



# SPECIFICATIONS AND TOLERANCES

for Reference Standards  
and Field Standard

Weights and Measures



## 6. Specifications and Tolerances for Thermometers

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# Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures

## 6. Specifications and Tolerances for Thermometers

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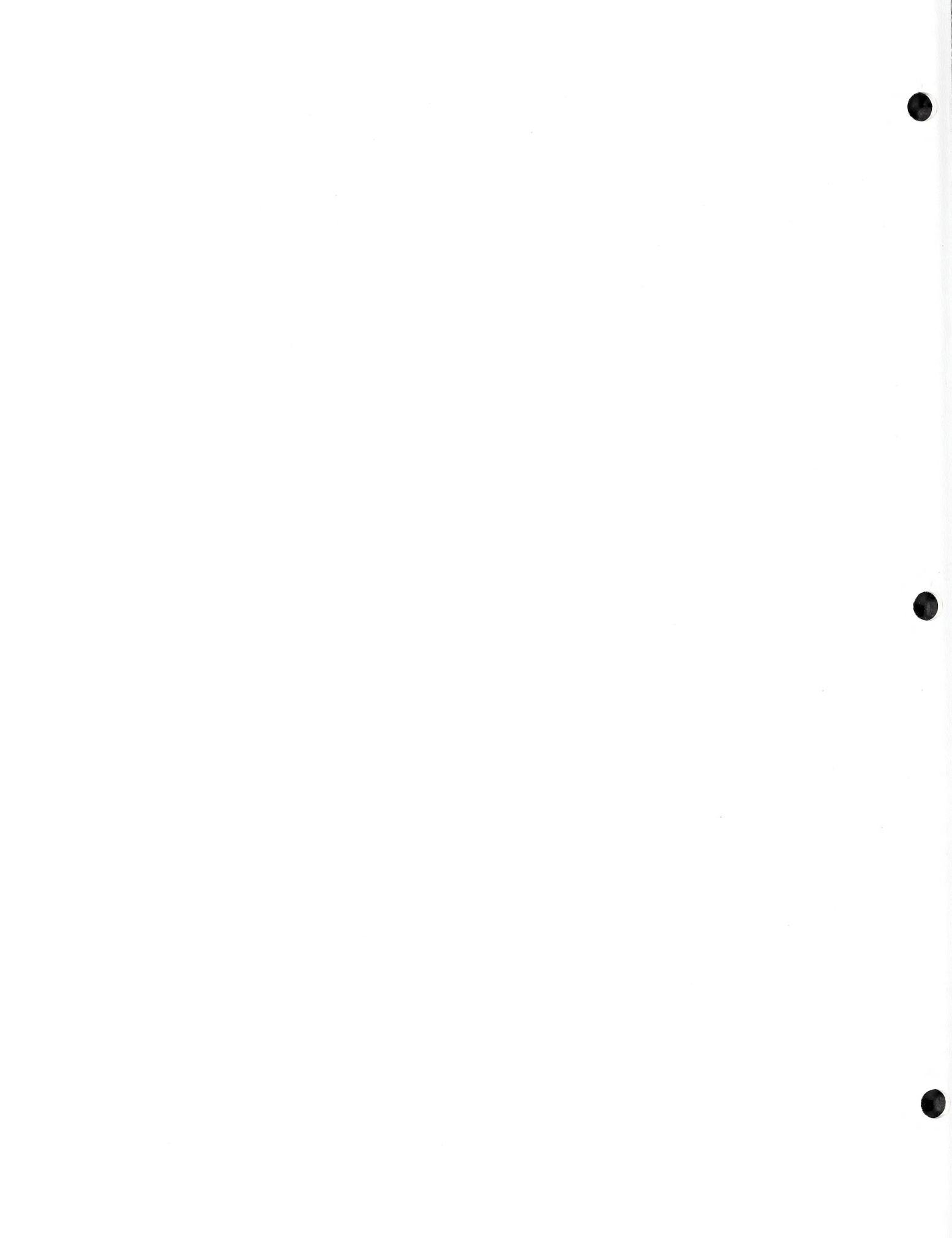
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## Preface

The effort to develop a 105-series handbook for field standard temperature measuring devices was undertaken by Joe Rothleder (CA) in 1990 in response to the need for specifications, tolerances, and procedures for such devices used in weights and measures enforcement activities. This publication is the result of the draft prepared by Joe Rothleder.

