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Standard Guide for the Preparation and Evaluation of Liquid Baths Used for Temperature Calibration by Comparison¹

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INTRODUCTION

Many of the Standards and Test Methods under the jurisdiction of ASTM committee E20 on Temperature Measurement make reference to the use of controlled temperature fluid baths for the calibration of thermometers by the comparison method. In this method the thermometer under test is measured while immersed in an isothermal medium whose temperature is simultaneously determined by a calibrated reference thermometer. The uncertainty of all such comparison calibrations depends upon how well the isothermal conditions can be maintained. The bath temperature must be stable over time and uniform within the working space at the operating temperatures. This guide provides basic information, options and instructions that will enable the user to prepare and evaluate controlled temperature baths for calibrations.

1. Scope

1.1 This guide is intended for use with controlled temperature comparison baths that contain test fluids and operate within the temperature range of -100°C to 550°C .

1.2 This guide describes the essential features of controlled temperature fluid baths used for the purpose of thermometer calibration by the comparison method.

1.3 This guide does not address the details on the design and construction of controlled-temperature fluid baths.

1.4 This guide describes a method to define the working space of a bath and evaluate the temperature variations within this space. Ideally, the working space will be as close as possible to isothermal.

1.5 This guide does not address fixed point baths, ice point baths, or vapor baths.

1.6 This guide does not address fluidized powder baths.

1.7 This guide does not address baths that are programmed to change temperature.

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 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*²

E1 Specification for ASTM Liquid-in-Glass Thermometers
E344 Terminology Relating to Thermometry and Hydrometry
E644 Test Methods for Testing Industrial Resistance Thermometers

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 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.

E839 Test Methods for Sheathed Thermocouples and Sheathed Thermocouple Cable

2.2 Other Documents:

ITS-90 The International Temperature Scale of 1990³

NIST Monograph 126 Platinum Resistance Thermometry⁴

NIST Monograph 150 Liquid-in-Glass Thermometry⁴

NIST SP 250-22 Platinum Resistance Thermometer Calibrations⁴

NIST SP 250-23 Liquid-in-Glass Thermometer Calibration Service⁴

3. Terminology

3.1 Standard terms used in this guide are defined in Terminology E344.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *bath gradient error, n*—the error caused by temperature differences within the working space of the bath.

3.2.2 *immersion error, n*—an error caused by heat conduction, radiation or both between the temperature sensing portion of the sensor used in the bath and the environment external to the measurement system. Immersion error is caused by an incorrect immersion length and the resulting incorrect thermal contact of the temperature sensing portion of the sensor with the medium under measurement.

3.2.3 *isothermal, adj*—of, related to, or designating a region of nominally uniform temperature.

3.2.4 *thermal stability, n*—the degree of variability of the temperatures within a specified working space over a specified time interval.

3.2.5 *working space, n*—the region within a controlled temperature bath where the temperature uncertainty is maintained within acceptable limits for the purpose of performing calibrations by the comparison method.

3.2.6 *working temperature range, n*—the minimum to maximum temperature range for which the bath system provides adequate stability and uniformity.

4. Summary of Practice

4.1 This guide is intended to provide basic information that will enable the user to evaluate various controlled temperature bath features and to enable the user to prepare and properly utilize such controlled temperature baths for calibration of thermometers by the comparison method.

5. Significance and Use

5.1 The design of a controlled temperature bath will determine what thermometers can be calibrated and to what extent an isothermal condition is achieved. The lack of thermal stability and uniformity of the bath are sources of error that contribute to the overall calibration uncertainty.

5.2 This guide describes a procedure for determining the effective working space for a controlled temperature fluid bath.

5.3 This guide describes a procedure for determining the thermal stability within a controlled temperature fluid bath. Overall thermal stability is composed of the bath performance as specified by the manufacturer of the bath equipment and as a component of calibration uncertainty.

5.4 This guide describes a procedure for determining the temperature uniformity of the working space of the controlled temperature fluid bath.

6. Procedure

6.1 *Bath System*—A controlled temperature fluid bath system will incorporate most, if not all, of the following components: a fluid medium; a mechanical design that provides for containment and circulation of the fluid; a monitoring thermometer; a temperature control unit; and elements that provide for heating, cooling, or both. There are many commercially available controlled temperature baths. These baths operate from as low as -100 °C to as high as +550 °C, although no single bath system is capable of operation over that entire range. The design of each individual bath will create practical limits for the working temperature range. These limits are determined by considering the minimum and maximum temperature ratings for each of the components in the bath system. The user is advised to carefully review the bath manufacturer's literature to be certain that the bath system is suitable for the intended calibration temperature range and the types of thermometers to be tested. Figs. 1-4 represent various designs of controlled temperature fluid bath systems. Fig. 4 shows a block diagram of a comparison calibration setup.

6.1.1 *Fluid Medium*—There are many types of fluid media suitable for use in liquid temperature comparison baths. The physical properties of the medium will establish the limits for the safe operating temperature range, as well as determine the overall performance of the bath system. Fig. 5 provides a partial listing of common bath media that have been used successfully for liquid temperature comparison baths. This guide is not intended to restrict the user to only those fluids shown in Fig. 5. It is advisable for the user to review carefully the manufacturer's literature on any alternative fluid to be certain that it complies with the safety considerations of 6.1.1.1.

6.1.1.1 *Safety and Environmental Impact Considerations*—(See 1.9.) It is strongly recommended that the Material Safety Data Sheet (MSDS) of any material used as a fluid medium be reviewed and understood by the user before the material is handled for the first time. The data sheets of all test fluids should be kept readily available during bath operation in case of accidents or spills. Additionally, some producers of bath fluids provide a Global Warming Potential Index in their specifications that should be considered when choosing a bath fluid.

(1) *Temperature Limits*—Fig. 5 provides minimum and maximum safe operating temperatures for several common bath media. Flash point temperatures are also given for certain flammable media. Consult the manufacturer's MSDS document for each bath fluid used.

³ Preston-Thomas, H., *METROLOGIA*, Vol. 27, 1990, pp 3-10 and 107 (errata). Mangum, B. W., *JOURNAL OF RESEARCH*, National Institute of Standards and Technology, Vol 95, 1990, p. 69.

⁴ Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, <http://www.nist.gov>.