INTERNATIONAL

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

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1. Scope*

1.1 This practice covers 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~~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 mm^2/s to 150 mm^2/s as measured at a reference temperature of 40 °C and to temperatures from −50 °C 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.

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

1.5 *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:*[2]

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
D2422 Classification of Industrial Fluid Lubricants by Viscosity System
D2983 Test Method for Low-Temperature Viscosity of Automatic Transmission Fluids, Hydraulic Fluids, and Lubricants using a Rotational Viscometer
D5621 Test Method for Sonic Shear Stability of Hydraulic Fluids
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E1953 Practice for Description of Thermal Analysis and Rheology Apparatus

2.2 *Society of Automotive Engineers (SAE) Standards:*[3]

J300 Engine Oil Viscosity Classification
J306 Axle and Manual Transmission Lubricant Viscosity Classification

3. Terminology

3.1 *Definitions:*

3.1.1 *hydraulic fluid, n*—a liquid used in hydraulic systems for lubrication and transmission of power.

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

3.1.2.1 *Discussion—*

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[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.N0 on Hydraulic Fluids.

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[2] 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.

[3] Available from ~~Society of Automotive Engineers~~ SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA ~~15096-0001,~~15096, http://www.sae.org.

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

For gravity flow under a given hydrostatic head, the pressure head of a liquid is proportional to its density. Therefore, kinematic viscosity is a measure of the resistance to flow of a liquid under gravity.

3.1.3 *Newtonian oil or fluid, n*—an oil or fluid that at a given temperature exhibits a constant viscosity at all shear rates or shear stresses.

3.1.4 *non-Newtonian oil or fluid, n*—an oil or fluid that at a given temperature exhibits a viscosity that varies with changing shear stress or shear rate.

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

3.1.6 *shear rate, n*—the velocity gradient in fluid flow.

3.1.7 *shear stability, n*—the resistance of a polymer-thickened fluid to shear degradation.

3.1.8 *shear stress, n*—the motivating force per unit area for fluid flow.

3.1.9 *viscosity, n*—the ratio between the applied shear stress and the rate of shear.

3.1.9.1 *Discussion*—

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

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

3.2 *Definitions of Terms Specific to This Standard:*

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

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 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 D2422. 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,~~ rotational viscometer (see Practice E1953), Test Method D2983.

6.1.1 The viscosity shall be interpolated from measurements at three temperatures spanning the temperature at which the viscosity is ~~750 mPa·s.~~ 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 temperature determined in 6.1.1 shall be rounded to a whole number in accordance with Practice E29.

6.1.3 The low temperature viscosity grade is determined by matching the temperature determined in 6.1.2 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 D445) of a fluid which has been sheared using Test Method D5621.

6.2.1 The kinematic viscosity determined in 6.2 shall be rounded to a whole number in accordance with Practice E29.

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 D445) 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 D2270 on fluid which has been sheared using Test Method D5621.

6.3.1 The viscosity index determined in 6.3 shall be rounded to the nearest ten units in accordance with Practice E29. 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 D2270. The viscosity index designation for the fluid is established by rounding this viscosity index to the nearest ten units in accordance with Practice E29.

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 D445 and D2270 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 D2422 (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 D2422, 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.

TABLE 1 Low Temperature Viscosity Grades for Hydraulic Fluid Classifications

Viscosity Grade	Temperature, °C, for ~~Brookfield~~Rotational 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.

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

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 °C 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 °C 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 mm^2/s 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 mm^2/s (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