



Standard Test Method for Calculation of Stagnation Enthalpy from Heat Transfer Theory and Experimental Measurements of Stagnation-Point Heat Transfer and Pressure¹

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INTRODUCTION

The enthalpy (energy per unit mass) determination in a hot gas aerodynamic simulation device is a difficult measurement. Even at temperatures that can be measured with thermocouples, there are many corrections to be made at 600 K and above. Methods that are used for temperatures above the range of thermocouples that give bulk or average enthalpy values are energy balance (see Practice E 341), sonic flow (**1**, **2**),² and the pressure rise method (**3**). Local enthalpy values (thus distribution) may be obtained by using either an energy balance probe (see Method E 470), or the spectrometric technique described in Ref (**4**).

1. Scope

1.1 This test method covers the calculation from heat transfer theory of the stagnation enthalpy from experimental measurements of the stagnation-point heat transfer and stagnation pressure.

1.2 Advantages:

1.2.1 A value of stagnation enthalpy can be obtained at the location in the stream where the model is tested. This value gives a consistent set of data, along with heat transfer and stagnation pressure, for ablation computations.

1.2.2 This computation of stagnation enthalpy does not require the measurement of any arc heater parameters.

1.3 *Limitations and Considerations*—There are many factors that may contribute to an error using this type of approach to calculate stagnation enthalpy, including:

1.3.1 *Turbulence*—The turbulence generated by adding energy to the stream may cause deviation from the laminar equilibrium heat transfer theory.

1.3.2 *Equilibrium, Nonequilibrium, or Frozen State of Gas*—The reaction rates and expansions may be such that the gas is far from thermodynamic equilibrium.

1.3.3 *Noncatalytic Effects*—The surface recombination rates and the characteristics of the metallic calorimeter may give a heat transfer deviation from the equilibrium theory.

1.3.4 *Free Electric Currents*—The arc-heated gas stream may have free electric currents that will contribute to measured experimental heat transfer rates.

1.3.5 *Nonuniform Pressure Profile*—A nonuniform pressure profile in the region of the stream at the point of the heat transfer measurement could distort the stagnation point velocity gradient.

1.3.6 *Mach Number Effects*—The nondimensional stagnation-point velocity gradient is a function of the Mach number. In addition, the Mach number is a function of enthalpy and pressure such that an iterative process is necessary.

1.3.7 *Model Shape*—The nondimensional stagnation-point velocity gradient is a function of model shape.

1.3.8 *Radiation Effects*—The hot gas stream may contribute a radiative component to the heat transfer rate.

1.3.9 *Heat Transfer Rate Measurement*—An error may be made in the heat transfer measurement (see Methods E 469 and Test Methods E 422, E 457, E 459, and E 511).

1.3.10 *Contamination*—The electrode material may be of a large enough percentage of the mass flow rate to contribute to the heat transfer rate measurement.

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.*

¹ 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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² The boldface numbers in parentheses refer to the list of references appended to this method.