2 and 3 for a probability level of 95 % are based entirely on the precision levels given in ISO 3104 for base and formulated oils. They give an indication of the precision of the viscosity index attributed to the precision of kinematic viscosity given in ISO 3104.

Table 2 — Precision for procedure A

Kinematic viscosity at 100 °C	VI = 0				VI = 100			
	Repeatability, r		Reproducibility, R		Repeatability, r		Reproducibility, R	
mm^2/s	Base oil	Formulated	Base oil	Formulated	Base oil	Formulated	Base oil	Formulated
4	0,98	2,31	5,77	6,75	0,73	1,73	4,32	5,05
6	0,71	1,68	4,20	4,91	0,40	0,94	2,35	2,75
8	0,57	1,35	3,38	3,95	0,30	0,70	1,75	2,05
15	0,45	1,06	2,66	3,11	0,20	0,48	1,19	1,39
30	0,39	0,92	2,29	2,68	0,14	0,33	0,82	0,96
50	0,36	0,85	2,11	2,47	0,11	0,26	0,65	0,76

Table 3 — Precision for procedure B

Kinematic viscosity at 100 °C	VI = 100				VI = 200			
	Repeatability, r		Reproducibility, R		Repeatability, r		Reproducibility, R	
mm^2/s	Base oil	Formulated	Base oil	Formulated	Base oil	Formulated	Base oil	Formulated
4	0,50	1,18	2,94	3,44	0,77	1,82	4,54	5,31
6	0,37	0,87	2,18	2,55	0,57	1,34	3,35	3,92
8	0,31	0,74	1,84	2,15	0,48	1,13	2,82	3,30
15	0,23	0,55	1,37	1,61	0,36	0,84	2,11	2,46
30	0,19	0,44	1,11	1,30	0,29	0,68	1,71	2,00
50	0,17	0,40	0,99	1,16	0,26	0,61	1,52	1,78

NOTE Tables 2 and 3 show the precision attributed to base oils and formulated oils given in ISO 3104, as calculated approaching VI = 100 from VIs less than 100 by procedure A, and calculated approaching VI = 100 from VIs greater than 100 by procedure B. The attributed precision for other VIs may be roughly estimated by interpolation within each table.

9 Test report

The test report shall contain at least the following information:

a) a reference to this International Standard;

b) the type and complete identification of the product tested;

c) the result of the test (see clause 7);

d) whether procedure A or procedure B was used;

e) any deviation, by agreement or otherwise, from the procedure specified;

f) the date of the test.

ICS 75.080

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