



Designation: E 511 – 73 (Reapproved 1994)^{ε1}

Standard Test Method for Measuring Heat Flux Using a Copper-Constantan Circular Foil, Heat-Flux Gage¹

This standard is issued under the fixed designation E 511; 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.

^{ε1} NOTE—Section 10 was added editorially in December 1994.

1. Scope

1.1 This test method describes the measurement of heat flux absorbed by a thin circular foil of copper-constantan construction by either convection or radiation or a combination of both.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are 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 circular foil heat-flux gage provides a self-generated millivolt output in response to the thermal energy absorbed. The sensing foil (see Fig. 1) is connected at its perimeter to a heat sink having a thermoelectric potential different from that of the foil material, thus forming a thermocouple junction. Another thermocouple junction is made at the center of the foil using a fine wire. When the sensor is exposed to a heat source, the heat flux absorbed by the circular foil is transferred radially to the heat sink, and an equilibrium temperature difference is rapidly established between the center and edge of the foil. The equilibrium thermoelectric potential, E , between the center and edge of the foil will then vary in proportion to the heat flux, q , absorbed by the foil. The body is normally made of copper and the foil of thermocouple-type constantan. If these metals are used in the gage, the thermoelectric potential will be directly proportional to heat flux absorbed such that

$$q = KE \quad (1)$$

where K is a constant determined experimentally during calibration. All further discussion will assume the use of these two metals in the gage since this construction is by far the most common.

3. Significance and Use

3.1 The purpose of this test method is to measure the heat flux at a location from a radiant or convective source, or both. In the case of radiant energy, the absorptivity of the surface of the instrument should be known. In the case of convection energy, particularly at high velocities, the shape and size of the probe body in which the foil sensor is mounted should be the same as the test specimen.

3.2 The gage has certain limitations as follows:

3.2.1 The gage cannot measure conduction.

3.2.2 The body temperature must be in the range from 50 to 450°F (–45 to 235°C) in order for the calibration to be valid. At lower or higher temperatures, the gage is no longer linear due to changes in thermoelectric output not compensated for by changes in physical properties of the constantan foil.

3.2.3 Foil diameters and thickness are limited. Maximum optimum foil diameter to thickness ratio is 4 to 1 for sensors less than 2.54-mm (0.100-in.) diameter. Foil diameters range from 25.4 to 0.254 mm (1.0 to 0.010 in.) with most gages between 6.35 and 1.02 mm (0.250 and 0.040 in.).

3.2.4 Large-diameter foils in vacuum environment have significantly different sensitivities than in air and should not be so used unless calibrated in vacuum.

3.2.5 Response time is a function of the radius or diameter of the foil squared. Range is from 0.001 s (0.25 mm (0.010 in.) in diameter) to 6 s (25.4 mm (1 in.) in diameter). Response time is defined as the time to sense 63 % of a step function.

3.2.6 The response time, τ , is approximated by the formula $\tau = 6D^2$, where D is in inches (**1**)² or $\tau = 0.0094 D^2$ where D is in millimetres. The sensitivity of the gage may be expressed by the equation $E/q = 0.03 D^2/S$ where D is the diameter of the foil in inches, S is the thickness of the foil in inches, E is the emf in millivolts and q is the heat flux in Btu/ft²·s. In SI, the equation is $E/q = 0.0046 D^2/S$, where D and S are in millimetres, and q is in cal/cm²·s or $E/q = 19.3 D^2/S$ where D and S are in metres and q is in W/m².

3.2.7 The field of uniform flux must exceed the area of the sensor.

¹ This test method is under the jurisdiction of ASTM Committee E-21 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 test method.