



Designation: E 638 – 78 (Reapproved 1992)

Standard Test Method for Calibration of Heat Transfer Rate Calorimeters Using a Narrow-Angle Blackbody Radiation Facility¹

This standard is issued under the fixed designation E 638; 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 employing the narrow beam of thermal energy emitted through the aperture of a blackbody to calibrate calorimetric devices. Although the calorimeter normally responds to incident heat which is predominantly convective, this method of calibration employs radiant energy. Use of radiant energy dictates that the absolute value of radiant flux at the surface of the calorimeter be determined to provide an accurate calibration. This method, applicable in place of the wide-angle source technique, is suited to relatively low values of irradiance (typically less than 10^6 W/m^2).

1.2 *This standard does not purport to address all of the safety problems, 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. Terminology

2.1 Heat transfer rate calorimeters are distinguished by their ability to respond to convective as well as radiative heat transfer. Since the calibration employs only radiant energy, the absolute value of the incident flux for calibration must be known. This is emphasized because instruments used to measure thermal radiation may be calibrated in a similar arrangement to evaluate the radiant flux of a source.

2.2 *radiant flux*—the thermal energy being emitted per unit time.

2.3 *heat transfer rate, as employed in this method*—the thermal energy per unit time associated with a unit area.

2.4 *blackbody*—an ideal thermal radiator. It is characterized as a radiator that emits, for an equilibrium temperature, the maximum energy density possible at every spectral wavelength. The ideal blackbody may be approximated to a high degree of accuracy by a cavity with opaque walls at a uniform temperature. A necessary condition for a blackbody is that the walls of the cavity be at a uniform temperature. The apparatus designed to perform this function is also often called a blackbody.

2.5 *emissivity*—the degree to which a specimen or surface

departs from the ideal radiative surface is measured by its emissivity, a dimensionless ratio, which compares the emission rate of a real surface or cavity with that of an ideal radiator. The ratio is always less than unity. The apparatus constructed as a blackbody produces near Planckian radiation by an artifice. Multiple internal reflection within the cavity and concurrent absorption results in nearly all radiation being contained within the cavity. The losses through the aperture plate required to utilize the radiation created prevents it from being totally Planckian. Surface thermal gradients in the cavity walls also contribute to departures of the emitted flux from a true Planckian distribution.

2.6 The symbols used in this test method are defined as follows:

- d = diameter of sensor
- $\bar{D}$ = effective diameter of blackbody cavity
- D = defined expression (Eq 2)
- e = aperture diameter
- E = rate of heat transfer
- $\bar{E}$ = defined expression (Eq 2)
- F = configuration factor (Eq 2)
- L = distance separating sensor face and effective cavity
- T = temperature
- x = distance separating aperture and effective cavity
- X = defined expression (Eq 2)
- α = absorptivity
- Δ = fractional uncertainty (for example, Δu = fractional uncertainty in u)
- ϵ = emissivity
- σ = Boltzmann constant
- ϕ = fractional uncertainty, calorimeter readout

3. Summary of Test Method

3.1 To implement the calibration technique, a blackbody radiation source is required. Equipment providing the highest possible source temperature is recommended. The blackbody is aligned coaxially with the calorimeter sensor and an aperture stop is installed between the two. The geometry must be determined to ensure that a radiative source of precisely defined size is directed upon the sensor element. The geometric relations of the system are used to help determine a view factor. The thermal absorptance of the calorimeter is considered, together with the calculated view factor (which is the dominant