Special thanks regarding this handbook is also given to Karl Herken, metrologist with the State of Kansas, for his assistance with review of reference materials, evaluation of comments submitted during peer review, and for typing and editing the document in WordPerfect format. Thanks are also given to numerous metrologists (of both State and industry laboratories) for their technical review of several drafts.



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# SPECIFICATIONS AND TOLERANCES FOR REFERENCE STANDARDS AND FIELD STANDARD WEIGHTS AND MEASURES

## 6. Specifications and Tolerances for Thermometers

These specifications and tolerances are recommended as minimum requirements for temperature measuring devices, hereafter referred to as thermometers, used by State and local weights and measures programs for thermometer testing associated with device and quantity control enforcement activities.

Key words: field standards, liquid-in-glass thermometer, temperature specifications, temperature standards, thermometers.

### Introduction

The thermometers and associated tolerances specified herein are intended for weights and measures applications where temperature is a factor in the procedures used during testing for compliance to National Institute of Standards and Technology (NIST) Handbook 44<sup>1</sup> and Handbook 133.<sup>2</sup>

This handbook is intended to provide the weights and measures official with a useful summary of the extensive body of information on the manufacturing, use and calibration of thermometers. It is intended to be used as a guide when purchasing and using thermometers determined to be suitable for weights and measures applications in terms of meeting the specifications and tolerances contained herein. The specific temperature range, type and physical characteristics of each thermometer are to be selected by the user consistent with application requirements and to meet specifications.

Tolerance testing or calibration of thermometers included in this handbook are based on the following:

- Temperatures are relative to "The International Temperature Scale of 1990 (ITS-90)".<sup>3</sup> Guidelines for realizing these temperatures are available in NIST Technical Note 1265.<sup>4</sup>
- Testing at, or correcting data to, the applicable immersion depth of the thermometer under test.
- Testing conducted while operating the thermometer in accordance with the manufacturer's instructions.

Additional information may be obtained by reviewing the applicable documents referenced in this handbook.

### 1 Scope

#### 1.1 Thermometer Types

This publication covers various types of thermometers within the temperature range of -30 °C to 50 °C [-20 °F to 120 °F]. This is the extreme overall temperature testing range for weights and measures enforcement activities, as incorporated in Table 1. The actual temperature range of purchased

thermometers may differ due to local requirements and type of thermometer desired.

## **1.2 Classification**

### **1.2.1 Type**

Thermometers are divided into types based on design.

#### **1.2.1.1 Type I**

Liquid-in-glass thermometers that have a 0 °C [32 °F] reference point. These thermometers tend to be stable with time and use. Once tolerance tested, the thermometer can be checked at the reference point to verify that it remains in tolerance.

#### **1.2.1.2 Type II**

Electronic thermometers using analog or digital readout. These thermometers have active electrical components that can change with time, requiring periodic retesting of tolerance and possibly requiring adjustment, repair or replacement.

#### **1.2.1.3 Type III**

Thermometers of any design other than Type I and II, but capable of meeting the specifications.

## **1.2.2 Specific Class Applications**

### **1.2.2.1 Class 1**

Thermometers typically used as accessory thermometers for the testing of the moisture in grain (e.g., ASTM No. 63F). See Handbook 44 and Table 1 for additional details.

### **1.2.2.2 Class 2**

Thermometers that are used in general weights and measures programs, including device testing and quantity control functions.

## **1.3 Retroactivity**

These specifications are not intended to make obsolete those field standards in use prior to publication of these specifications. All new thermometers must meet these requirements prior to verification for legal use. The described specifications apply to all thermometers placed in service after the publication of this standard; tolerances apply to all thermometers in service. A thermometer in service prior to the publication of this standard that has maintained tolerances between verification tests shall continue to be acceptable.

