An American National Standard

Standard Practice for
Defining the Viscosity Characteristics of Hydraulic Fluids[1]

This standard is issued under the fixed designation D 6080; 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 practice is applicable to all hydraulic fluids based either on petroleum, synthetic, or naturally-occurring base stocks. It is not intended for water-containing hydraulic fluids.

1.2 For determination of viscosities at low temperature, this practice uses millipascal·second (mPa·s) as the unit of viscosity. For reference, 1 mPa·s is equivalent to 1 centipoise (cP). For determination of viscosities at high temperature, this practice uses millimetre squared per second (mm^2/s) as the unit of kinematic viscosity. For reference, 1 mm^2/s is equivalent to 1 centistoke (cSt).

1.3 This practice is applicable to fluids ranging in kinematic viscosity from about 4 to 150 mm^2/s as measured at a reference temperature of 40°C and to temperatures from −50 to +16°C for a fluid viscosity of 750 mPa·s.

NOTE 1—Fluids of lesser or greater viscosity than the range described in 1.3 are seldom used as hydraulic fluids. Any mathematical extrapolation of the system to either higher or lower viscosity grades may not be appropriate. Any need to expand the system should be evaluated on its own merit.

2. Referenced Documents

2.1 *ASTM Standards:*

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)[2]

D 2270 Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 and 100°C[2]

D 2422 Classification of Industrial Fluid Lubricants by Viscosity System[2]

D 2983 Test Method for Low-Temperature Viscosity of Lubricants Measured by Brookfield Viscometer[2]

D 5621 Test Method for Sonic Shear Stability of Hydraulic Fluids[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

2.2 *Society of Automotive Engineers (SAE) Standards:*[5]

J300 Engine Oil Viscosity Classification

J306 Axle and Manual Transmission Lubricant Viscosity Classification

3. Terminology

3.1 *Definitions:*

3.1.1 *viscosity*—the ratio between the applied shear stress and shear rate.

3.1.1.1 *Discussion*—Viscosity is sometimes called the coefficient of dynamic viscosity. This coefficient is a measure of the resistance to flow of the liquid.

3.1.2 *kinematic viscosity*—the ratio of the viscosity to the density of a liquid.

3.1.2.1 *Discussion*—Kinematic viscosity is a measure of the resistance to flow of a liquid under gravity.

3.1.3 *shear stress*—the motivating force per unit area for fluid flow.

3.1.4 *shear rate*—the velocity gradient in fluid flow.

3.1.5 *Newtonian fluid*—a fluid that at a given temperature exhibits a constant viscosity at all shear rates or shear stresses.

3.1.6 *non-Newtonian fluid*—a fluid that exhibits a viscosity that varies with changing shear stress or shear rate.

3.1.7 *density*—the mass per unit volume.

3.1.8 *hydraulic fluid*—a fluid used in hydraulic systems for transmitting power.

3.1.9 *viscosity index (VI)*—an arbitrary number used to characterize the variation of the kinematic viscosity of a fluid with temperature.

3.1.10 *shear degradation*—the decrease in molecular weight of a polymeric thickener (VI improver) as a result of exposure to high shear stress.

3.1.11 *in-service viscosity*—the viscosity of fluid during operation of a hydraulic pump or circuit components.

3.1.12 *shear stability*—the resistance of a polymer-thickened fluid to shear degradation.

4. Summary of Practice

4.1 High VI hydraulic fluids often contain high molecular weight thickeners, called viscosity index (VI) improvers, which impart non-Newtonian characteristics to the fluid. These

[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.N0 on Hydraulic Fluids.

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

[3] *Annual Book of ASTM Standards*, Vol 05.03.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] Available from Society of Automotive Engineers, 400 Commonwealth Dr., Warrendale, PA 15096.

polymers may shear degrade with use, and reduce the in-service viscosity of the fluids.

4.2 This practice provides uniform guidelines for characterizing oils in terms of both their high and low temperature viscosities before and after exposure to high shear stress.

4.2.1 Since the performance of fluids at temperatures higher than 40°C is determined in the worst case, that is, most severe situation, by the sheared oil viscosity, the viscosity and viscosity index used to characterize fluids in this practice are those of the sheared fluid.

