Designation: D6793 – 02 (Reapproved 2012)

Standard Test Method for Determination of Isothermal Secant and Tangent Bulk Modulus[1]

This standard is issued under the fixed designation D6793; 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 test method covers the determination of isothermal secant and tangent bulk modulus of liquids which are stable and compatible with stainless steel under the conditions of test.

1.2 This test method is designed to be used over the temperature range from -40 to 200°C and from ambient to 68.95 Mpa (10 000 psig).

NOTE 1—Because of the design of the test apparatus, the upper limit of pressure which can be attained is limited by the bulk modulus of the test fluid. Pressures as high as 68.95 Mpa will not be attained for fluids of relatively low bulk modulus at the test temperature.

1.3 This test method assumes that the user is proficient in the assembly and use of medium pressure (m/p) threaded and coned fittings which are intended for use at pressures up to 137.9 Mpa (20 000 psig).

1.4 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 2—Because hydraulic pressure in the test system is produced by purely mechanical means, the test method is not subject to the hazards associated with systems which are pressurized pneumatically. Even small leaks will result in immediate drop in pressure to ambient without production of a high pressure liquid stream or mist.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products

D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products

E300 Practice for Sampling Industrial Chemicals

3. Terminology

3.1 *Definitions:*

3.1.1 *isothermal secant bulk modulus, n*—the product of original fluid volume and the slope of the secant drawn from the origin to any specified point on the plot of pressure versus volume change divided by volume at constant temperature.

3.1.2 *isothermal tangent bulk modulus, n*—the product of fluid volume at any specified pressure and the partial derivative of fluid pressure with respect to volume at constant temperature.

4. Summary of Test Method

4.1 *Determination of Isothermal Secant Bulk Modulus:*

4.1.1 A piston in the form of a medium pressure valve is forced into a chamber which is liquid-filled. The pressure created by the insertion of the piston is measured.

4.2 A system constant $V/\Delta V$ is determined by use of a standard of known bulk modulus as follows:

$$\left(\frac{V}{\Delta V}\right) = \frac{\bar{B}_i}{P} = \frac{\bar{B}_i}{(P_n - P_o)} \quad (1)$$

where:

$\bar{B}_i$ = isothermal secant bulk modulus,
P_o = pressure at the origin before insertion of the piston, and
P_n = pressure of the system at insertion of piston to Position n.

NOTE 3—$V/\Delta V$ is thus a constant determined by system volume and piston displacement only. It is independent of temperature and when known, can be used to determine isothermal secant bulk modulus from pressure data obtained for various degrees of piston insertion.

4.3 Isothermal tangent bulk modulus and sample density, if desired, may be determined from isothermal secant bulk modulus data determined as a function of pressure by use of the calculations in Section 12.

5. Significance and Use

5.1 Isothermal secant bulk modulus (static bulk modulus) is a property that measures the compressibility of a liquid. The greater the value, the less the compressibility of the liquid.

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.L0.07 on Engineering Sciences of High Performance Fluids and Solids (Formally D02.1100).

Current edition approved April 15, 2012. Published May 2012. Originally approved in 2002. Last previous edition approved in 2007 as D6793–02(2007). DOI: 10.1520/D6793-02R12.

[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.

5.2 Isothermal secant bulk modulus is employed in the design of high performance hydraulic fluid and braking systems. High bulk modulus is desirable in that the response time of a system is faster when applied pressure more directly effects the action of the system rather than in the compression of the working liquid.

5.3 If isothermal secant bulk modulus is known as a function of pressure, the data may be used to calculate isothermal tangent bulk modulus and density as a function of pressure. The data may not, however, be used to determine isentropic (dynamic) bulk modulus. That property is usually determined from velocity of sound measurements and differs from isothermal bulk modulus by the ratio of $C_p/C_v = \gamma$ (the ratio of heat capacity at constant pressure to that at constant volume for the test specimen.

