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Standard Guide for In-Service Lubricant Viscosity Measurement[1]

This standard is issued under the fixed designation D8185; 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 *Significance and Determination of Viscosity*—The purpose of this guide is to provide sufficient knowledge for a person with some technical background in lubrication or condition monitoring from which they can determine the best choice for measuring viscosity of an in-service oil. Such information from this guide should enable the user to engage in productive discussions with colleagues, service providers, managers, and service personnel about obtaining and using information on and from viscosity. There are a number of different approaches to viscometric measurement, and this guide is intended to be a helpful resource in selecting the most appropriate viscometric approach to gain information for the in-service fluid.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.3 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *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)

D446 Specifications and Operating Instructions for Glass Capillary Kinematic Viscometers

D2983 Test Method for Low-Temperature Viscosity of Automatic Transmission Fluids, Hydraulic Fluids, and Lubricants using a Rotational Viscometer

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products

D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants

D4378 Practice for In-Service Monitoring of Mineral Turbine Oils for Steam, Gas, and Combined Cycle Turbines

D4683 Test Method for Measuring Viscosity of New and Used Engine Oils at High Shear Rate and High Temperature by Tapered Bearing Simulator Viscometer at 150 °C

D5133 Test Method for Low Temperature, Low Shear Rate, Viscosity/Temperature Dependence of Lubricating Oils Using a Temperature-Scanning Technique

D5293 Test Method for Apparent Viscosity of Engine Oils and Base Stocks Between –10 °C and –35 °C Using Cold-Cranking Simulator

D5478 Test Methods for Viscosity of Materials by a Falling Needle Viscometer

D6224 Practice for In-Service Monitoring of Lubricating Oil for Auxiliary Power Plant Equipment

D6299 Practice for Applying Statistical Quality Assurance and Control Charting Techniques to Evaluate Analytical Measurement System Performance

D6304 Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration

[1] This guide is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.96.01 on In-Service Lubricant Viscosity Testing Practices and Techniques.

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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.

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

D6616 Test Method for Measuring Viscosity at High Shear Rate by Tapered Bearing Simulator Viscometer at 100 °C
D6896 Test Method for Determination of Yield Stress and Apparent Viscosity of Used Engine Oils at Low Temperature
D7042 Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)
D7110 Test Method for Determining the Viscosity-Temperature Relationship of Used and Soot-Containing Engine Oils at Low Temperatures
D7279 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids by Automated Houillon Viscometer
D7483 Test Method for Determination of Dynamic Viscosity and Derived Kinematic Viscosity of Liquids by Oscillating Piston Viscometer
D8092 Test Method for Field Determination of Kinematic Viscosity Using a Microchannel Viscometer

2.2 *SAE AIR Standard:*[3]

SAE AIR 5704 Field Viscosity Test for Thickened Aircraft Anti-icing Fluids

3. Definitions and Terms

3.1 For definitions of terms used in this guide, refer to Terminology D4175.

3.2 *What is Viscosity?*

3.2.1 Viscosity is commonly recognized as the ease or difficulty with which a fluid flows—that is, its fluidity. Often it is very evident that temperature has a strong effect on fluidity—viscosity always increases with decreasing temperature and vice versa.

3.2.2 A fluid's viscosity arises from the degree of its internal molecular resistance to motion and a fluid flows only under sufficient force whether that force is gravity or some other source. Stirring, pumping, causing fluid to flow in a pipe or lubricating a machine are all examples of shear—applying a force to cause a fluid to move. For a simple example, consider filling a glass of water and a separate glass full of thick used oil, and stir each glassful at the same velocity (shear rate) with an identical spoon held in the same manner. The thicker used oil will require more force to move the spoon than the water, which is consistent with the used oil having a higher viscosity than the water.

3.2.3 Isaac Newton defined viscosity originally as the ratio of the force moving the fluid over the rate at which the fluid moves in response to that force. Fig. 1 helps to visualize this relationship. The edges of the two plates are shown with fluid between. As predicted from Newton's law regarding viscous flow, when the upper plate is moved under a steady force over the stationary bottom plate, this produces a linear shear gradient through the fluid as shown. Depending on the viscosity of the fluid between the plates, the ratio of the force per area (technically named 'shear-stress' and indicated in Eq 1 by τ) causing motion of the upper plate at the shear gradient (termed shear rate and indicated by $\delta u/\delta y$) is given by Newton's law as:

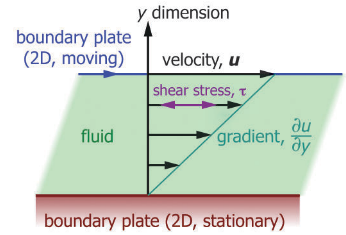

FIG. 1 Depiction of Velocity Gradient in a Flowing Fluid

$$\eta = \tau/\delta u/\delta y \tag{1}$$

3.2.4 Fig. 1 is, of course, a very simple example of fluid flow to clearly show the relationship in Eq 1. However, fluid flow can and does take many much more complex patterns of flow in the process of lubrication and hydraulic service. All of these patterns are expressed by Eq 1 if the fluid is Newtonian in behavior. However, many fluids and lubricants have flow patterns called "non-Newtonian" and these important lubricants will be discussed further on in this guide.

3.3 *Two Frequently Used Forms of Viscosity Measurement that Produce Different Values:*

3.3.1 In the early years of measuring the viscosity of lubricants, most viscometric measurements of fluids were done using glass capillary viscometers, and these are still used widely today. However, in the mid-1930s, rotational viscometry was commercially introduced and has since become widely used, particularly in high shear rate viscometry, which was introduced particularly for viscometric information on non-Newtonian oils.

3.3.2 However, regarding information on Newtonian oils (which are non-shear rate susceptible), capillary and rotational viscometers—at the same temperature, produce different viscometric values for a very simple reason. The reason is that gravimetric viscometry is also a function of the density of the fluid that causes the fluid to flow through the capillary. Thus, the rate at which the fluid flows through the capillary is not only dependent on a fluid's viscosity but also on its density. This form of viscometry has been termed "kinematic viscosity." It was formerly measured and reported in units of centiStokes, cSt. This unit became obsolete in 1976 when worldwide System International, SI, unit of mm^2/s was introduced, (for information = 1.0 cSt = 1.0 mm^2/s).

3.3.3 True viscosity is called "dynamic viscosity" and was formerly measured in the units of centipoise, cP. This unit became obsolete in 1976 when the worldwide System International, SI, the unit of mPa·s was introduced, (for information 1.0 cP = 1.0 mPa·s).

3.3.4 With Newtonian fluids, the two viscosity values differed from one another as shown by Eq 2 in which ν is the kinematic viscosity, η is the true, dynamic viscosity and ρ is the fluid's density at the temperature of measurement.

$$\nu = \eta/\rho \tag{2}$$

Both gravimetric capillary and rotational approaches to measuring viscosity have remained popular and, over time, other viscometric instruments have become available.

3.3.5 However, when selecting a viscosity-measuring technique for an in-service fluid or lubricant, it is critically

[3] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.