4.2.2 This practice classifies oils at low temperature by their new oil properties. Low temperature viscosities do not decrease greatly, if at all, with polymer shear degradation. Furthermore, this approach ensures that the fluid will be properly classified under the worst-case conditions, that is, when the fluid is new.

4.3 This practice may be used with either Newtonian or non-Newtonian hydraulic fluids. This provides the user with a more reasonable basis to compare fluids than previous practices.

5. Significance and Use

5.1 The purpose of this practice is to establish viscosity designations derived from viscosities measured by test methods which have a meaningful relationship to hydraulic fluid performance. This permits lubricant suppliers, lubricant users, and equipment designers to have a uniform and common basis for designating, specifying, or selecting the viscosity characteristics of hydraulic fluids.

5.2 This practice is not intended to be a replacement for Classification D 2422. Rather, it is an enhancement intended to provide a better description of the viscosity characteristics of lubricants used as hydraulic fluids.

5.3 This practice implies no evaluation of hydraulic oil quality other than its viscosity and shear stability under the conditions specified.

5.4 While it is not intended for other functional fluids, this practice may be useful in high-shear-stress applications where viscosity index (VI) improvers are used to extend the useful operating temperature range of the fluid.

5.5 This practice does not apply to other lubricants for which viscosity classification systems already exist, for example, SAE J300 for automotive engine oils and SAE J306 for axle and manual transmission lubricants.

6. Procedure

6.1 The low temperature viscosity grade of a fluid is based on the viscosity of new oil measured using a Brookfield viscometer, Test Method D 2983.

6.1.1 The viscosity shall be interpolated from measurements at three temperatures spanning the temperature at which the viscosity is 750 mPa·s. A smooth graph of these data (log viscosity versus temperature) determines the temperature at which the oil has a viscosity of 750 mPa·s.

6.1.2 The lower viscosity limit for Test Method D 2983 is currently stated to be 1000 mPa·s. This equipment limitation is shown in Table 1 of that method. Newer equipment is available which permits measurement of lower viscosities and Test Method D 2983 is currently being revised with a lower viscosity limit of 500 mPa·s.

TABLE 1 Low Temperature Viscosity Grades for Hydraulic Fluid Classifications

Viscosity Grade	Temperature,° C, for Brookfield Viscosity of 750 mPa·s[A]	
	min	max
L5	...	−50
L7	−49	−42
L10	−41	−33
L15	−32	−23
L22	−22	−15
L32	−14	− 8
L46	− 7	− 2
L68	− 1	4
L100	5	10
L150	11	16

[A] The temperature range for a given L-grade is approximately equivalent to that for an ISO grade of the same numerical designation and having a viscosity index of 100, that is, the temperature range for the L10 grade is approximately the same as that for an ISO VG 10 grade with a viscosity index of 100.

6.1.3 The temperature determined in 6.1.1 shall be rounded to a whole number in accordance with Practice E 29.

6.1.4 The low temperature viscosity grade is determined by matching the temperature determined in 6.1.3 with the requirements shown in Table 1.

6.2 The high temperature viscosity designation of a fluid is the 40°C kinematic viscosity (Test Method D 445) of a fluid which has been sheared using Test Method D 5621.

6.2.1 The kinematic viscosity determined in 6.2 shall be rounded to a whole number in accordance with Practice E 29.

6.2.2 For a fluid known to contain no polymeric components which will shear degrade, the high temperature viscosity designation is the 40°C kinematic viscosity (Test Method D 445) of the new fluid, rounded per 6.2.1.

6.2.3 If the 40°C kinematic viscosity from 6.2.1 fails to meet the same designation consistently (for example, it varies because of spread in base stock or component specifications, or variability in kinematic viscosity or shear stability measurements), the lower designation must be used to ensure conformance with 6.5 below.

6.3 The viscosity index designation of the fluid is based on the viscosity index as determined using Practice D 2270 on fluid which has been sheared using Test Method D 5621.

6.3.1 The viscosity index determined in 6.3 shall be rounded to the nearest ten units in accordance with Practice E 29. This value is the viscosity index designation.