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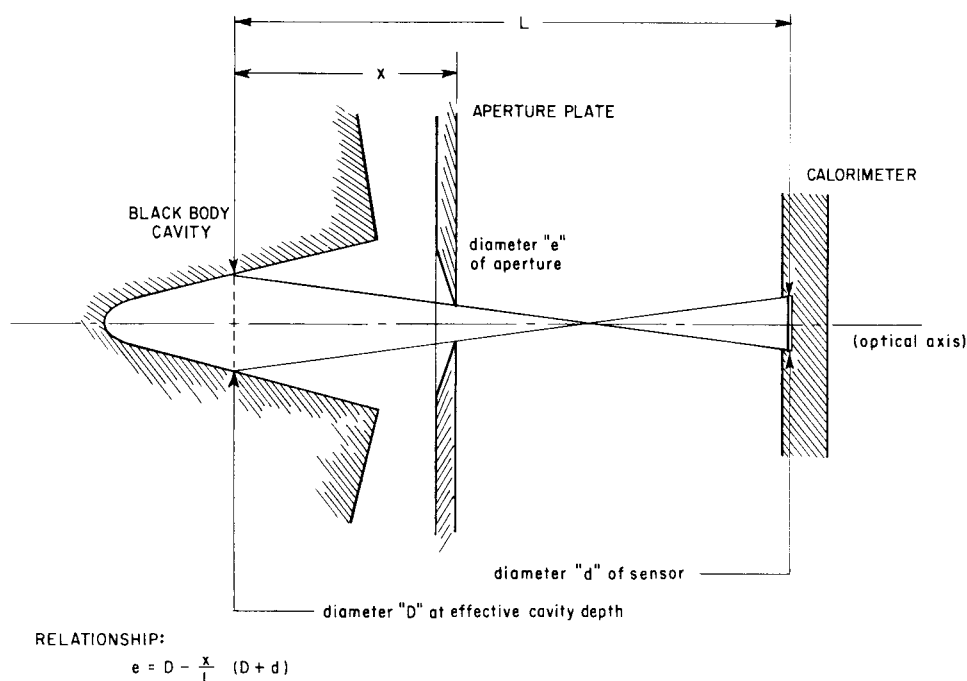


FIG. 1 Arrangement of Equipment for Calibration of Calorimeter

variable) to evaluate the radiant flux absorbed at the face of the calorimeter.

4. Significance and Use

4.1 The calibration technique may be employed on any sensor responsive to applied thermal energy. In this method, it is intended that the calibration be in terms of an absolute energy deposition rate. During use, energy is normally transmitted to the calorimeter by convection, although the calibration employs radiant energy for calibration. For this reason, the radiant heat transfer used for calibration must be the absorbed portion of the radiant flux incident upon the surface of the calorimeter.

4.2 This test method may be used as an alternative to that employing a wide-angle source (1).² Its principal advantage lies in the fact that blackbody cavities, such as those this method uses, are commercially available. Furthermore, calibration of a cavity may be directly traceable to the National Bureau of Standards through brightness temperature measurements. A blackbody cavity provides nearly perfect blackbody radiation for low-level heat transfer rate calibration. The experimental geometries must be carefully arranged and measured in order to assess correctly the view factor. In addition, the absorptance of the calorimeter surface must be determined in order to obtain the net energy transfer. The system uses the net absorbed thermal radiation for calibration.

4.3 The primary assumption upon which the method is based is that the calibration is made possible by the use of spectrally Planckian radiation. However, observation has shown that gradients exist in some blackbody configurations. Therefore, care must be exercised in employing a blackbody

for the calibration in order to minimize the deviation of the radiation incident upon the calorimeter from a Planckian distribution. For example, although a conical cavity may emit essentially uniform radiation in the region of the apex of the cone, the temperatures sustained and the corresponding thermal flux emitted diminish near the exit end. Prior evaluation of the cavity (or of others with differing geometries) must establish the depth to which the radiation emitted from the interior surface is considered to be uniform. The sensor must be subjected to radiant energy emanating from the region of uniform flux emission. It is for this reason that an aperture plate is introduced. Its geometry restricts the field of view accessible to the sensor to that from which uniform thermal energy is emitted. The dimension "D" in Fig. 1 is intended to depict the outer limit of the uniformly heated portion of the cavity. The equation noted on Fig. 1 relates the designated cavity diameter, the sensor diameter, and other dimensions established for the calibration equipment arrangement.

5. Apparatus

5.1 To perform the calibration, three basic elements are required: a calibrated blackbody, the calorimeter requiring calibration, and an aperture stop with which to define the area of the radiation source. The aperture stop must be cool enough to contribute negligible radiant energy relative to that which passes through the aperture. Typically, a temperature difference of 350 K will limit the contribution of an aperture stop at ambient conditions to less than 4½ % of the contributed energy.

5.2 The blackbody apparatus is basically a furnace. Its elements usually consist of a refractory liner surrounding a cavity, a resistance heater, a thick layer of insulation and often, some form of cooling water to control the outside temperature of the equipment. Typical constructions are shown in Refs. (2)

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