



Standard Test Method for Measuring Heat-Transfer Rate Using a Thermal Capacitance (Slug) Calorimeter¹

This standard is issued under the fixed designation E457; 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 describes the measurement of heat transfer rate using a thermal capacitance-type calorimeter which assumes one-dimensional heat conduction into a cylindrical piece of material (slug) with known physical properties.

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

NOTE 1—For information see Test Methods E285, E422, E458, E459, and E511.

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

2. Referenced Documents

2.1 ASTM Standards:²

E285 Test Method for Oxyacetylene Ablation Testing of Thermal Insulation Materials

E422 Test Method for Measuring Heat Flux Using a Water-Cooled Calorimeter

E458 Test Method for Heat of Ablation

E459 Test Method for Measuring Heat Transfer Rate Using a Thin-Skin Calorimeter

E511 Test Method for Measuring Heat Flux Using a Copper-Constantan Circular Foil, Heat-Flux Transducer

3. Summary of Test Method

3.1 The measurement of heat transfer rate to a slug or thermal capacitance type calorimeter may be determined from the following data:

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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.

3.1.1 Density and specific heat of the slug material,

3.1.2 Length or axial distance from the front face of the cylindrical slug to the back-face thermocouple,

3.1.3 Slope of the temperature—time curve generated by the back-face thermocouple, and

3.1.4 Calorimeter temperature history.

3.2 The heat transfer rate is thus determined numerically by multiplying the density, specific heat, and length of the slug by the slope of the temperature—time curve obtained by the data acquisition system (see Eq 1).

3.3 The technique for measuring heat transfer rate by the thermal capacitance method is illustrated schematically in Fig. 1. The apparatus shown is a typical slug calorimeter which, for example, can be used to determine both stagnation region heat transfer rate and side-wall or afterbody heat transfer rate values. The annular insulator serves the purpose of minimizing heat transfer to or from the body of the calorimeter, thus approximating one-dimensional heat flow. The body of the calorimeter is configured to establish flow and should have the same size and shape as that used for ablation models or test specimens.

3.3.1 For the control volume specified in this test method, a thermal energy balance during the period of initial linear temperature response where heat losses are assumed negligible can be stated as follows:

$$\begin{aligned} \text{Energy Received by the Calorimeter (front face)} \\ &= \text{Energy Conducted Axially Into the Slug} \\ q_c &= \rho C_p l (\Delta T / \Delta \tau) = (MC_p / A) (\Delta T / \Delta \tau) \end{aligned} \quad (1)$$

where:

q_c = calorimeter heat transfer rate, W/m²,

ρ = density of slug material, kg/m³,

C_p = average specific heat of slug material during the temperature rise (ΔT), J/kg·K,

l = length or axial distance from front face of slug to the thermocouple location (back-face), m,

$\Delta T = (T_f - T_i)$ = calorimeter slug temperature rise during exposure to heat source (linear part of curve), K,

$\Delta \tau = (\tau_f - \tau_i)$ = time period corresponding to ΔT temperature rise, s,

M = mass of the cylindrical slug, kg,

A = cross-sectional area of slug, m².