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Standard Guide for Digital Contact Thermometers[1]

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ε[1] NOTE—Changes were made editorially in February 2013.

1. Scope

1.1 This Guide describes general-purpose, digital contact thermometers (hereafter simply called "digital thermometers") that provide temperature readings in units of degrees Celsius or degrees Fahrenheit, or both. The different types of temperature sensors for these thermometers are described, and their relative merits are discussed. Nine accuracy classes are introduced for digital thermometerhes; these classes consider the accuracy of the sensor/measuring-instrument unit.

1.2 The proposed accuracy classes for digital thermometers pertain to the temperature interval of –200 °C to 500 °C, an interval of special interest for many applications in thermometry. All of the temperature sensor types for the digital thermometers discussed are able to measure temperature over at least some range within this interval. Some types are also able to measure beyond this interval. To qualify for an accuracy class, the thermometer must measure correctly to within a specified value (in units of °C) over this interval or over the subinterval in which they are capable of making measurements. Those thermometers that can measure temperature in ranges beyond this interval generally have larger measurement uncertainty in these ranges.

1.3 The digital thermometer sensors discussed are platinum resistance sensors, thermistors, and thermocouples. The range of use for these types of sensors is provided. The measurement uncertainty of a sensor is determined by its tolerance class or grade and whether the sensor has been calibrated.

1.4 This Guide provides a number of recommendations for the manufacture and selection of a digital thermometer. First, it recommends that the thermometer's sensor conform to applicable ASTM specifications. Also, it recommends minimum standards for documentation on the thermometer and informational markings on the probe and measuring instrument.

1.5 The derived SI units (degrees Celsius) found in this Guide are to be considered standard. However, thermometers displaying degrees Fahrenheit are compliant with this guide as long as all other guidance is followed.

1.6 *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 and health practices and determine the applicability of regulatory limitations prior to use. Some specific hazards statements are given in Section 7 on Hazards.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E230 Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples
E344 Terminology Relating to Thermometry and Hydrometry
E563 Practice for Preparation and Use of an Ice-Point Bath as a Reference Temperature
E608/E608M Specification for Mineral-Insulated, Metal-Sheathed Base Metal Thermocouples
E644 Test Methods for Testing Industrial Resistance Thermometers
E839 Test Methods for Sheathed Thermocouples and Sheathed Thermocouple Cable
E879 Specification for Thermistor Sensors for General Purpose and Laboratory Temperature Measurements
E1137/E1137M Specification for Industrial Platinum Resistance Thermometers
E2181/E2181M Specification for Compacted Mineral-Insulated, Metal-Sheathed, Noble Metal Thermocouples and Thermocouple Cable
E2593 Guide for Accuracy Verification of Industrial Platinum Resistance Thermometers
E2846 Guide for Thermocouple Verification

3. Terminology

3.1 *Definitions:* The definitions given in Terminology E344 apply to terms used in this guide.

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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.

3.2 *Definitions:*

3.2.1 *accuracy class, n*—class of an item that meets certain metrological requirements intended to keep errors within specified limits.

3.2.1.1 *Discussion*—This document describes accuracy classes for digital thermometers.

3.2.2 *calibration uncertainty, n*—parameter, derived from the analysis of a calibration of a measuring instrument, that characterizes the range in which the true calibration result is estimated to lie within a given confidence level.

3.2.3 *digital contact thermometer, n*—a device that measures temperature through direct contact with a sensor and provides a digital output or display of the determined value, or both.

3.2.3.1 *Discussion*—This device consists of a temperature sensor connected to a measuring instrument; this instrument measures the temperature-dependent quantity of the sensor, computes the temperature from the measured quantity, and provides a digital output or display of the temperature, or both. The sensor is sometimes located inside the instrument.

3.2.4 *measuring instrument, n*—the instrument in a digital thermometer that is used to measure the temperature-dependent quantity of the sensor.

