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.

Designation: E1461 – 13 (Reapproved 2022)

Standard Test Method for Thermal Diffusivity by the Flash Method[1]

This standard is issued under the fixed designation E1461; 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 diffusivity of primarily homogeneous isotropic solid materials. Thermal diffusivity values ranging from 0.1 to 1000 $(mm)^2\ s^{-1}$ are measurable by this test method from about 75 to 2800 K.

1.2 Practice E2585 is adjunct to this test method and contains detailed information regarding the use of the flash method. The two documents are complementing each other.

1.3 This test method is a more detailed form of Test Method C714, having applicability to much wider ranges of materials, applications, and temperatures, with improved accuracy of measurements.

1.4 This test method is intended to allow a wide variety of apparatus designs. It is not practical in a test method of this type to establish details of construction and procedures to cover all contingencies that might offer difficulties to a person without pertinent technical knowledge, or to restrict research and development for improvements in the basic technique.

1.5 This test method is applicable to the measurements performed on essentially fully dense (preferably, but low porosity would be acceptable), homogeneous, and isotropic solid materials that are opaque to the applied energy pulse. Experience shows that some deviation from these strict guidelines can be accommodated with care and proper experimental design, substantially broadening the usefulness of the method.

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

1.7 For systems employing lasers as power sources, it is imperative that the safety requirement be fully met.

1.8 *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.*

1.9 *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]

C714 Test Method for Thermal Diffusivity of Carbon and Graphite by Thermal Pulse Method

E228 Test Method for Linear Thermal Expansion of Solid Materials With a Push-Rod Dilatometer

E2585 Practice for Thermal Diffusivity by the Flash Method

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *thermal conductivity, λ, of a solid material*—the time rate of steady heat flow through unit thickness of an infinite slab of a homogeneous material in a direction perpendicular to the surface, induced by unit temperature difference. The property must be identified with a specific mean temperature, since it varies with temperature.

3.1.2 *thermal diffusivity, α, of a solid material*—the property given by the thermal conductivity divided by the product of the density and heat capacity per unit mass.

3.2 *Description of Symbols and Units Specific to This Standard:*

3.2.1 D—diameter, m.

3.2.2 C_p—specific heat capacity, $J \cdot g^{-1} \cdot K^{-1}$.

3.2.3 k—constant depending on percent rise.

3.2.4 K—correction factors.

3.2.5 K_1, K_2—constants depending on β.

3.2.6 L—specimen thickness, mm.

3.2.7 t—response time, s.

3.2.8 $t_{1/2}$—half-rise time or time required for the rear face temperature rise to reach one half of its maximum value, s.

[1] This test method is under the jurisdiction of ASTM Committee E37 on Thermal Measurements and is the direct responsibility of Subcommittee E37.05 on Thermophysical 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.

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3.2.9 t^*—dimensionless time ($t^* = 4\alpha_s \ t/D_T^2$).

3.2.10 T—temperature, K.

3.2.11 α—thermal diffusivity, $(\mathrm{mm})^2/\mathrm{s}$.

3.2.12 β—fraction of pulse duration required to reach maximum intensity.

3.2.13 ρ—density, $\mathrm{g/(cm)^3}$.

3.2.14 λ—thermal conductivity, $\mathrm{W{\cdot}m^{-1}{\cdot}K^{-1}}$.

3.2.15 Δt_5—$T(5t_{½}) / T(t_{½})$.

3.2.16 Δt_{10}—$T(10t_{½}) / T(t_{½})$.

3.2.17 ΔT_{max}—temperature difference between baseline and maximum rise, K.

3.2.18 τ—pulse duration (see Fig. 1).

3.3 *Description of Subscripts Specific to This Standard:*

3.3.1 x—percent rise.

3.3.2 R—ratio.

3.3.3 max—maximum.

3.3.4 p—constant pressure.

4. Summary of Test Method

4.1 A small, thin disc specimen is subjected to a high-intensity short duration radiant energy pulse (Fig. 2). The energy of the pulse is absorbed on the front surface of the specimen and the resulting rear face temperature rise (thermal curve) is recorded. The thermal diffusivity value is calculated from the specimen thickness and the time required for the rear face temperature rise to reach a percentage of its maximum value (Fig. 3). When the thermal diffusivity of the specimen is to be determined over a temperature range, the measurement must be repeated at each temperature of interest.

NOTE 1—This test method is described in detail in a number of publications (**1, 2**)[3] and review articles (**3, 4, 5**). A summary of the theory can be found in Appendix X1.

5. Significance and Use

5.1 Thermal diffusivity is an important transient thermal property, required for such purposes such as design applications, determination of safe operating temperature, process control, and quality assurance.

[3] The boldface numbers given in parentheses refer to a list of references at the end of the text.

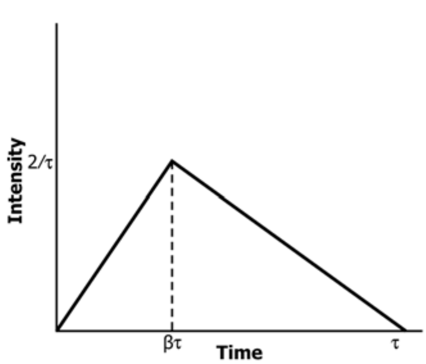

FIG. 1 Laser Pulse Shape

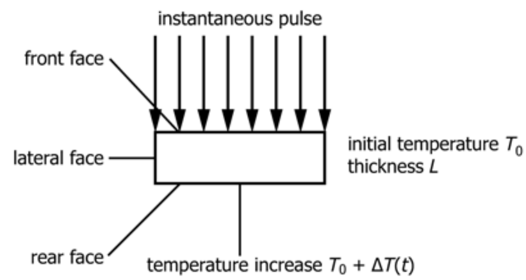

FIG. 2 Schematic of the Flash Method

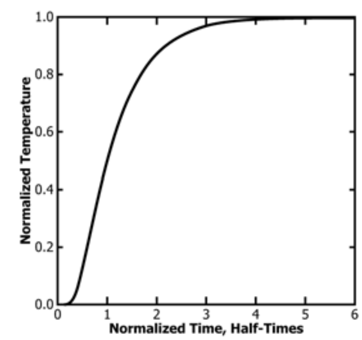

FIG. 3 Characteristic Thermal Curve for the Flash Method

5.2 The flash method is used to measure values of thermal diffusivity, α, of a wide range of solid materials. It is particularly advantageous because of simple specimen geometry, small specimen size requirements, rapidity of measurement and ease of handling.

5.3 Under certain strict conditions, specific heat capacity of a homogeneous isotropic opaque solid specimen can be determined when the method is used in a quantitative fashion (see Appendix X2).

5.4 Thermal diffusivity results, together with related values of specific heat capacity (C_p) and density (ρ) values, can be used in many cases to derive thermal conductivity (λ), according to the relationship:

$$\lambda = \alpha \, C_p \, \rho \tag{1}$$

6. Interferences

6.1 In principle, the thermal diffusivity is obtained from the thickness of the specimen and from a characteristic time function describing the propagation of heat from the front surface of the specimen to its back surface. The sources of uncertainties in the measurement are associated with the specimen itself, the temperature measurements, the performance of the detector and of the data acquisition system, the data analysis and more specifically the finite pulse time effect, the nonuniform heating of the specimen and the heat losses (radiative and conductive). These sources of uncertainty can be considered systematic, and should be carefully considered for each experiment. Errors random in nature (noise, for example) can be best estimated by performing a large number of repeat experiments. The relative standard deviation of the obtained results is a good representation of the random component of the