



Standard Test Method for Measuring Heat Flux Using a Copper-Constantan Circular Foil, Heat-Flux Transducer¹

This standard is issued under the fixed designation E511; 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 radiative heat flux using a transducer whose sensing element (**1, 2**)² is a thin circular metal foil. These sensors are often called Gardon Gauges.

1.2 The values stated in SI units are to be regarded as the standard. The values stated in parentheses are provided for information only.

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. Summary of Test Method

2.1 The purpose of this test method is to facilitate measurement of a radiant heat flux. Although the sensor will measure heat fluxes from mixed radiative – convective or pure convective sources, the uncertainty will increase as the convective fraction of the total heat flux increases.

2.2 The circular foil heat flux transducer generates a millivolt output in response to the rate of thermal energy absorbed (see Fig. 1). The perimeter of the circular metal foil sensing element is mounted in a metal heat sink, forming a reference thermocouple junction due to their different thermoelectric potentials. A differential thermocouple is created by a second thermocouple junction formed at the center of the foil using a fine wire of the same metal as the heat sink. When the sensing element is exposed to a heat source, most of the heat energy absorbed at the surface of the circular foil is conducted radially to the heat sink. If the heat flux is uniform and heat transfer down the center wire is neglected, a parabolic temperature profile is established between the center and edge of the foil

under steady-state conditions. The center – perimeter temperature difference produces a thermoelectric potential, E , that will vary in proportion to the absorbed heat flux, q' . With prescribed foil diameter, thickness, and materials, the potential E is almost linearly proportional to the average heat flux q' absorbed by the foil. This relationship is described by the following equation:

$$E = Kq' \quad (1)$$

where:

K = a sensitivity constant determined experimentally.

2.3 For nearly linear response, the heat sink and the center wire of the transducer are made of high purity copper and the foil of thermocouple grade Constantan. This combination of materials produces a nearly linear output over a gauge temperature range from -45 to 232°C (-50 to 450°F). The linear range results from the basically offsetting effects of temperature-dependent changes in the thermal conductivity and the Seebeck coefficient of the Constantan (**3**). All further discussion is based on the use of these two metals, since engineering practice has demonstrated they are commonly the most useful.

3. Description of the Instrument

3.1 Fig. 1 is a sectional view of an example circular foil heat-flux transducer. It consists of a circular Constantan foil attached by a metallic bonding process to a heat sink of oxygen-free high conductivity copper (OFHC), with copper leads attached at the center of the circular foil and at any point on the heat-sink body. The transducer impedance is usually less than 1 Ω . To minimize current flow, the data acquisition system (DAS) should be a potentiometric system or have an input impedance of at least 100 000 Ω .

3.2 As noted in 2.3, an approximately linear output (versus heat flux) is produced when the body and center wire of the transducer are constructed of copper and the circular foil is constantan. Other metal combinations may be employed for use at higher temperatures, but most (**4**) are nonlinear.

3.3 Because the thermocouple junction at the edge of the foil is the reference for the center thermocouple, no cold junction compensation is required with this instrument. The wire leads used to convey the signal from the transducer to the readout device are normally made of stranded, tinned copper,

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 at the end of this standard.