3.2.5 *probe, n*—an assembly, including the transducer (sensor), that is used to position the transducer in the specific location at which the temperature is to be measured.

3.2.6 *reference-junction compensator, n*—a device that measures the temperature of a thermocouple's reference junction and adds to or subtracts from the reference-junction emf a compensating voltage that simulates a reference junction temperature of 0 °C.

3.2.6.1 *Discussion*—The compensating voltage may be added or subtracted electronically or digitally.

3.2.7 *response time, n*—the time required for a sensor to change a specified percentage of the total difference between its initial and final temperatures when the sensor is subjected to a step function change in temperature.

3.2.8 *sensing point, n*—the location on a temperature sensor where the temperature is (or is assumed to be) measured.

3.2.8.1 *Discussion*—A thermocouple's sensing point is its measuring junction (although the signal in the thermocouple is generated along the two thermocouple wires in regions where a temperature gradient exists). A platinum resistance thermometer contains a sensing element that may be large enough to experience spatial temperature variations; in this case the sensing point is the central point in the element where the temperature is assumed to be that measured by the platinum resistance thermometer.

3.2.9 *time constant, n*—the 63.2 % response time of a sensor that exhibits a single-exponential response.

3.2.10 *tolerance, n*—in a measurement instrument, the permitted variation of a measured value from the correct value.

3.2.10.1 *Discussion*—If a measurement instrument is stated to measure correctly to within a tolerance, the instrument is classified as "in tolerance" and it is assumed that measurements made with it will measure correctly to within this tolerance. An instrument that is not classified as "in tolerance" is classified as "out of tolerance."

4. Significance and Use

4.1 Digital thermometers are used for measuring temperature in many laboratories and industrial applications.

4.2 For many applications, digital thermometers using external probes are considered environmentally-safe alternatives to mercury-in-glass thermometers. **(1)**[3]

4.3 Some digital thermometers are also used as reference or working temperature standards in verification and calibration of thermometers and also in determining the conditions necessary for evaluating the performance of other measuring instruments used in legal metrology and industry.

5. Description of the Instruments

5.1 *Basic Description of a Digital Thermometer*

5.1.1 A digital thermometer consists of a temperature sensor, often mounted in a probe, connected to a measuring instrument. The instrument measures the temperature-dependent quantity of the sensor, computes the temperature from that measured quantity, and provides a digital output or display of the computed temperature, or both.

5.2 *Types of Digital Thermometer Sensors*

5.2.1 *Platinum Resistance Thermometer (PRT)*. The electrical resistance of a PRT's platinum element increases nearly linearly as its temperature increases, making it a temperature sensor. A PRT sensor consists of a platinum filament of fine wire or film supported by an insulating body. The sensor is usually mounted in a protective glass coating with size 2 mm to 4 mm or a sheathed probe (glass or stainless steel) with a typical outer diameter of 1.6 mm to 6.4 mm; this arrangement protects the sensor from physical damage and chemical contamination but still allows thermal transfer between the sensor and its environment. This sensor package often determines the temperature capability and accuracy of the device. The sensor is connected to a measuring instrument by electrically conducting leads. The number of leads can be 2, 3, or 4. The measuring instrument determines the resistance of the PRT's sensing element by applying a known current through it and measuring the voltage across it. Most measuring instruments for PRTs calculate the temperature of the sensor using the relevant resistance/temperature equations. The PRT calibration is defined as either a nominal resistance-temperature relationship with an interchangeability tolerance (for example, Specification E1137/E1137M) or a single sensor calibration with estimated uncertainty. A nominal relationship allows the readout device to be programmed with a single resistance-temperature relationship for a specified PRT family. Interchangeability tolerances are usually greater than 0.1 °C and increase as temperatures deviate from the ice-point. Alternatively, a sensor-specific calibration is used when a nominal curve does

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

not exist or when the interchangeability tolerances do not support accuracy needs. PRT calibration uncertainties less than 0.01 °C are possible depending on temperature range, PRT stability and test measurement capability.

