Designation: ~~D5930 – 16~~ D5930 – 17

Standard Test Method for Thermal Conductivity of Plastics by Means of a Transient Line-Source Technique[1]

This standard is issued under the fixed designation D5930; 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 the thermal conductivity of plastics over a temperature range from –40 to 400°C. It is possible to measure the thermal conductivity of ~~materials~~ filled and unfilled thermoplastics, thermosets, and rubbers in the range from 0.08 to 2.0 ~~W/m.K covering thermoplastics, thermosets, and rubbers, filled and reinforced.~~W/m.K.

1.2 The values stated in SI units shall be regarded as standard.

1.3 *This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish proper safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—There is no known ISO equivalent to this test method.

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]

C177 Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus

C518 Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus

C1113 Test Method for Thermal Conductivity of Refractories by Hot Wire (Platinum Resistance Thermometer Technique)

D618 Practice for Conditioning Plastics for Testing

D883 Terminology Relating to Plastics

D2717 Test Method for Thermal Conductivity of Liquids

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E1225 Test Method for Thermal Conductivity of Solids Using the Guarded-Comparative-Longitudinal Heat Flow Technique

3. Terminology

3.1 *Definitions*—Terminology used in this standard is in accordance with Terminology D883.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *temperature transient, n*—the temperature rise associated with the perturbation of a system, initially at a uniform temperature. The system does not attain thermal equilibrium during the transient.

3.2.2 *thermal conductivity, n*—the time rate of steady heat flow/unit area through unit thickness of a homogeneous material in a direction perpendicular to the surface induced by a unit temperature difference.

3.2.2.1 *Discussion*—

[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.

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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**

Where other modes of heat transfer are present in addition to conduction, such as convection and radiation, this property often is referred to as the apparent thermal conductivity, λ_{app}.

3.2.2.2 *Discussion—*

Thermal conductivity must be associated with the conditions under which it is measured, such as temperature and pressure, as well as the compositional variation of the material. It is possible that thermal conductivity will vary with direction and orientation of the specimen since some materials are not isotropic with respect to thermal conductivity. In the case of thermoset polymers, it is possible that thermal conductivity will vary with the extent of cure.

3.2.3 *thermal diffusivity*—a heat-transport property given by the thermal conductivity divided by the thermal mass, which is a product of the density and the heat capacity.

3.3 *Symbols:*

3.3.1 C—Probe constant.

3.3.2 λ—Thermal conductivity, W/m.K.

3.3.3 Q—Heat output per unit length, W/m.

3.3.4 T_2—The temperature (K) recorded at time t_2.

3.3.5 T_1—The temperature (K) recorded at time t_1.

3.4 *Subscript:*

3.4.1 *av*—average.

3.4.2 *app*—apparent.

3.4.3 *ref*—reference.

4. Summary of Test Method

4.1 *Line-Source Technique*—This is a transient method for determining thermal conductivity (**1, 2**).[3] A line source of heat is located at the center of the specimen being tested. The apparatus is at a constant initial temperature. During the course of the measurement, a known amount of heat produced by the line-source results in a heat wave propagating radially into the specimen. The rate of heat propagation is related to the thermal diffusivity of the polymer. The temperature rise of the line-source varies linearly with the logarithm of time (**3**). It is possible to use this relationship to directly calculate the thermal conductivity of the sample. There are a number of ways to achieve the line source of heat. In this test method, it is in the form of a probe as described in 7.2.

5. Significance and Use

5.1 The relative simplicity of the test method makes it applicable for a wide range of materials (**4, 5**). The technique is capable of fast measurements, making it possible to take data before the materials suffer thermal degradation. Alternatively, it is possible to study the effect of compositional changes such as chemical reaction or aging (**6**). Short measurement times permit generation of large amounts of data with little effort. The line-source probe and the accompanying test specimen are small in size, making it possible to subject the sample to a wide range of test conditions. Because this test method does not contain a numerical precision and bias statement, it shall not be used as a referee test method in case of dispute.

6. Interferences

6.1 The line-source method produces results of highest precision with materials where intimate contact with the probe has been established, thereby eliminating effects of thermal contact resistance. These materials include viscous fluids and soft solids.

6.1.1 *Thermal-Contact Resistance*—In the solid state, it is possible that a contact resistance is developed due to the interface between the specimen and the measuring device. Conventional methods attempt to account for this by introducing a conductive paste between the specimen and the sensor. This reduces, but some effect of contact resistance is still possible. In the line-source method, contact resistance manifests itself as a nonlinearity in the initial portion of the transient (see Fig. 1). The technique has a method to account for this phenomenon. By extending the time of the measurement, it is possible to progress beyond the region of thermal-contact resistance, achieving a state where the contact resistance does not contribute to the measured transient (**7**). This state typically is achieved after about 10 to 20 s in the measurement. The larger the contact resistance, the greater is this time. It is, therefore, important to make a sufficiently long measurement to exclude the portion of the transient that shows the effect of the contact resistance. The duration of measurement, however, must not be too long, ~~or else the~~ because the possibility of the heat wave striking a sample boundary exists, thereby violating the theoretical ~~conditions~~requirements of the measurement.

