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An American National Standard

Standard Test Method for Calibration of Refractory Metal Thermocouples Using a Radiation Thermometer[1]

This standard is issued under the fixed designation E452; 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 calibration of refractory metal thermocouples using a radiation thermometer as the standard instrument. This test method is intended for use with types of thermocouples that cannot be exposed to an oxidizing atmosphere. These procedures are appropriate for thermocouple calibrations at temperatures above 800 °C (1472 °F).

1.2 The calibration method is applicable to the following thermocouple assemblies:

1.2.1 *Type 1*—Bare-wire thermocouple assemblies in which vacuum or an inert or reducing gas is the only electrical insulating medium between the thermoelements.

1.2.2 *Type 2*—Assemblies in which loose fitting ceramic insulating pieces, such as single-bore or double-bore tubes, are placed over the thermoelements.

1.2.3 *Type 2A*—Assemblies in which loose fitting ceramic insulating pieces, such as single-bore or double-bore tubes, are placed over the thermoelements, permanently enclosed and sealed in a loose fitting metal or ceramic tube.

1.2.4 *Type 3*—Swaged assemblies in which a refractory insulating powder is compressed around the thermoelements and encased in a thin-walled tube or sheath made of a high melting point metal or alloy.

1.2.5 *Type 4*—Thermocouple assemblies in which one thermoelement is in the shape of a closed-end protection tube and the other thermoelement is a solid wire or rod that is coaxially supported inside the closed-end tube. The space between the two thermoelements can be filled with an inert or reducing gas, or with ceramic insulating materials, or kept under vacuum.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E344 Terminology Relating to Thermometry and Hydrometry

E563 Practice for Preparation and Use of an Ice-Point Bath as a Reference Temperature

E988 Temperature-Electromotive Force (EMF) Tables for Tungsten-Rhenium Thermocouples (Withdrawn 2011)[3]

E1256 Test Methods for Radiation Thermometers (Single Waveband Type)

E1751 Guide for Temperature Electromotive Force (emf) Tables for Non-Letter Designated Thermocouple Combinations

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method see Terminology E344.

3.1.2 *radiation thermometer, n*—radiometer calibrated to indicate the temperature of a blackbody.

3.1.2.1 *Discussion*—Radiation thermometers include instruments having the following or similar names: (*1*) optical radiation thermometer, (*2*) photoelectric pyrometer, (*3*) single wavelength automatic thermometer, (*4*) disappearing filament pyrometer, (*5*) dual wavelength pyrometer or ratio radiation thermometer, (*6*) visual optical thermometer, (*7*) infrared thermometer, (*8*) infrared pyrometer, and permutations on the terms above as well as some manufacturer-specific names.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *automatic radiation thermometer, n*—radiation thermometer whose temperature reading is determined by electronic means.

[1] This test method is under the jurisdiction of ASTM Committee E20 on Temperature Measurementand is the direct responsibility of Subcommittee E20.11 on Thermocouples - Calibration.

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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 last approved version of this historical standard is referenced on www.astm.org.

3.2.2 *disappearing filament pyrometer, n*—radiation thermometer that requires an observer to match visually the brightness of a heated filament mounted inside the radiation thermometer to that of the measured object.

3.2.3 *equalizing block, n*—object, usually metal, that when placed in a nonuniform temperature region, has greater temperature uniformity (due to its relatively high thermoconductivity and mass) than the medium surrounding the object.

3.2.4 *spectral emissivity, n*—ratio of the spectral radiance at a point on a particular specimen and in a particular direction from that point to that emitted by a blackbody at the same temperature.

3.2.5 *spectral radiance, n*—power radiated by a specimen in a particular direction, per unit wavelength, per unit projected area of the specimen, and per unit solid angle.

3.2.6 *spectral response, n*—signal detected by a radiometer at a particular wavelength of incident radiation, per unit power of incident radiation.

3.2.7 *test thermocouple, n*—thermocouple that is to have its temperature-emf relationship determined by reference to a temperature standard.