Temperature range, vibration tolerability and stability (against drift) are key characteristic to consider when selecting a PRT for a particular accuracy class. PRT designs vary widely between manufacturers and can be tailored to meet the needs of specific applications. General guidelines are summarized in Table 1.

5.2.2 *Thermistor*—The electrical resistance of a thermistor (a semiconductor of blended metal oxides) varies with its temperature, making it a temperature sensor. The resistance of a thermistor can either increase as the temperature increases (positive temperature coefficient, or PTC) or decrease as the temperature increases (negative temperature coefficient, or NTC). Most thermistors that are used as temperature sensors are of the NTC type. Thermistor sensors are frequently used for temperature measurements in the range −20 to 100 °C. They are sometimes used for special applications over the ranges −196 to −20 °C and 100 to 150 °C. Thermistors have the advantages of high resolution, a fast response time, and low uncertainty over their specified range. They also have excellent stability and very good vibration tolerability. Many thermistors are either encapsulated with epoxy or sealed with a protective glass coating, resulting in a typical bead size of 0.5 mm to 3 mm. Others are mounted in a stainless steel sheath with a typical outer diameter of 0.9 mm to 6.4 mm. If the thermistor is external to the measuring instrument, it is connected to the instrument by electrical leads that are electrically insulated from the environment and from each other. An external thermistor is often located inside a protective sheathed probe; this arrangement protects the sensor from physical damage and chemical contamination but still allows thermal transfer between the sensor and its environment. Thermistors usually have two leads to measure the resistance across the thermistor material. The measuring instrument determines the combined resistance of the thermistor and leads by applying a known current through them and measuring the voltage across the ends of the leads. The instrument calculates the temperature of the thermistor using a specific resistance/temperature equation relevant to the type of thermistor. The temperature calculation requires the use of several coefficients, the values of which are stored in the instrument. For thermistor types used in clinical laboratory temperature measurements, nominal values of these coefficients may be obtained from Table 1 of Specification E879. For other thermistor types, the nominal values are generally obtained from the manufacturer. Use of the nominal values calculates temperature to within the tolerance of the thermistor type. Calibration-determined coefficient values may be entered into some instrument models, enabling more accurate temperature determination for an individual thermistor sensor. A summary of the characteristics of thermistors is listed in Table 1.

5.2.3 *Thermocouple*—A thermocouple consists of two parallel dissimilar homogeneous metal wires, called thermoelements. These thermoelements, which are usually of equal length, are joined physically and electrically at one end, called the measuring junction. The other end is called the reference junction. When there is a temperature difference between the measuring junction and reference junction, an electromotive force (emf) is produced across each thermoelement, generated in the region where temperature gradients exist. Because the thermoelements are dissimilar, an electromotive force difference (called a thermocouple emf) is produced across the reference junction. This thermocouple emf (a voltage) increases as the temperature difference increases, making the thermocouple a sensor for temperature differences. When the reference-junction temperature is known, the thermocouple may be used as a temperature sensor that determines the temperature of the measuring junction. The reference junction of the thermocouple is attached to terminals on the measuring instrument, which determines the electromotive force (emf) across the reference junction. Thermocouple wires are often covered with ceramic, fiberglass, or polymer insulations, and the measuring junction is often mounted in a sheathed stainless steel probe with a typical outer diameter of 0.2 mm to 6.4 mm for additional protection of the sensor.