6.3.2 For fluids which do not contain polymeric components, the viscosity index is determined on the new fluid using Practice D 2270. The viscosity index designation for the fluid is established by rounding this viscosity index to the nearest ten units in accordance with Practice E 29.

NOTE 2—The guidelines for rounding viscosity in 6.2.1 and 6.2.2 and viscosity index in 6.3.1 and 6.3.2 are specific to this practice and should not be confused with the larger number of significant figures that can be reported when Test Methods D 445 and D 2270 are used for other purposes.

6.3.3 If the viscosity index fails to meet the same designation consistently, that is, it varies between the lower values for one designation and the higher values for the next lower designation (for example, it varies because of spread in base stock or component specifications, or variability in kinematic viscosity or shear stability measurements), the lower designation must be used to ensure conformance with 6.5 below.

6.4 For the sake of uniformity of nomenclature in identifying the viscosity characteristics of hydraulic fluids, the following designation shall be used:

ISO VG xx
Lyy-zz (VI)

where *xx* is the new oil viscosity grade as determined by Classification D 2422 (Table 2); Lyy is the low temperature viscosity grade as determined in 6.1; zz is the high temperature sheared viscosity designation as determined in 6.2; and VI is the viscosity index designation as determined in 6.3.

6.4.1 If the new oil viscosity does not meet a grade described by Classification D 2422, the ISO VG xx portion of the designation does not apply. In such cases, the Lyy-zz (VI) designation may still be used, and the use of any other descriptors for the new oil is at the discretion of the fluid marketer.

6.4.2 Examples of use of this practice are shown in Table 3.

6.5 An oil blender may use any manufacturing control that seems appropriate to his operation. However, it is the responsibility of the blender to ensure that all production fully meets the requirements for the viscosity designation on the container.

7. Interpretation of Results

7.1 The designation determined for a hydraulic fluid as described in 6.4 may be used in combination with a manufacturer's viscosity recommendations for specific equipment to estimate an acceptable temperature range over which that fluid may be used in that equipment.

7.2 The low temperature grade determined in 6.1, Lyy, defines the lowest recommended fluid temperature at which the fluid may be used in equipment with a start-up, under load limit of 750 mPa·s, max.

7.2.1 The low temperature limit is determined by comparing the Lyy designation with the corresponding temperature in Table 1.

7.2.2 *Example 1a*—For an oil with the designation:

ISO VG 46
L32-40 ,

the low temperature grade is defined by L32. Reference to Table 1 indicates that this oil has a viscosity of 750 mPa·s at a temperature between −8 and −14°C. Hence, in equipment which has a low temperature start-up viscosity limit of 750 mPa·s, the oil in this example may be used down to at least −8°C.

7.2.3 *Example 2a*—For an oil with the designation:

ISO VG 68
L46-57

the low temperature grade is defined by L46. Reference to Table 1 indicates that this oil has a viscosity of 750 mPa·s at a temperature between −2 and −7°C. Hence, in equipment which has a low temperature start-up viscosity limit of 750 mPa·s, the oil in this example may be used down to at least −2°C.

7.2.4 This practice is not quantitative when a manufacturer specifies lower or higher start-up viscosity limits. However, the process described in 6.1 can be used to determine low temperature limitations corresponding to any start-up viscosity.

7.3 The high temperature designation determined in 6.2 and the viscosity index determined in 6.3, zz (VI), can be used in combination with the data in Figs. 1-4 to estimate high temperature operating limits (Fig. 1 and Fig. 2) and optimum operating temperatures (Fig. 3 and Fig. 4) for the fluid.

7.3.1 Fig. 1 and Fig. 2 apply directly to equipment which has minimum operating kinematic viscosity limits of 10 and 13 mm^2/s, respectively.

7.3.1.1 Find the value zz on the horizontal axis labeled High Temperature Viscosity Designation.

7.3.1.2 Read vertically from the point defined by 7.3.1.1 to the curve corresponding to the viscosity index, VI, interpolating, if necessary.

7.3.1.3 Read horizontally from the point defined by 7.3.1.2 to the vertical axis labeled Temperature, °C, for a Kinematic Viscosity of 10 (or 13) mm^2/s. This is the upper temperature limit for fluid operation.

