



Standard Test Method for Measuring Heat Flux Using a Water-Cooled Calorimeter¹

This standard is issued under the fixed designation E422; 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 covers the measurement of a steady heat flux to a given water-cooled surface by means of a system energy balance.

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

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

E235 Specification for Thermocouples, Sheathed, Type K and Type N, for Nuclear or for Other High-Reliability Applications

3. Summary of Test Method

3.1 A measure of the heat flux to a given water-cooled surface is based upon the following measurements: (1) the water mass flow rate and (2) the temperature rise of coolant water. The heat flux is determined numerically by multiplying the water coolant flow rate by the specific heat and rise in temperature of the water and dividing this value by the surface area across which heat has been transferred.

3.2 The apparatus for measuring heat flux by the energy-balance technique is illustrated schematically in Fig. 1. It is a typical constant-flow water calorimeter used to measure stagnation region heat flux to a flat-faced specimen. Other calorimeter shapes can also be easily used. The heat flux is measured using the central circular sensing area, shown in Fig.

1. The water-cooled annular guard ring serves the purpose of preventing heat transfer to the sides of the calorimeter and establishes flat-plate flow. An energy balance on the system (the centrally located calorimeter in Fig. 1) requires that the energy crossing the sensing surface (A , in Fig. 1) of the calorimeter be equated to the energy absorbed by the calorimeter cooling water. Interpretation of the data obtained is not within the scope of this discussion; consequently, such effects as recombination efficiency of the surface and thermochemical state of the boundary layer are outside the scope of this test method. It should be noted that recombination effects at low pressures can cause serious discrepancies in heat flux measurements (such as discussed in Ref (1))³ depending upon the surface material on the calorimeter.

3.3 For the particular control volume cited, the energy balance can be written as follows:

$$E_{\text{CAL}} = [mC_p(\Delta T_0 - \Delta T_1)]/A \quad (1)$$

where:

E_{CAL} = energy flux transferred to calorimeter face, $\text{W}\cdot\text{m}^{-2}$
 m = mass flow rate of coolant water, $\text{kg}\cdot\text{s}^{-1}$
 C_p = water specific heat, $\text{J}\cdot\text{kg}^{-1}\cdot\text{K}^{-1}$,
 ΔT_0 = $T_{0_2} - T_{0_1}$ calorimeter water bulk temperature rise during operation, K,
 ΔT_1 = $T_2 - T_1$ = calorimeter water apparent bulk temperature rise before operation, K,
 T_{0_2} = water exhaust bulk temperature during operation, K,
 T_{0_1} = water inlet bulk temperature during operation, K,
 T_2 = water exhaust bulk temperature before operation, K,
 T_1 = water inlet bulk temperature before operation, K, and
 A = sensing surface area of calorimeter, m^2 .

3.4 An examination of Eq 1 shows that to obtain a value of the energy transferred to the calorimeter, measurements must be made of the water coolant flow rate, the temperature rise of the coolant, and the surface area across which heat is transferred. With regard to the latter quantity it is assumed that the surface area to which heat is transferred is well defined. As is indicated in Fig. 1, the design of the calorimeter is such that the heat transfer area is confined by design to the front or directly heated surface. To minimize side heating or side heat losses, a

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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 The boldface numbers in parentheses refer to the list of references at the end of this test method.