The emf across the reference junction is used along with the known emf/temperature relations to calculate the measuring junction temperature. However, these relations assume that the reference-junction temperature is 0 °C. This is never the case with a digital thermometer, so a reference-junction compensator inside the measuring instrument simulates this arrangement. It measures the actual temperature of the reference junction Trj and adds to or subtracts from the reference-junction emf a compensating voltage that simulates a reference junction temperature of 0 °C. The compensating voltage may be added or subtracted either electronically (before the emf measurement) or digitally (after the emf measurement). This compensating voltage is equivalent to that which the thermocouple would produce if the measuring junction temperature were Trj and the reference junction temperature were 0 °C. The instrument then calculates the temperature of the measuring junction using the emf/temperature equation provided in Note 2 of Table 7 of Specification E230. This calculation requires use of several coefficients, the values of which are stored in the instrument. Nominal values of these coefficients may be obtained from Table 7 of Specification E230. Use of the nominal values calculates temperature to within an uncertainty determined by the stated tolerance of the thermocouple and the uncertainty of the reference junction compensation. Calibration-determined coefficient values may be entered into some instrument models; this enables an individual thermocouple sensor (or a group of thermocouple sensors made using the same wire lot) to measure temperature with an uncertainty that is less than the stated tolerance of similar uncalibrated thermocouples.

A thermocouple sensor has the advantages of a relatively large temperature range and being compact and mechanically robust. There are several types of thermocouples that may be used, each with their own temperature ranges and tolerances. Some of the more commonly used thermocouples are types E, J, K, N, R, S, and T. The respective temperature ranges and characteristics of these thermocouples are shown in Table 1.

TABLE 1 Summary of Thermometer Sensors and Their Typical Characteristics

NOTE 1—See text for a more complete description. The descriptions provided here are general and may not pertain to individual sensor models. The accuracy of a sensor is dependent on many factors (calibration, temperature, environmental history), making a quantitative description of it nontrivial. It is described here qualitatively for the purpose of comparison. ASTM tolerance values for platinum resistance thermometers (PRTs), thermocouples, and some thermistors are found inStandard Specifications E1137/E1137M, E230, and E879, respectively.

Temperature Sensor	Temperature-Dependent Quantity	Nominal Temperature Range	Available Sensor Protection	Size (Diameter)	Stability (against drift)	Vibration Tolerability	Accuracy
PRT: wire	Resistance of platinum wire	−200 to 650 °C (−328 to 1202 °F)	Glass coating, glass or stainless steel sheath	2 to 4 mm glass coated, 1.6 to 6.4 mm dia. sheath	Good to Excellent depending on temperature range and design	Limited to Very Good depending on design	2 leads: Fair 3 leads: Very Good 4 leads: Excellent
PRT: thin film	Resistance of a platinum film	−70 to 300 °C (−94 to 572 °F)					
Thermistor	Resistance of a semiconductor	−50 to 100 °C (−58 to 212 °F), typical	Epoxy or glass bead, stainless steel sheath	0.5 to 3 mm bead, 0.9 to 6.4 mm dia. sheath	Excellent	Very good	Excellent
Thermocouple Types E		−200 to 870 °C (−328 °F to 1600 °F)					
Thermocouple Types J		0 to 760 °C (32 to 1400 °F)					
Thermocouple Types K	Emf difference between two dissimilar wires	−200 to 1260 °C (−328 to 2300 °F)	2–bore ceramic tubing, fiberglass, or polymer insulation, stainless steel sheath	0.06 to 2 mm measuring junction, 0.2 to 6.4 mm dia. sheath	Good, increases as temperature decreases	Excellent	Good, increases as temperature approaches 0 °C
Thermocouple Types T		−200 to 370 °C (−328 to 698 °F)					
Thermocouple Types N		0 to 1260 °C (32 to 2300 °F)					
Thermocouple Types R, S		0 to 1480 °C (32 to 2700 °F)			Very good, increases as temperature decreases		Very good, increases as temperature decreases

Thermocouples can be very stable if used only at temperatures near ambient. Their stability decreases at higher temperatures due to oxidation-related drift. Therefore, thermocouple uncertainties can be reduced considerably if the calibration/usage temperature range is smaller and near ambient, where oxidation is small or nonexistent.