3.2.8 *thermocouple calibration point, n*—temperature, established by a standard, at which the emf developed by a thermocouple is determined.

4. Summary of Test Method

4.1 The thermocouple is calibrated by determining the temperature of its measuring junction with a radiation thermometer and recording the emf of the thermocouple at that temperature. The measuring junction of the thermocouple is placed in an equalizing block containing a cavity which approximates blackbody conditions. The radiation thermometer is sighted on the cavity in the equalizing block and the blackbody temperature or true temperature of the block, including the measuring junction, is determined.

4.2 Since the spectral emissivity of the radiation emanating from a properly designed blackbody is considered unity (one) for all practical purposes, no spectral emissivity corrections need be applied to optical pyrometer determinations of the blackbody temperature.

4.3 Although the use of a radiation thermometer (Note 1) is less may require more effort and more complex apparatus to achieve a sensitivity equivalent to that of commonly used thermocouples, a radiation thermometer has the advantage of being physically separated from the test assembly; thus, its calibration is not influenced by the temperatures and atmospheres in the test chamber. By comparison, a standard thermocouple that is used to calibrate another thermocouple must be subjected to the temperatures at which the calibrations are performed and in some cases must be exposed to the environment that is common to the test thermocouple. If a standard thermocouple is exposed to high temperatures or contaminating environments, or both, for long periods of time, its calibration becomes questionable and the uncertainty in the bias of the calibration increases.

NOTE 1—Disappearing filament pyrometers are somewhat less sensitive than many of the thermocouples used above 800 °C (1472 °F). The advantages of physical separation of the disappearing filament pyrometer from the test assembly may still justify its use over use of a standard thermocouple.

5. Significance and Use

5.1 This test method is intended to be used by wire producers and thermocouple manufacturers for certification of refractory metal thermocouples. It is intended to provide a consistent method for calibration of refractory metal thermocouples referenced to a calibrated radiation thermometer. Uncertainty in calibration and operation of the radiation thermometer, and proper construction and use of the test furnace are of primary importance.

5.2 Calibration establishes the temperature-emf relationship for a particular thermocouple under a specific temperature and chemical environment. However, during high temperature calibration or application at elevated temperatures in vacuum, oxidizing, reducing or contaminating environments, and depending on temperature distribution, local irreversible changes may occur in the Seebeck Coefficient of one or both thermoelements. If the introduced inhomogeneities are significant, the emf from the thermocouple will depend on the distribution of temperature between the measuring and reference junctions.

5.3 At high temperatures, the accuracy of refractory metal thermocouples may be limited by electrical shunting errors through the ceramic insulators of the thermocouple assembly. This effect may be reduced by careful choice of the insulator material, but above approximately 2100 °C, the electrical shunting errors may be significant even for the best insulators available.

6. Sources of Error

6.1 The most prevalent sources of error (Note 2) in this method of calibration are: (*1*) improper design of the blackbody enclosure, (*2*) severe temperature gradients in the vicinity of the blackbody enclosure, (*3*) heat conduction losses along the thermoelements, and (*4*) improper alignment of the radiation thermometer with respect to the blackbody cavity and unaccounted transmission losses along the optical path of the radiation thermometer.

NOTE 2—These are exclusive of any errors that are made in the radiation thermometer measurements or the thermocouple-emf measurements.

7. Apparatus

7.1 *Furnace:*

7.1.1 The calibration furnace should be designed so that any temperature within the desired calibration temperature range can be maintained constant within a maximum change of 1 °C (1.8 °F) per minute in the equalizing block over the period of any observation. Figs. 1-3 show three types of furnaces (**1 and 2**)[4] that can be used for calibrating refractory-metal thermocouples. Fig. 4 is a detailed drawing of the upper section of the furnace in Fig. 3. An equalizing block containing a blackbody

[4] The boldface numbers in parentheses refer to the list of references at the end of this standard.