



## Standard Test Method for Measuring Extreme Heat-Transfer Rates from High-Energy Environments Using a Transient, Null-Point Calorimeter<sup>1</sup>

This standard is issued under the fixed designation E 598; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This test method covers the measurement of the heat-transfer rate or the heat flux to the surface of a solid body (test sample) using the measured transient temperature rise of a thermocouple located at the null point of a calorimeter that is installed in the body and is configured to simulate a semi-infinite solid. By definition the null point is a unique position on the axial centerline of a disturbed body which experiences the same transient temperature history as that on the surface of a solid body in the absence of the physical disturbance (hole) for the same heat-flux input.

1.2 Null-point calorimeters have been used to measure high convective or radiant heat-transfer rates to bodies immersed in both flowing and static environments of air, nitrogen, carbon dioxide, helium, hydrogen, and mixtures of these and other gases. Flow velocities have ranged from zero (static) through subsonic to hypersonic, total flow enthalpies from 1.16 to greater than  $4.65 \times 10^1$  MJ/kg ( $5 \times 10^2$  to greater than  $2 \times 10^4$  Btu/lb.), and body pressures from  $10^5$  to greater than  $1.5 \times 10^7$  Pa (atmospheric to greater than  $1.5 \times 10^2$  atm). Measured heat-transfer rates have ranged from 5.68 to  $2.84 \times 10^2$  MW/m<sup>2</sup> ( $5 \times 10^2$  to  $2.5 \times 10^4$  Btu/ft<sup>2</sup>-sec).

1.3 The most common use of null-point calorimeters is to measure heat-transfer rates at the stagnation point of a solid body that is immersed in a high pressure, high enthalpy flowing gas stream, with the body axis usually oriented parallel to the flow axis (zero angle-of-attack). Use of null-point calorimeters at off-stagnation point locations and for angle-of-attack testing may pose special problems of calorimeter design and data interpretation.

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:

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee E21 on Space Simulation and Applications of Space Technology and is the direct responsibility of Subcommittee E21.08 on Thermal Protection.

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E 422 Test Method for Measuring Heat Flux Using a Water-Cooled Calorimeter<sup>2</sup>

E 511 Test Method for Measuring Heat Flux Using a Copper-Constantan Circular Foil, Heat-Flux Gage<sup>2</sup>

### 3. Terminology

#### 3.1 Symbols:

- $a$  = Radius of null-point cavity, m (in.)
- $b$  = Distance from front surface of null-point calorimeter to the null-point cavity, m (in.)
- $C_p$  = Specific heat capacity, J/kg-K (Btu/lb-°F)
- $d$  = Diameter of null-point cavity, m (in.)
- $k$  = Thermal conductivity, W/m-K (Btu/in.-sec-°F)
- $L$  = Length of null-point calorimeter, m (in.)
- $q$  = Calculated or measured heat flux or heat-transfer-rate, W/m<sup>2</sup> (Btu/ft<sup>2</sup>-sec)
- $q_0$  = Constant heat flux or heat-transfer-rate, W/m<sup>2</sup> (Btu/ft<sup>2</sup>-sec)
- $R$  = Radial distance from axial centerline of TRAX analytical model, m (in.)
- $r$  = Radial distance from axial centerline of null-point cavity, m (in.)
- $T$  = Temperature, K (°F)
- $T_b$  = Temperature on axial centerline of null point, K (°F)
- $T_s$  = Temperature on surface of null-point calorimeter, K (°F)
- $t$  = Time, sec
- $Z$  = Distance in axial direction of TRAX analytical model, m (in.)
- $\alpha$  = Thermal diffusivity, m<sup>2</sup>/sec (in.<sup>2</sup>/sec)
- $\rho$  = Density, kg/m<sup>3</sup> (lb/in.<sup>3</sup>)

### 4. History of Test Method

4.1 From literature reviews it appears that Masters and Stein **(1)**<sup>3</sup> were the first to document the results of an analytical study of the temperature effects of axial cavities drilled from the backside of a wall which is heated on the front surface (see Fig. 1). These investigators were primarily concerned with the deviation of the temperature measured in the bottom of the

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 15.03.

<sup>3</sup> The boldface numbers in parentheses refer to the list of references at the end of this test method.