5.3 *Immersion—*When measuring the temperature of a medium, the end of a sensor probe must be immersed in it by a minimum depth. Immersing the probe by at least this 'minimum immersion length" ensures that the sensing point is immersed to a depth where any heat flux occurring in the probe stem will not result in a measurement error. When properly immersed, the sensor can measure the correct temperature of the medium to within its tolerance or calibration uncertainty. The minimum immersion length generally includes a small segment of the stem; this segment is almost always part of the probe. The value of the minimum immersion length varies considerably and depends on the type of sensor, the design of the probe, and the environment in which the probe is immersed. Design parameters affecting the minimum immersion length include the sheath diameter (if applicable) and the diameter of the leads (PRT or thermistor) or the diameter of the thermoelements (thermocouple). Manufacturers sometimes provide an estimated minimum immersion length in their product specifications. This length may be determined experimentally by slowly immersing the probe into a medium of uniform temperature (for example, an ice bath, as constructed by Standard Practice E563) until the indicated temperature no longer changes significantly. For a PRT probe, the test described in Section 7 of Test Method E644 should be used.

5.4 *Response Time—*When temperature of a medium changes, the indicated temperature of a sensor probe immersed in the medium does not follow the change immediately, but lags by a characteristic amount. This amount may be related to the response time t_r of the probe and or the configuration of the instrument.

5.4.1 *Sensor—*A sensor's response time is related to its time constant. The time constant τ is defined in terms of the probe's response to an instantaneous temperature change $\Delta T = T_f – T_i$, where T_i is the initial temperature and T_f is the final temperature. The time constant is defined as the time required for the indicated temperature to change from T_i to T_f by an amount $\alpha \Delta T$, where $\alpha = 1–e^{-1} = 0.632$. The value of τ depends on the type of sensor and the particular design of the sensor, as well as the thermal properties of the medium into which the sensor is immersed. Design parameters affecting τ include the sheath diameter (if applicable) and electrically-insulating materials. A typical value of τ for a sheathed sensor is several seconds, but considerable variation exists. Manufacturers sometimes provide the maximum time constant of their sensors in their product specifications. The response time is defined as the time required for the indicated temperature to change from T_i to T_f by an acceptable proportion β (chosen by the user) of the actual change, where $0 \leq \beta \leq 1$. The response time is then given by $T_r = –\ln(1 – \beta)\,\tau$. As examples, for $\beta = 0.90$, $T_r = 2.30\tau$; for $\beta = 0.95$, $T_r = 3.00\tau$; for $\beta = 0.99$, $T_r = 4.61\tau$. This response time may be determined experimentally using the test methods described in Section 9 of Test Method E644 and Section 10.7 of Test Method E839.

5.4.2 *Measuring Instrument—*At minimum, the instrument's response time is determined by the time period between sample measurements. This time (or its inverse, the sampling rate) may sometimes be programmed into the instrument by the user. The default value is usually mentioned in the product specifications by the manufacturer. The response time may also be increased if there is filtering of the measured signal. When filtering is used, the displayed result includes measurements taken over a longer period of time than the sampling period; these measurements are averaged to obtain the displayed result. This averaging produces a more stable reading, but increases the response time. Measuring instruments generally do not filter when they are used in their default configuration. If filtering is used, the user should consult the product manual for information on the response time of the instrument.

5.5 *Susceptibility to Environmental Disturbances—*The indicated temperature displayed on a particular digital thermometer may be susceptible to certain environmental disturbances, such as strong electric or magnetic fields, or both. It may also be susceptible to electromagnetic interference (EMI), also known as radio-frequency interference (RFI). Prospective users of digital thermometers should determine what kinds of environmental disturbances exist in the areas where the thermometer is to be used, and inquire whether these disturbances would significantly compromise the integrity of the temperature measurements made by the thermometer.