## **1.4 Safety**

*This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all safety problems 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.*

### **1.4.1 MSDS of Measured Products**

Commercial liquid-measuring devices, tested with these field standards, are typically used to measure quantities of petroleum products. Petroleum products are known hazardous materials and hazardous wastes. The user is encouraged to obtain Material Safety Data Sheets (MSDS) from the manufacturer of any product encountered. Federal and local safety and disposal regulations concerning hazardous materials encountered should be reviewed by the user.

### **1.4.2 Specific Concerns**

The use of liquid-in-glass thermometers can bring the user and others into contact with broken glass and spilled mercury (an identified hazardous material). The user should exercise care and take steps to be

familiar with the instructions relative to first aid for cuts, contents of the "Material Safety Data Sheet" (MSDS) for mercury and the use of "mercury spill clean up kits" for proper clean up and disposal of mercury.

## 2 Reference Documents

### 2.1 NIST

- 2.1.1 NIST Handbook 44, Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices.
- 2.1.2 NIST Handbook 133, Checking the Net Contents of Packaged Goods. (Current edition.)
- 2.1.3 NIST Special Publication 250-23,<sup>5</sup> Liquid-in-Glass Thermometer Calibration Service.
- 2.1.4 NIST Technical Note 1265, Guidelines for Realizing the International Temperature Scale of 1990 (ITS-90).
- 2.1.5 NBS Monograph 174,<sup>6</sup> Thermometer Calibration: A Model for State Calibration Laboratories.
- 2.1.6 NIST Special Publication 819, A Procedure for the Effective Recalibration of Liquid-in-Glass Thermometers, J.A. Wise, 1991.
- 2.1.7 NIST IR 5341, Assessment of Uncertainties of Liquid-in-Glass Thermometer Calibrations at the National Institute of Standards and Technology, J.A. Wise, 1994.

### 2.2 ASTM<sup>7</sup>

- 2.2.1 ASTM Standard E 1-95, Standard Specification for ASTM Thermometers,
- 2.2.2 ASTM Standard E 77-92, Standard Method for Inspection and Verification of Liquid-in-Glass Thermometers.

## 3 Terminology

*Bulb.* The reservoir for the liquid in a liquid-in-glass thermometer.

*Ice Point.* The fixed point between ice and air-saturated water under a pressure of 1 standard atmosphere (101 325 Pa) and is 0 °C on the ITS 90.

*Partial-Immersion Thermometer.* A liquid-in-glass thermometer designed to indicate temperatures correctly when the bulb and a specified part of the stem are exposed to the temperature being measured.

*Reference Point (e.g., Ice point).* The ice point is an example of a series of stable and reproducible temperature reference points; selected to monitor changes in the bulb volume of liquid-in-glass thermometers.

*Stem.* The capillary tube of a liquid-in-glass thermometer through which the fluid moves with change of temperature.

*Tolerance.* Limit of maximum permissible error relative to the true value of the measured temperature.

*Total-Immersion Thermometer.* A liquid-in-glass thermometer designed to indicate temperatures correctly when just that portion of the thermometer containing the liquid is exposed to the temperature being measured.

*Uncertainty.* Parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand.

*Verification.* The process of testing a thermometer for compliance with specifications.

## **4 Specifications**

### **4.1 General**

The specifications below provide key requirements to facilitate efficient thermometer use and tolerance testing. The tolerance for Class 2 thermometers, provided in Table 1, is based on applications requiring the highest accuracy. This will reduce the need for single purpose thermometers and the accidental use of thermometers unsuitable for a specific application. Specifications are based on information available in applicable referenced documents.

### **4.2 Temperature Range**

See Table 1 for temperature ranges needed for weights and measures activities. The actual range of purchased thermometers may differ due to factors including local requirements, availability, cost, and type of thermometer desired.

### **4.3 Materials and Workmanship**

Type I thermometers must conform to specifications contained in ASTM E1-95,<sup>8</sup> sections 4 through 13. Type II and Type III thermometers must provide equivalent or superior performance to Type I thermometers.

### **4.4 Physical and Mechanical**

All thermometer stems, probes or other portions of the thermometer that must be immersed in a product, environment or thermometer well must fit the available space and be readable by the user.

