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Standard Guide for Use of Fixed-Point Cells for Reference Temperatures¹

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INTRODUCTION

During melting and freezing, pure material transforms from the solid state to the liquid state or from the liquid state to the solid state at a constant temperature. That constant temperature is referred to as a fixed point. Fixed points approached in the melting direction are referred to as melting points and fixed points approached in the freezing direction are referred to as freezing points. Fixed points of highly purified materials can serve as reference temperatures, and in fact, the International Temperature Scale of 1990 (ITS-90)² relies on the melting and freezing points of some highly purified metals as defining fixed points. Fixed points can be realized in commercially available systems incorporating fixed-point cells. When the cells are properly made and used, they establish useful reference temperatures for the calibration of thermometers and for other industrial and laboratory purposes; with care, these fixed points can be realized with an uncertainty of a few millikelvins³ or less.

1. Scope

1.1 This guide describes the essential features of fixed-point cells and auxiliary apparatus, and the techniques required to realize fixed points in the temperature range from 29 °C to 1085 °C.³

1.2 Design and construction requirements of fixed-point cells are not addressed in this guide. Typical examples are given in Figs. 1 and 2.

1.3 This guide is intended to describe good practice and establish uniform procedures for the realization of fixed points.

1.4 This guide emphasizes principles. The emphasis on principles is intended to aid the user in evaluating cells, in improving technique for using cells, and in establishing procedures for specific applications.

1.5 For the purposes of this guide, the use of fixed-point cells for the accurate calibration of thermometers is restricted

to immersion-type thermometers that, when inserted into the reentrant well of the cell, (1) indicate the temperature only of the isothermal region of the well, and (2) do not significantly alter the temperature of the isothermal region of the well by heat transfer.

1.6 This guide does not address all of the details of thermometer calibration.

1.7 This guide is intended to complement special operating instructions supplied by manufacturers of fixed-point apparatus.

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

1.9 The following hazard caveat pertains only to the test method portion, Section 7, of this guide. *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.*

1.10 *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.*

¹ This guide is under the jurisdiction of ASTM Committee E20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.07 on Fundamentals in Thermometry.

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² Preston-Thomas, H., “The International Temperature Scale of 1990 (ITS-90),” *Metrologia*, Vol 27, No. 1, 1990, pp. 3–10. For errata see *ibid*, Vol 27, No. 2, 1990, p. 107.

³ In this guide, temperature intervals are expressed in kelvins (K) and millikelvins (mK). Values of temperature are expressed in degrees Celsius (°C), ITS-90.

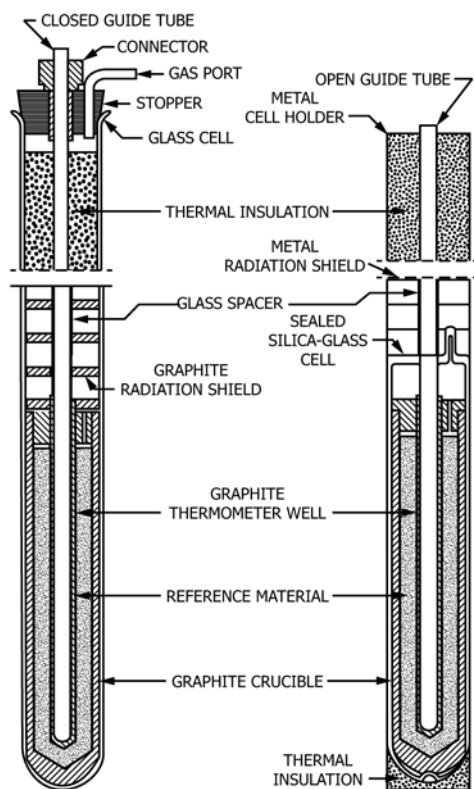


FIG. 1 Examples of Fixed-Point Cells

2. Referenced Documents

2.1 ASTM Standards:⁴

- E344 Terminology Relating to Thermometry and Hydrometry
- E644 Test Methods for Testing Industrial Resistance Thermometers

3. Terminology

3.1 Definitions:

3.1.1 *reference temperature, n*—a fixed, reproducible temperature, to which a value is assigned, that can be used for the calibration of thermometers or other purposes.

3.1.2 Additional terms used in this guide are defined in Terminology E344.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *first cryoscopic constant, A, n*—a constant of proportionality between the freezing point depression of, and concentration of impurities in, a sample of reference material, given by the ratio of the molar heat of fusion of the pure material, L , to the product of the molar gas constant, R , and the square of the thermodynamic temperature of fusion, T , of the pure material (freezing point):

$$A = \frac{L}{RT^2} \quad (1)$$

⁴ 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.

3.2.2 *fixed-point cell, n*—a device that contains and protects a sample of reference material in such a manner that the phase transition of the material can establish a reference temperature.

3.2.3 *freeze, n*—an experiment or test run conducted with a fixed-point cell while the reference material in the cell solidifies.

3.2.4 *freezing curve, n*—the entire time-temperature relation of the reference material in a fixed-point cell during freezing, including initial cooling, undercool, recalescence, freezing plateau, and final cooling to complete solidification.

3.2.4.1 *Discussion*—Graphic representations of freezing curves are shown in Figs. 3 and 4.

3.2.5 *freezing plateau, n*—the time period during freezing when the temperature does not change significantly.

3.2.6 *freezing range, n*—the range of temperature over which most of the reference material in a fixed-point cell solidifies.

3.2.6.1 *Discussion*—The freezing range is indicated graphically in Fig. 3.

3.2.7 *melt, n*—an experiment or test run conducted with a fixed-point cell while the reference material in the cell liquifies.

3.2.8 *melting curve, n*—the entire time-temperature relation of the reference material in a fixed-point cell during melting, including initial heating, melting plateau, and final heating to complete liquification.

3.2.8.1 *Discussion*—Graphic representations of melting curves are shown in Figs. 5 and 6.

3.2.9 *melting plateau, n*—the period during melting in which the temperature does not change significantly.

3.2.10 *melting range, n*—the range of temperature over which most of the reference material in a fixed-point cell melts.

3.2.11 *nucleation, n*—the formation of crystal nuclei in liquid in the supercooled state.

3.2.12 *recalescence, n*—the sudden increase in temperature of reference material in the supercooled state upon nucleation and crystal growth, due to the release of latent heat of fusion of the reference material.

3.2.13 *reference material, n*—the material in a fixed-point cell that melts and freezes during use, the fixed point of which can establish a reference temperature.

3.2.14 *supercooled state, n*—the meta-stable state of reference material in which the temperature of the liquid phase is below the freezing point.

3.2.15 *undercool, n*—the temperature depression below the fixed point of reference material in the supercooled state.

4. Summary of Guide

4.1 A fixed-point cell is used for thermometer calibration by establishing and sustaining a reference material at either the melting or freezing point, to which a value of temperature has been assigned. The thermometer to be calibrated is inserted into a reentrant well in the cell; the well itself is surrounded by the melting or freezing reference material.

4.2 For freezing point realizations, the cell is heated to melt the reference material. The temperature of the surrounding