6. Apparatus

6.1 The apparatus for the determination of isothermal secant bulk modulus is shown schematically in Fig. 1. An oven capable of maintaining temperature within ±0.1°C at the desired test temperature is required. All fittings are of the coned and threaded m/p type for use at working pressures up to 137.9 Mpa (20 000 psig). Pressure is created in the system by use of the pressure valve (see 3 in Fig. 1) by which a piston (valve stem) is inserted into the liquid-filled system by turning 1,2,3…*n* turns as determined by a scale affixed to the valve stem to ensure repeatability of turns from the starting point. Pressure transducers, thermocouples and system fixtures should be such as to have minimal contribution to system volume so that the system volume is such as to allow a maximum pressure increase for any given degree of insertion of the pressure valve stem.

7. Reagents and Materials

7.1 *Cleaning Solvent*—Mineral spirits conforming to Specification D235, Type I.

7.2 *Other Solvents*—Some test specimens may not be soluble in mineral spirits. A suitable solvent for such materials will be needed to clean the apparatus after their use. The solvent must be compatible with stainless steel and the elastomeric components of the valves in the test apparatus.

8. Sampling

8.1 Obtain a representative sample of the test specimen in accordance with the requirements of Practice D4057, D4177, or E300.

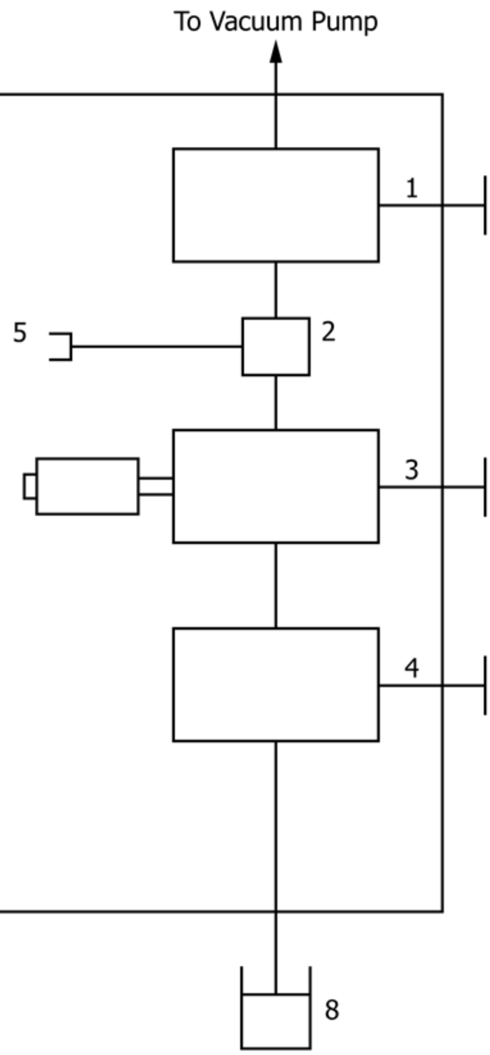
9. Preparation of Apparatus

9.1 Introduce a portion of mineral spirits into the sample container (Fig. 1, Item 8).

9.2 Open Valves 1 and 4 and slowly draw the mineral spirits through the system by gentle application of vacuum.

NOTE 4—Always use a trap between the test apparatus and the vacuum source to prevent introduction of the liquid solvent or the test specimen into the vacuum system.

9.3 Replace the sample container with an empty vessel and allow excess solvent to drain from the test system. Repeat 9.1 – 9.3.



1 = Top valve
2 = A Tee
3 = Pressure valve
4 = Bottom valve
5 = Thermocouple
6 = Pressure transducer
7 = Oven
8 = Sample container

NOTE 1—All fittings are m/p coned and threaded type for use at working pressure up to 20 000 psig.

FIG. 1 Apparatus for Determination of Secant Bulk Modulus

9.4 Remove the vessel containing excess solvent and with Valves 1 and 4 open allow the vacuum pump to draw air through the test system to evaporate the residual solvent. Start at ambient temperature and raise the oven temperature to 100°C while drawing air through the system.

9.5 When the oven temperature reaches 100°C, close Valve 4 and allow the vacuum pump to release the pressure in the test system to complete removal of solvent residues by evaporation.

10. Calibration

10.1 With the cleaned system at ambient temperature introduce the calibrating fluid (usually water) into container 8.