### **4.5 Graduations**

The graduations and spacing for Type I thermometers must conform to specifications contained in ASTM E1-91, sections 4 through 13. See Table 1 for minimum graduations.

### **4.5.1 Readability**

The readability for Type I thermometers must be at least 0.5 division with the unaided eye.

### **4.5.2 Type II and Type III**

Thermometers must provide resolution equivalent to Type I thermometers. In the case of Type II electronic digital thermometers the last digit of readout must be 0.01 °F and/or °C for Class 1 and 0.1 °F and /or °C for Class 2 thermometers.

### **4.6 Immersion**

Type I, Class 1 thermometers (reference NIST Handbook 44) are total immersion types. Class 2 liquid-in-glass thermometers, may be of the total or partial immersion type. If the procedure fails to recommend the use of a total or partial immersion thermometer, then the decision should be governed by the physical limitations in thermometer placement.

### **4.7 Applications**

Based on temperature ranges and tolerances of the Class 2 thermometers covered by this handbook, it is expected that the use of total versus partial immersion thermometers will have errors less than 0.1 °C [0.2 °F]. Additional information on this subject can be obtained in NIST Special Publication 250-23.

## **5 Tolerance**

### **5.1 Tolerance**

Tolerance for thermometers tested in accordance with this handbook are provided in Table 1. The tolerance is  $\pm 1$  division for all liquid-in-glass thermometers. The specifications permit, within the tolerance, the direct reading of temperature, without the use of corrections.



## 5.2 Testing Failures

Thermometers that exceed the standard temperature values during testing, by more than the tolerance will be rejected; or, if users are properly instructed, calibrated and then used with corrections.

## 6 Verification Requirements

### 6.1 Legal Requirements

The specifications and tolerances herein specified are intended to permit the use of the equipment in normal field testing operations as standards having nominal values. Weights and measures requirements, including but not limited to, inspection, testing, and sealing, by a NIST recognized laboratory shall be followed.

NOTE: Some States have requirements not documented here. Check with the local jurisdiction for specific requirements.

### 6.2 Traceability

Field standards used for legal metrology shall be traceable to national standards by calibration in a laboratory recognized by NIST in that parameter, range, and scope and evidence shall be documented and provided.

### 6.3 Calibration Verification

The laboratory will issue a report document for those thermometers that are in compliance with the specifications herein and that have been tested and found to be within tolerance.

### 6.4 Initial and Periodic Verification

Field standards must be verified prior to use and rechecked as often as regulations or circumstances require, especially when damage is known or suspected. Consideration must be given to any State or local weights and measures regulations. The retest of liquid-in-glass thermometers may be a simple

verification of the ice point to determine stability.

### 6.5 Reverification Type I

After initial verification, a liquid-in-glass thermometer, may be reverified by determining the change in temperature at the ice point  $0\text{ }^{\circ}\text{C}$  [ $32\text{ }^{\circ}\text{F}$ ] relative to the ice point reading during initial verification. The change in reading must be applied to all the initial calibration data point readings to determine if the liquid-in-glass thermometer remains in tolerance. If the liquid-in-glass thermometer was initially calibrated with reported corrections, the corrections must be updated to account for the change in the ice-point reading.

**6.6 Reverification Type II and Type III**  
Type II and III temperature sensing devices require complete testing at reverification.

### 6.7 Failing Tolerance

Thermometers failing to meet the specifications and tolerance will be returned to the submitter for repair or replacement. If a thermometer is out of tolerance, a report may be issued to provide corrections that must be applied at time of use.

## 7 Test Methods

### 7.1 Documented Test Procedures

Verification or calibration of thermometers shall be by an approved NIST procedure, ASTM procedure, or internationally recognized method if legal for trade measurements are to be made. Additional requirements may have to be met depending on the jurisdiction in which the device will be used.

### 7.2 Tolerance / Calibration

In cases where the observed verification value, plus or minus the uncertainty, is within

tolerance, a report stating that the thermometer is “within tolerance” may be adequate. In addition, a verification tolerance test requires that the expanded uncertainty be less than one third of the applicable tolerance. The complete calibration of thermometers, including the reporting and use of corrections and uncertainties, is often required, especially for standard thermometers used in grain moisture and liquid-in-glass thermometers that will be reverified through a test of the ice point.

