



Designation: ~~D 696-03~~ Designation: D 696 - 08

Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between -30°C and 30°C with a Vitreous Silica Dilatometer¹

This standard is issued under the fixed designation D 696; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This test method covers determination of the coefficient of linear thermal expansion for plastic materials having coefficients of expansion greater than $1 \times 10^{-6} \text{ }^{\circ}\text{C}/^{\circ}\text{C}$ by use of a vitreous silica dilatometer. At the test temperatures and under the stresses imposed, the plastic materials shall have a negligible creep or elastic strain rate or both, insofar as these properties would significantly affect the accuracy of the measurements.

NOTE 1—There is no similar or equivalent ISO standard.

1.1.1 Test Method E 228 shall be used for temperatures other than -30°C to 30°C .

1.1.2 This test method shall not be used for measurements on materials having a very low coefficient of expansion (less than $1 \times 10^{-6} \text{ }^{\circ}\text{C}/^{\circ}\text{C}$). For materials having very low coefficient of expansion, interferometer or capacitance techniques are recommended.

1.2 The thermal expansion of a plastic is composed of a reversible component on which are superimposed changes in length due to changes in moisture content, curing, loss of plasticizer or solvents, release of stresses, phase changes and other factors. This test method is intended for determining the coefficient of linear thermal expansion under the exclusion of these factors as far as possible. In general, it will not be possible to exclude the effect of these factors completely. For this reason, the test method can be expected to give only an approximation to the true thermal expansion.

1.3 The values stated in SI units are to be regarded as the standard. The values in parentheses are for information only.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*²

D 618 Practice for Conditioning Plastics for Testing

D 883 Terminology Relating to Plastics

~~D 4065 Practice for Determining and Reporting Dynamic Mechanical Properties of Plastics~~ Practice for Plastics: Dynamic Mechanical Properties: Determination and Report of Procedures

E 228 Test Method for Linear Thermal Expansion of Solid Materials with a Vitreous Silica Push-Rod Dilatometer

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E 831 Test Method for Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology D 883 unless otherwise specified.

4. Summary of Test Method

4.1 This test method is intended to provide a means of determining the coefficient of linear thermal expansion of plastics which are not distorted or indented by the thrust of the dilatometer on the specimen. For materials that indent, see 8.4. The specimen is

¹ This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.30 on Thermal Properties (Section D20.30.07).

Current edition approved April 10, 2003. Published June 2003. Originally approved in 1942. Last previous edition approved in 1998 as D696-98.

Current edition approved Nov. 1, 2008. Published November 2008. Originally approved in 1942. Last previous edition approved in 2003 as D 696 - 03.

² Annual Book of ASTM Standards, Vol 08.01.

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.

placed at the bottom of the outer dilatometer tube with the inner one resting on it. The measuring device which is firmly attached to the outer tube is in contact with the top of the inner tube and indicates variations in the length of the specimen with changes in temperature. Temperature changes are brought about by immersing the outer tube in a liquid bath or other controlled temperature environment maintained at the desired temperature.

5. Significance and Use

5.1 The coefficient of linear thermal expansion, α , between temperatures T_1 and T_2 for a specimen whose length is L_0 at the reference temperature, is given by the following equation:

$$\alpha = (L_2 - L_1) / [L_0(T_2 - T_1)] = \Delta L / L_0 \Delta T$$

where L_1 and L_2 are the specimen lengths at temperatures T_1 and T_2 , respectively. α is, therefore, obtained by dividing the linear expansion per unit length by the change in temperature.

5.2 The nature of most plastics and the construction of the dilatometer make -30 to $+30^\circ\text{C}$ [-22°F (-22°F to $+54^\circ\text{F}$) $+54^\circ\text{F}$] a convenient temperature range for linear thermal expansion measurements of plastics. This range covers the temperatures in which plastics are most commonly used. Where testing outside of this temperature range or when linear thermal expansion characteristics of a particular plastic are not known through this temperature range, particular attention shall be paid to the factors mentioned in 1.2 and special preliminary investigations by thermo-mechanical analysis, such as that prescribed in Practice D 4065 for the location of transition temperatures, may be required to avoid excessive error. Other ways of locating phase changes or transition temperatures using the dilatometer itself may be employed to cover the range of temperatures in question by using smaller steps than 30°C [54°F (54°F) or by observing the rate of expansion during a steady rise in temperature of the specimen. Once such a transition point has been located, a separate coefficient of expansion for a temperature range below and above the transition point shall be determined. For specification and comparison purposes, the range from -30°C to $+30^\circ\text{C}$ [-22°F (-22°F to $+86^\circ\text{F}$) $+86^\circ\text{F}$] (provided it is known that no transition exists in this range) shall be used.