6. Digital Thermometer Accuracy Classes Within the Interval -200 to 500 °C

6.1 Table 2 introduces accuracy classes for complete digital thermometer units based on the tolerance of both the sensor and the measuring instrument. These accuracy classes pertain only to measurements within the interval −200 to 500 °C. The tolerance is expected to be larger than that of the sensor alone. For a PRT-based thermometer and a thermistor-based thermometer, the tolerance/uncertainty of the measuring instrument includes that for resistance measurement and for sensor self-heating. For a thermocouple-based thermometer, the tolerance of the measuring instrument includes that for voltage measurement and for reference-junction compensation. Many digital thermometers feature measuring instruments that may be disconnected from their sensor and connected to another sensor. Therefore, it must be emphasized that a digital thermometer accuracy class refers to a particular sensor/

TABLE 2 Accuracy Classes and Their Respective Tolerances for Digital Thermometers

Class	Tolerance
A	≤ 0.01 °C
B	≤ 0.02 °C
C	≤ 0.05 °C
D	≤ 0.1 °C
E	≤ 0.2 °C
F	≤ 0.5 °C
G	≤ 1.0 °C
H	≤ 2.0 °C
I	≤ 5.0 °C

measuring-instrument combination, and that changing this combination may change the accuracy class.

6.2 *Calibrated Digital Thermometers*—A digital thermometer may be calibrated before or after being provided to a customer. Calibration laboratories provide measurement uncertainties rather than tolerances to accompany their calibration results. Therefore, in order to determine its accuracy class, a thermometer's measurement uncertainty will need to be converted to a tolerance. Such a conversion is nontrivial because tolerance and measurement uncertainty are differently defined quantities with no defined relation. However, a reasonable conversion may be based on the tolerance verification methods described in ANSI/NCSLI Z540.3-2006 (**2**). Using this basis, a tolerance may be considered roughly equivalent to an uncertainty with a coverage factor of k=3 (confidence interval of 98 %). Likewise, a tolerance may be considered roughly equivalent to an uncertainty with a coverage factor of k=2 (confidence interval of 95 %) multiplied by a factor of 3/2.

Example: A calibrated digital thermometer is declared to have a measurement uncertainty (k = 2) of 0.1 °C. The corresponding tolerance is then obtained by multiplying the calibration uncertainty by 3/2, providing a value of 0.15 °C. This thermometer would then belong in Accuracy Class E.

6.3 *Accuracy Verification*—It is important to periodically verify the accuracy of digital thermometers. This accuracy can be verified by comparing the thermometer with reference standards, tests at thermometric fixed points and periodic recalibration. (**3**) For example, the temperature of an ice bath (0 °C) prepared using Practice E563 is stable and reproducible to within 0.002 °C, and so periodic immersion of the digital thermometer in an ice bath is a convenient and useful test for thermometer drift. Verification tests for PRT and thermocouple sensors are described in Guide E2593 and Guide E2846, respectively.

7. Recommendations for Manufacturing and Selection

The following recommendations are made for the manufacturing and selection of digital thermometers:

7.1 *Units*—The temperature values displayed by a digital thermometer should be in units of degrees Celsius (°C) or degrees Fahrenheit (°F), or both.

7.2 *Traceability*—The temperature values displayed by a digital thermometer should be on the International Temperature Scale of 1990 (ITS-90) and traceable to national and international standards. (**4**) Traceability is accomplished if the thermometer's calibration or tolerance test can be related to the temperature standard of a national measurement institute through a series of intermediate reference-thermometer calibrations with known uncertainty.

7.3 *Environment:*

7.3.1 *Operating Environment*—In all documentation where the digital thermometer accuracy is described, a description of the operating environment required for the measuring instrument in order that the thermometer meet this accuracy should be provided (see 7.3.3).

7.3.2 *Storage Environment*—In all documentation where the digital thermometer accuracy is described, a description of the storage and transportation environment required for the measuring instrument in order that the thermometer meet this accuracy should be provided (see 7.3.3).

7.3.3 *Environmental Description*—Environmental descriptions should include the ranges of all relevant environmental parameters, for example, the temperature of the measuring instrument, the relative humidity, and the ambient pressure.