7.3.1.4 *Example 1b*—For the oil in Example 1a in 7.2.2, the high temperature designation and VI are 40 and 150, respectively. Assume that the equipment of interest has a recommended kinematic viscosity minimum of 13 mm^2/s; hence, Fig. 2 should be used. As described in 7.3.1.1, find the value 40 on the horizontal axis labeled High Temperature Viscosity Designation. As described in 7.3.1.2, read vertically from 40 until intersecting the curve labeled VI = 150. Finally, as described in 7.3.1.3, read horizontally to the vertical axis labeled Temperature, °C, for a Kinematic Viscosity of 13 mm^2/s. The value corresponding to a high temperature viscosity designation of 40 and a viscosity index of 150 is 75°C. Hence, in equipment which has a recommended kinematic viscosity minimum of 13 mm^2/s, fluid temperature for the oil in this example should not exceed 75°C.

7.3.1.5 *Example 2b*—For the oil in Example 2a in 7.2.3, the high temperature designation and VI are 57 and 170, respectively. Assume that the equipment of interest has a recommended kinematic viscosity minimum of 10 mm^2/s; hence, Fig. 1 should be used. Find the value 57 on the horizontal axis labeled High Temperature Viscosity Designation. Read vertically from 57 until intersecting the curves labeled VI = 150 and VI = 200. Interpolate between the curves to a value of VI = 170 and read horizontally to the vertical axis labeled Temperature, °C, for a Kinematic Viscosity of 10 mm^2/s. The value corresponding to a high temperature viscosity designation of 57 and

TABLE 2 ISO Viscosity System for Hydraulic Fluids

Viscosity Grade Identification	Mid-Point Viscosity, mm^2/s at 40°C	Kinematic Viscosity Limits, mm^2/s at 40°C	
		min	max
ISO 5	4.6	4.14	5.06
ISO 7	6.8	6.12	7.48
ISO 10	10	9.00	11.0
ISO 15	15	13.5	16.5
ISO 22	22	19.8	24.2
ISO 32	32	28.8	35.2
ISO 46	46	41.4	50.6
ISO 68	68	61.2	74.8
ISO 100	100	90.0	110
ISO 150	150	135	165

TABLE 3 Examples of Using Viscosity Designation

NOTE 1—The examples in Tables 3 and 4 are not intended to be all inclusive. While some of the examples are common, that is not the intention.

40°C Kinematic Viscosity, mm²/s		Sheared Fluid Viscosity Index	Temperature, °C, Measured for Brookfield Viscosity of 750 mPa·s	Viscosity Designation
New Fluid	Sheared Fluid			
22.3	21.3	158	−23	ISO 22 L15-21 (160)
30.8	29.52	145	−15	ISO 32 L22-30 (150)
31.8	24.4	105	−11	ISO 32 L32-24 (110)
36.4	20.9	117	−13	[A] L32-21 (120)
38.3	31.8	138	−12	[A] L32-32 (140)
45.8	42.7	140	−5	ISO 46 L46-43 (140)
48.0	43.49	148	−8	ISO 46 L32-43 (150)
57.8	53.4	149	−4	[A] L46-53 (150)
69.0	67.0	116	0	ISO 68 L68-67 (120)
69.5	40.7	120	+ 1	ISO 68 L68-41 (120)
99.9	95.8	113	0	ISO 100 L68-96 (110)

[A] Viscosity of new fluid does not conform to ISO grade in accordance with Classification D 2422.