6. Apparatus

6.1 *Fused-Quartz-Tube Dilatometer* suitable for this test method is illustrated in Fig. 1. A clearance of approximately 1 mm is allowed between the inner and outer tubes.

6.2 *Device* for measuring the changes in length (dial gage, LVDT, or the equivalent) is fixed on the mounting fixture so that its position may be adjusted to accommodate specimens of varying length (see 8.2). The accuracy shall be such that the error of indication will not exceed $\pm 1.0 \mu\text{m}$ [$4 \times 10^{-5} \text{ in.}$ ($4 \times 10^{-5} \text{ in.}$)] for any length change. The weight of the inner silica tube plus the measuring device reaction shall not exert a stress of more than 70 kPa [10 psi (10 psi)] on the specimen so that the specimen is not distorted or appreciably indented.

6.3 *Scale or Caliper* capable of measuring the initial length of the specimen with an accuracy of $\pm 0.5 \%$.

6.4 *Controlled Temperature Environment* to control the temperature of the specimen. Arrange the bath so a uniform temperature is assured over the length of the specimen. Means shall be provided for stirring the bath and for controlling its temperature within $\pm 0.2^\circ\text{C}$ [$\pm 0.4^\circ\text{F}$ ($\pm 0.4^\circ\text{F}$)] at the time of the temperature and measuring device readings.

NOTE 2—If a fluid bath is used, it is preferable and not difficult to avoid contact between the bath liquid and the test specimen. If such contact is unavoidable, take care to select a fluid that will not affect the physical properties of the material under test.

6.5 *Thermometer or Thermocouple*—The bath temperature shall be measured by a thermometer or thermocouple capable of an accuracy of $\pm 0.1^\circ\text{C}$ [$\pm 0.2^\circ\text{F}$ ($\pm 0.2^\circ\text{F}$)].

7. Sampling

7.1 Sampling shall be conducted in accordance with the material specification for the material in question.

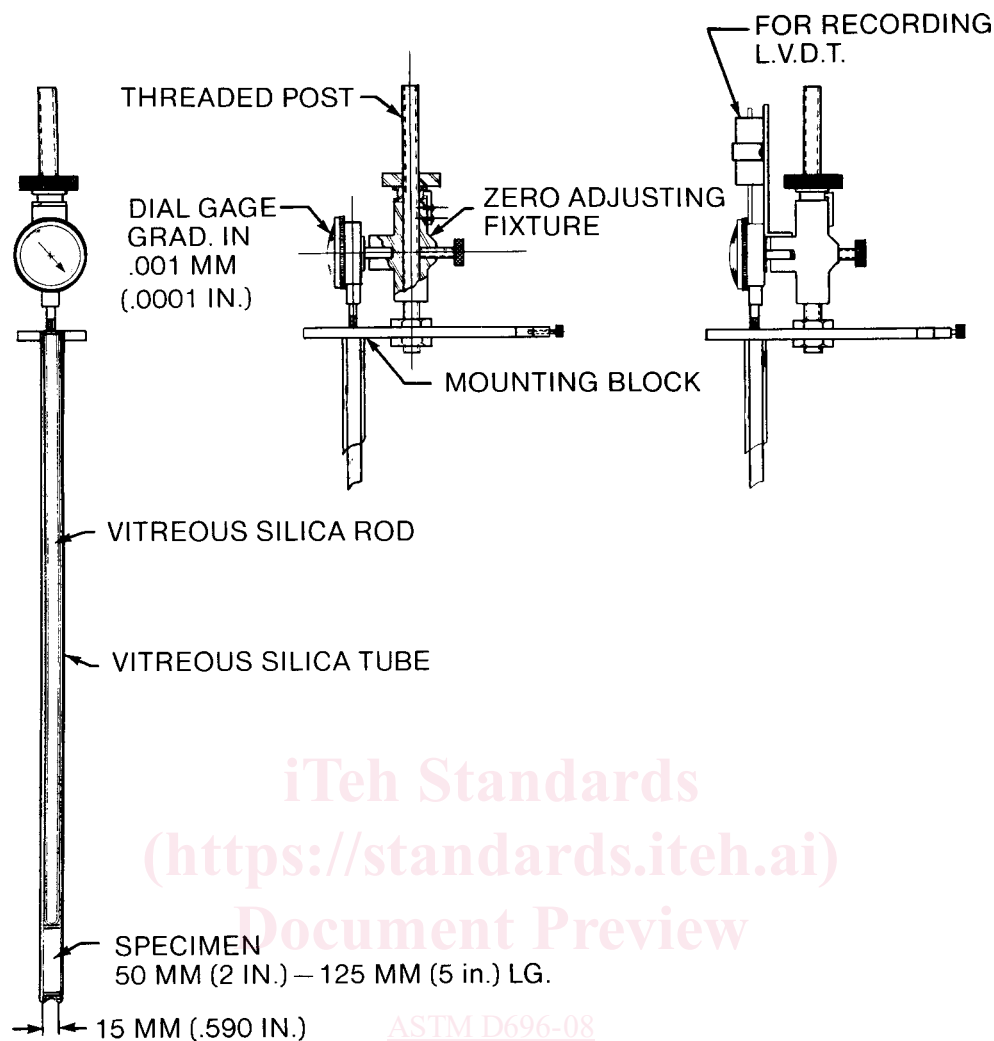
8. Test Specimen

8.1 The test specimens shall be prepared under conditions that give a minimum of strain or anisotropy, such as machining, molding, or casting operations.