7.3.4 *Labeling*—The instruction manual should include a statement that informs the user if the performance of the device may be degraded should one or more of the following occur:

7.3.4.1 Operation outside the manufacturer's stated temperature and humidity range.

7.3.4.2 Storage outside the manufacturer's stated temperature and humidity range.

7.3.4.3 Mechanical shock (for example, drop test).

7.4 *Digital Display:*

7.4.1 *Resolution*—The digital display should have incremental steps not larger than 1 °C or 1 °F, and steps not less than 10 % of the tolerance of the sensor/measuring-instrument combination.

7.4.2 *Readability*—At the outside surface of the instrument, the numerals should appear to be at least 2.5 mm (0.1 in.) high and 1.5 mm (0.059 in.) wide and appear to be separated from one another by a space of at least 0.7 mm (0.027 in.).

7.4.3 *Display Units*—The digital display should clearly include the temperature unit of the displayed numerical value.

7.5 *Battery Condition*—Battery-operated instruments should include an automatic indication of unreliable condition that is shown once the battery power is sufficiently low that the instrument accuracy is affected; this indication should be displayed until the battery condition is corrected. When an instrument uses a rechargeable battery, the indication should show when the battery is charging.

7.6 *Case Material*—The case material of the measuring instrument, sensor, and connecting cable should withstand physical cleaning without performance degradation. It should also withstand dropping without presenting an electrical safety hazard.

7.7 *Marking*—All markings for purposes of identification or instruction should be clear and legible. Deterioration should not occur when subjected to cleaning.

7.7.1 *Instrument Marking*—The instrument should be marked with the manufacturer's or distributor's name, model designation, serial number and/or lot number.

7.7.2 *Probe Marking*—Detachable reusable probes should be marked with at least the sensor type, manufacturer's or distributor's name or identification, and serial or lot number. If possible, the minimum immersion length of the probe should be marked as well.

7.7.3 *Operating Instructions*—Operating instructions should be provided on the instrument if possible. When space requirements dictate, the operating instructions on the instrument may be brief if detailed operating instructions are also provided.

7.7.4 *Care and Use Instructions*—Instructions for the care, use, and cleaning of the instrument should be provided.

7.7.5 *Identification*—In order that purchasers may identify products conforming to some or all of the criteria in this Guide, producers and distributors may include a statement of conformance in conjunction with their name and address on product labels, invoices, sales literature, and the like.

7.8 *Documentation:*

7.8.1 *Detailed Instructions*—Detailed instructions for use should be provided. These instructions should contain sufficient detail to provide a means for training in the operation, application, care, and cleaning of the instrument and accessories.

7.8.2 *Service and Repair Manual*—A service manual should be made available if user repair is permitted by the manufacturer. The service manual should provide theory of operation, maintenance information, test procedures, test equipment requirements, detailed diagrams, parts list, and specifications.

7.8.3 *Accuracy Determination*—The manufacturer should make available specific instructions for tests to determine the accuracy of the thermometer, including the temperature sensor.

7.8.4 *Influence from Environmental Disturbances*—The manufacturer's documentation should provide a statement of compliance to all pertinent standards for immunity to environmental disturbances, or a description of the effect of environmental disturbances (for example, strong magnetic or electric fields, or electromagnetic noise) on the thermometer, along with recommendations on how to minimize this effect.

7.8.5 *Recalibration*—The manufacturer should recommend a periodic recalibration cycle to ensure continuous performance consistent with the accuracy class of the thermometer. The manufacturer should provide specific instructions for the adjustment of the instrument if user adjustment is permitted by the manufacturer. Test equipment or fixtures required for adjustment should either be described in sufficient detail to permit fabrication or purchase, or the manufacturer's equipment or fixtures should be made available to users.

7.8.6 *Detailed Specifications*—The manufacturer should provide specifications of the digital thermometer's temperature range, accuracy, and minimum immersion length for all probes that may be used with the measurement instrument. It should also specify the environmental limits for the measuring instrument (see 7.3).

8. Keywords

8.1 digital; electronic; liquid-in-glass; mercury-in-glass; thermometer

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