### **7.3 Temperature Span**

Once determined to be operational and meeting the specifications in this handbook, thermometers should be verified or calibrated at three temperature points: starting at the 0 °C [32 °F] reference point and at two additional points, approximately equally spaced, maintaining 25 °C [50 °F] or less between points. Points should be selected by the user such that the lowest and highest test points span at least 60 percent of the temperature range used in test (see Table 1).

## **8 Uncertainties**

### **8.1 Legal Applications**

Uncertainties of the calibration must be evaluated according to the ISO Guide to the Expression of Uncertainty in Measurement,<sup>9</sup> 1993 to ensure that the three-to-one accuracy ratio contained in NIST Handbook 44 is maintained.

### **8.2 Sources of Variation**

#### **8.2.1 Accuracy Limit**

The uncertainty reported by NIST for many primary liquid-in-glass thermometers is around 0.03 °C<sup>10</sup> and is the maximum level acceptable for calibration of Class 1 thermometers. Thermometers with wider temperature ranges and/or greater accuracy shall be tested within the range and tolerance

specified in Table 1. The uncertainty of the laboratory standard must be less than one-third of the tolerance of the thermometer under test based on requirements in NIST Handbook 44.

#### **8.2.2 Repeatability**

Testing should be conducted in accordance with guidelines provided in NIST Special Publication 250-23 and NIST IR 5341 and repeatability of the measurements may be used to evaluate measurement uncertainties in use.

## Notes

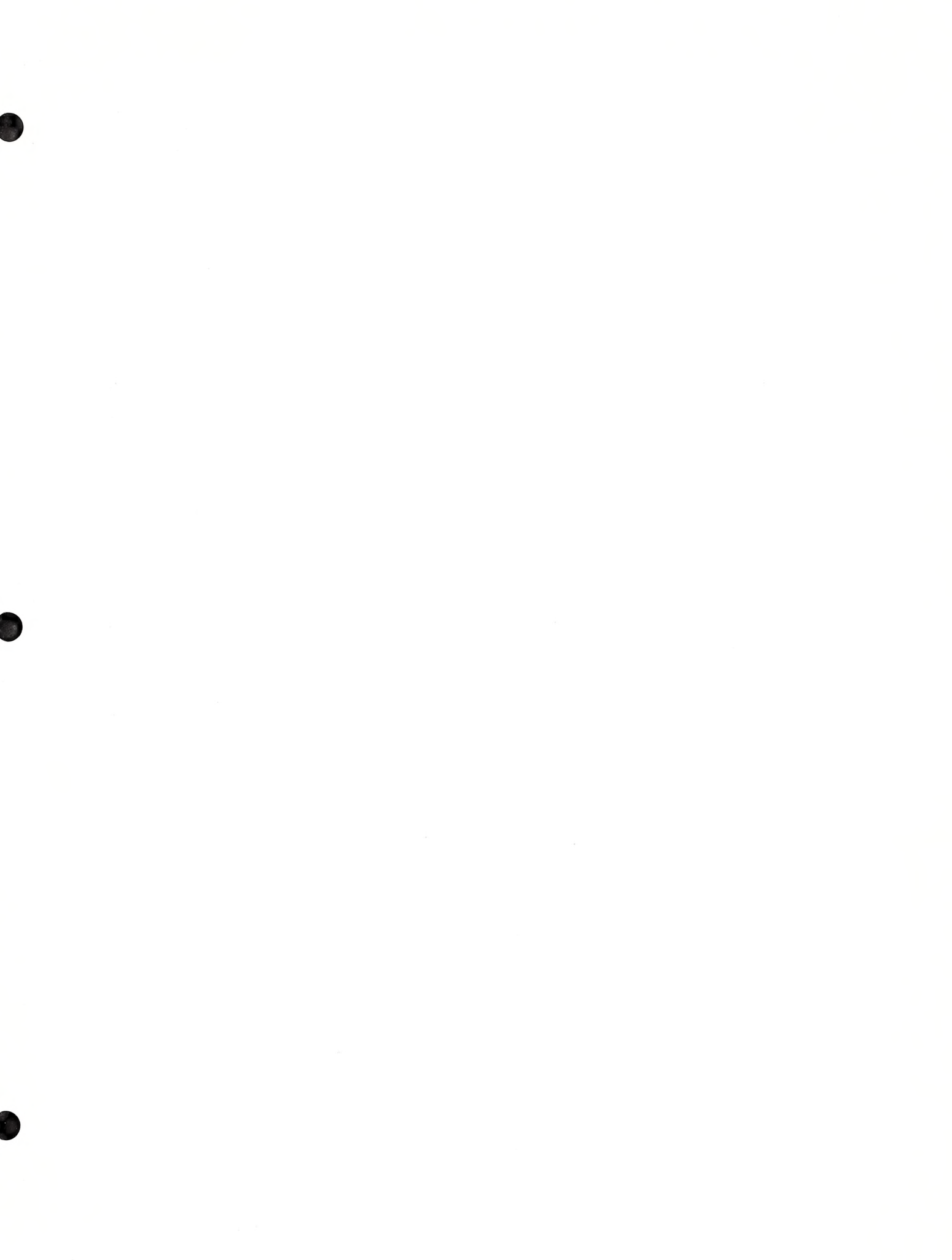
1. NIST Handbook 44, Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices. (See current edition.) NIST, Gaithersburg, MD, 20899.
2. NIST Handbook 133, Checking the Net Contents of Packaged Goods. (Current edition.) NIST, Gaithersburg, MD, 20899.
3. The International Temperature Scale of 1990 (ITS-90). *Metrologia* 27, 3-10 (1990); *Metrologia* 27, 107 (1990).
4. NIST Technical Note 1265, Guidelines for Realizing the International Temperature Scale of 1990 (ITS-90). NIST, Gaithersburg, MD, 20899.
5. NIST Special Publication 250-23, Liquid-in-glass Thermometer Calibration Service. NIST, Gaithersburg, MD, 20899.
6. NBS Monograph 174, Thermometer Calibration: A Model for State Calibration Laboratories. NIST, Gaithersburg, MD, 20899.
7. ASTM, American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428.
8. ASTM E1-95, Standard Specification for ASTM Thermometers. ASTM, American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428.
9. ISO, International Organization for Standardization, Geneva, Switzerland.
10. NIST IR 5341, Assessment of Uncertainties of Liquid-in-Glass Thermometer Calibrations at the National Institute of Standards and Technology, NIST, Gaithersburg, MD 20899.