8.2 The specimen length shall be between 50 mm and 125 mm.

NOTE 3—If specimens shorter than 50 mm are used, a loss in sensitivity results. If specimens greatly longer than 125 mm are used, the temperature gradient along the specimen may become difficult to control within the prescribed limits. The length used will be governed by the sensitivity and range of the measuring device, the extension expected and the accuracy desired. Generally speaking, the longer the specimen and the more sensitive the measuring device, the more accurate will be the determination if the temperature is well controlled.

8.3 The cross section of the test specimen may be round, square, or rectangular and shall fit easily into the measurement system of the dilatometer without excessive play on the one hand or friction on the other. The cross section of the specimen shall be large enough so that no bending or twisting of the specimen occurs. Convenient specimen cross sections are: 12.5 by 6.3 mm [$1/2 \text{ in.}$ by $1/4 \text{ in.}$], 12.5 by 3 mm [$1/2 \text{ in.}$], 12.5 by 3 mm [$1/2 \text{ in.}$ by $1/8 \text{ in.}$], 12.5 mm [$1/2 \text{ in.}$] in diameter or 6.3 mm [$1/4 \text{ in.}$] in diameter. If excessive play is found with some of the thinner specimen, guide sections shall be cemented or otherwise attached to the sides of the specimen to fill out the space.



ASTM D696-08
FIG. 1 Quartz-Tube Dilatometer

8.4 Cut the ends of the specimens flat and perpendicular to the length axis of the specimen. If a specimen indents from the use of the dilatometer, then flat, thin steel or aluminum plates shall be cemented or otherwise firmly attached to the specimen to aid in positioning it in the dilatometer. These plates shall be 0.3 to 0.5 mm $\{0.012(0.012 \text{ to } 0.020 \text{ in.})\}$ in thickness.

9. Conditioning

9.1 *Conditioning*—Condition the test specimens at $23 \pm 2^\circ\text{C}$ $\{73.4 \pm 3.6^\circ\text{F}\}$ and $50 \pm 5\%$ relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D618 unless otherwise specified by the contract or relevant material specification. In cases of disagreement, the tolerances shall be $\pm 1^\circ\text{C}$ $\{\pm 1.8^\circ\text{F}\}$ and $\pm 2\%$ relative humidity.

9.2 *Test Conditions*—Conduct tests in the Standard Laboratory Atmosphere of $23 \pm 2^\circ\text{C}$ $\{73.4 \pm 3.6^\circ\text{F}\}$ and $50 \pm 5\%$ relative humidity, unless otherwise specified by the contract or relevant material specification. In cases of disagreement, the tolerances shall be $\pm 1^\circ\text{C}$ $\{\pm 1.8^\circ\text{F}\}$ and $\pm 2\%$ relative humidity. — Condition the test specimens at $23 \pm 2^\circ\text{C}$ $\{73.4 \pm 3.6^\circ\text{F}\}$ and $50 \pm 10\%$ relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618 unless otherwise specified by the contract or relevant material specification. In cases of disagreement, the tolerances shall be $\pm 1^\circ\text{C}$ $\{\pm 1.8^\circ\text{F}\}$ and $\pm 5\%$ relative humidity.

10. Procedure

10.1 Measure the length of two conditioned specimens at room temperature to the nearest $25 \mu\text{m}$ $\{0.001 \text{ in.}\}$ $\{0.001 \text{ in.}\}$ with the scale or caliper (see 6.3).

10.2 Cement or otherwise attach the steel plates to the ends of the specimen to prevent indentation (see 8.4). Measure the new lengths of the specimens.

10.3 Mount each specimen in a dilatometer. Carefully install the dilatometer in the -30°C $\{-22^\circ\text{F}\}$ $\{-22^\circ\text{F}\}$ controlled environment. If liquid bath is used, make sure the top of the specimen is at least 50 mm $\{2 \text{ in.}\}$ $\{2 \text{ in.}\}$ below the liquid level of the bath. Maintain the temperature of the bath in the range from -32°C to -28°C $\{-26(-26 \text{ to } -18^\circ\text{F})\}$ $\{-18^\circ\text{F}\} \pm 0.2^\circ\text{C}$