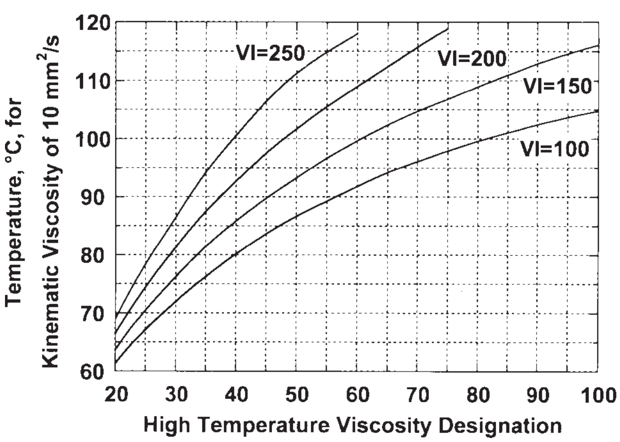

FIG. 1 Temperatures for a Kinematic Viscosity of 10 mm²/s

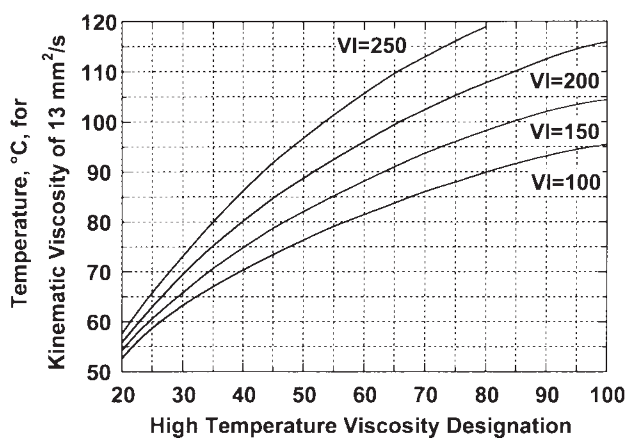

FIG. 2 Temperatures for a Kinematic Viscosity of 13 mm²/s

a viscosity index of 170 is 102°C. Hence, in equipment which has a recommended kinematic viscosity minimum of 10 mm^2/s, fluid temperature for the oil in this example should not exceed 102°C.

7.3.1.6 Approximate maximum fluid operating temperature can also be estimated for other minimum operating viscosities in the range of 10 to 13 mm^2/s by interpolation between Fig. 1 and Fig. 2.

7.3.2 Fig. 3 and Fig. 4 apply directly to equipment which has optimum operating viscosities of either 24 or 32 mm^2/s, respectively.

7.3.2.1 Find the value zz on the horizontal axis labeled High Temperature Viscosity Designation.

7.3.2.2 Read vertically from the point defined by 7.3.2.1 to the curve corresponding to the viscosity index, VI, interpolating, if necessary.

7.3.2.3 Read horizontally from the point defined by 7.3.2.2 to the vertical axis labeled Temperature, °C, for a Kinematic Viscosity of 24 (or 32) mm^2/s. This is the optimum temperature for fluid operation.

7.3.2.4 *Example 1c*—For the oil in Example 1a in 7.2.2, the high temperature designation and VI are 40 and 150, respectively. Assume that the equipment of interest has a recommended optimum operating kinematic viscosity of 24 mm^2/s; hence, Fig. 3 should be used. As described in 7.3.2.1, find the value 40 on the horizontal axis labeled High Temperature Viscosity Designation. As described in 7.3.2.2, read vertically from 40 until intersecting the curve labeled VI = 150. Finally, as described in 7.3.2.3, read horizontally to the vertical axis labeled Temperature,° C, for a Kinematic Viscosity of 24 mm^2/s. The value corresponding to a high temperature viscosity designation of 40 and a viscosity index of 150 is 54 to 55°C.