[3] The boldface numbers in parentheses refer to the list of references at the end of this standard.

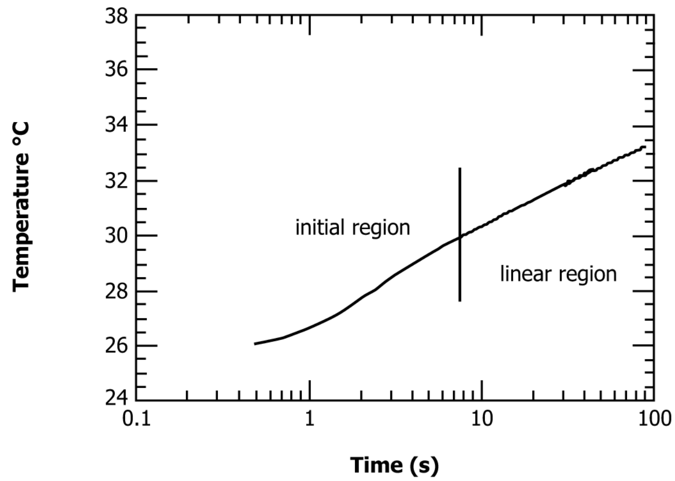

FIG. 1 Line-Source Transient

6.1.2 *Shrinkage Upon Solidification*—Plastics tend to shrink significantly upon solidification. This shrinkage is especially so for the semi-crystalline materials, which experience a significant change in specific volume upon crystallization. The probability exists that this crystallization will result in large gaps being developed between the specimen and the sensing device. To account for shrinkage, and possibly permit the line-source probe to move downward to take up the slack a simple compression scheme as described in 9.5 has been used successfully. Steps also must be taken to minimize specimen volume so as to reduce the extent of shrinkage.

6.2 Measurements ~~on~~ in viscid fluids are subject to the development of convection currents, which have been known to affect the measurement. Because of the transient nature of the measurement, these effects are not as pronounced. They cannot be eliminated, however.

6.3 Although the technique is not limited by temperature, at measurements above 500°C, a significant amount of heat transfer occurs due to radiation so that it is possible to measure only a λ_{app} ~~is possible to be measured.~~.

7. Apparatus

7.1 The apparatus consists of a line-source probe imbedded in a specimen contained in a constant-temperature environment. During the measurement, the line-source probe produces a precise amount of heat. The resulting temperature transient is recorded, preferably, on a computer data-acquisition system, as specified in 7.4. This transient is analyzed to obtain the thermal conductivity.

7.2 *Line-Source Probe*—The line-source probe contains a heater that runs the length of the probe (**3**). The length-to-diameter ratio of the probe must be greater than 20. The resistance of the line-source heater must be known to within ±0.1 %. The probe also contains a temperature sensor to measure the temperature transient. A typical sensor for the line-source probe is a high-sensitivity *J*-type thermocouple used because of its large Seebeck coefficient. The housing sheath of the probe must be robust enough to ensure that the probe does not bend or deform under the adverse conditions it is subject to during measurements.

7.3 *Heater Power Source*—The power input to the line-source heater comes from a DC voltage source. The precision of the voltage source must be within ±0.25 % over the entire duration of the test.

7.4 *Recording Device*—The temperature transient from the line-source probe is recorded for the duration of the test. A temperature measurement device with a resolution of 0.1°C is required. Data are acquired for 30 to 120 s depending on the type of material. Typical temperature rises are between 2 and 10°C over the duration of the measurement. The frequency of data acquisition must be at least once every second.

7.5 *Specimen Environment*—A constant-temperature environment must be maintained through the duration of the test so as to provide a temperature stability in the specimen of within ±0.1°C. Failure to attain this criterion will on occasions compromise the linearity of the transient, thereby affecting the test result. The environment shall be free from excessive vibration.

7.5.1 *Ambient*—For measurements close to ~~ambient,~~ ambient temperature, use of a stirred water bath is one method to be used to maintain the test temperature. Alternatively, placing the specimen, adequately shielded to protect it from convection, ~~placing in air~~ is a possible alternative.

7.5.2 *Cryogenic Temperatures*—Placing ~~an~~ a specimen adequately shielded from convection ~~specimen~~ in a controlled cryogenic bath or chamber is acceptable.

7.5.3 *Elevated Temperatures*—At temperatures above ambient, a special heated cell is required. This consists of a vertical cylindrical heated chamber, fitted with a removable plug at the bottom. The specimen is loaded from the top and is discharged through the bottom, once the test is complete (see Fig. 2).