**Table 1. Typical suggested ranges and associated tolerances**

Devices	Maximum Division Type I (liquid-in-glass)		Maximum Division Type II (digital)		Typical Range		Tolerance	
	(°F)	(°C)	(°F)	(°C)	(°F)	(°C)	(°F)	(°C)
Petroleum Products								
Wholesale petroleum meters	1	0.5	0.1	0.1	0 to 120	0 to 50	1	0.5
Liquefied petroleum gas meters	1	0.5	0.1	0.1	-20 to 120	0 to 50	1	0.5
Hydrocarbon gas vapor meters	1	0.5	0.1	0.1	60 to 120	15 to 50	1	0.5
Grain Moisture Testing								
Accessory Thermometer	1	0.5	0.1	0.1	32 to 104	0 to 40	1	0.5
Standard Thermometer	0.2	0.1	0.01	0.01	32 to 104	0 to 40	0.2	0.1
Quality Control								
Alcoholic beverages	1	0.5	0.1	0.1	-20 to 120	-30 to 50	1	0.5
Compressed gas in cylinders	1	0.5	0.1	0.1	20 to 100	-10 to 40	1	0.5
Petroleum products	1	0.5	0.1	0.1	-20 to 120	-30 to 50	1	0.5
Aerosol commodities	1	0.5	0.1	0.1	20 to 100	-10 to 40	1	0.5
Frozen foods	1	0.5	0.1	0.1	-30 to 120	0 to 50	1	0.5

Note: Temperature ranges may not correspond exactly between °C and °F units. Fahrenheit units listed first in accordance with field practice.







# *NIST* Technical Publications

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