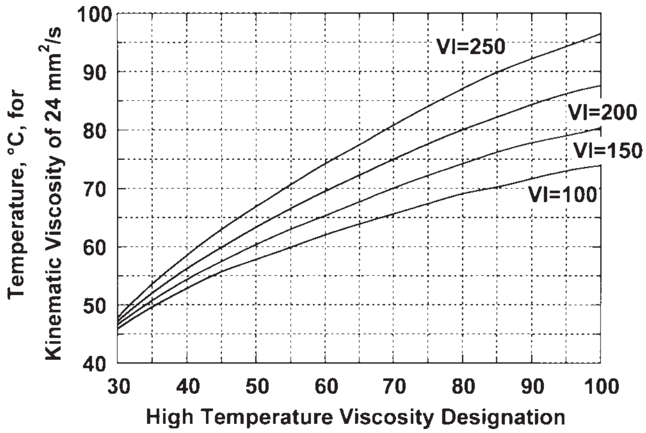

FIG. 3 Temperatures for a Kinematic Viscosity of 24 mm^2/s

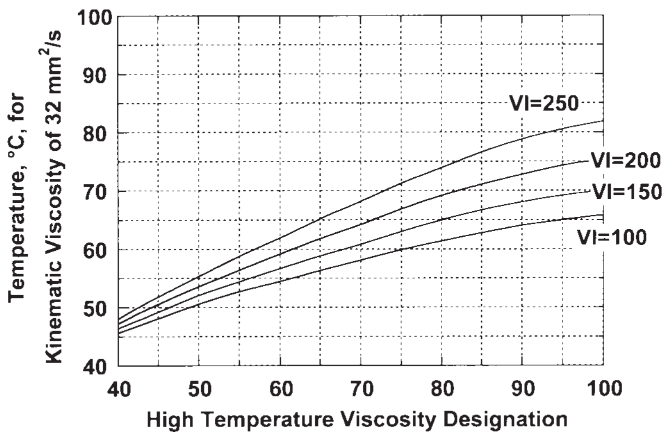

FIG. 4 Temperatures for a Kinematic Viscosity of 32 mm^2/s

Hence, in equipment which has a recommended optimum operating kinematic viscosity of 24 mm^2/s, fluid temperature for the oil in this example should be maintained at about 54 to 55°C.

7.3.2.5 *Example 2c*—For the oil in Example 2a in 7.2.3, the high temperature designation and VI are 57 and 170, respectively. Assume that the equipment of interest has a recommended optimum operating kinematic viscosity of 32 mm^2/s; hence, Fig. 4 should be used. Find the value 57 on the horizontal axis labeled High Temperature Viscosity Designation. Read vertically from 57 until intersecting the curves labeled VI = 150 and VI = 200. Interpolate between the curves to a value of VI = 170 and read horizontally to the vertical axis labeled Temperature, °C, for a Kinematic Viscosity of 32 mm^2/s. The value corresponding to a high temperature viscosity designation of 57 and a viscosity index of 170 is 56°C. Hence, in equipment which has a recommended optimum operating kinematic viscosity of 32 mm^2/s, fluid temperature for the oil in this example should be maintained at about 56°C.

7.3.2.6 Approximate optimum fluid operating temperature can also be estimated for other optimum operating viscosities in the range of 24 to 32 mm^2/s by interpolation between Fig. 3 and Fig. 4.

7.4 Examples of the application of Fig. 2 and Fig. 3 to the oils described in Table 3 (6.4.2) are shown in Table 4.

8. Adoption of Practice

8.1 Adoption of this practice is voluntary for all persons or organizations. The practice will be effective only when used widely by designers, producers, and consumers. There is nothing to prohibit the use of a viscosity grade or designation not listed in this practice if the producer and consumer mutually agree. It may be expected that hydraulic fluids with viscosity designations not in accordance with this practice will be less readily available to the purchaser than those products which do conform.

8.2 The establishment of standardized viscosity designations as described here shall not imply nor require that a full range of viscosities be made available by all lubricant suppliers for each and every type of hydraulic fluid which the supplier markets. Availability will be dictated by local demand.

9. Keywords

9.1 Brookfield viscosity; hydraulic fluid; shear stability; viscosity; viscosity classification

TABLE 4 Examples of Interpreting Viscosity Designation Using Figs. 2 and 3 to Estimate Operating Temperature Limits for Fluids

Viscosity Designation	Low[A] Temperature Limit °C	Temperature, °C, for Kinematic Viscosity	
		13 mm^2/s	24 mm^2/s
ISO 22 L15-21 (160)	−23	55	<45
ISO 32 L22-30 (150)	−15	66	47
ISO 32 L32-24 (110)	−8	58	<45
L32-21 (120)	−8	55	<45
L32-32 (140)	−8	67	48
ISO 46 L46-43 (140)	−2	77	57
ISO 46 L32-43 (150)	−8	78	56
L46-53 (150)	−2	84	62
ISO 68 L68-67 (120)	+ 4	87	66
ISO 68 L68-41 (120)	+ 4	73	54
ISO 100 L100-96 (110)	+ 10	96	75

[A] Low temperature operating limit, as designated from Table 1, based on 750 mPa's temperature measurement.