Designation: E879 – 12 E879 – 20

Standard Specification for Thermistor Sensors for General Purpose and Laboratory Temperature Measurements[1]

This standard is issued under the fixed designation E879; 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 specification covers the general requirements for Negative Temperature Coefficient (NTC) thermistor-type sensors intended to be used for laboratory temperature measurements or control, or both, within the range from −10from −10 °C to 105°C.105 °C.

1.2 This specification also covers the detailed requirements for ASTM designated sensors.

1.3 This specification also covers the requirements for general purpose, Negative Temperature Coefficient (NTC) thermistor-type sensors intended for use with Digital Contact Thermometers (also known as Digital Thermometers) within the range from −50–50 °C to +150°C.+150 °C.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 *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 safety, health, and healthenvironmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *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
E1502 Guide for Use of Fixed-Point Cells for Reference Temperatures
E1750 Guide for Use of Water Triple Point Cells
E2488 Guide for the Preparation and Evaluation of Liquid Baths Used for Temperature Calibration by Comparison
F29 Specification for Dumet Wire for Glass-to-Metal Seal Applications

2.2 *NIST Documents:*[3]

NIST Monograph 126 Platinum Resistance Thermometry
NIST Special Publication 250-22 Platinum Resistance Thermometer Calibration
NIST Technical Note 1265 Guidelines for Realizing the International Temperature Scale of 1990

2.3 *Other Documents:*

JCGM 100:2008 Evaluation of measurement data – Guide to the expression of uncertainty in measurement[4]
ANSI/NCSL Z540.3-2006 (R2013) Requirements for the Calibration of Measuring and Test Equipment[5]

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[1] This specification is under the jurisdiction of ASTM Committee E20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.03 on Resistance Thermometers.

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

[4] Available from the BIPM, Sevres, France, http:// www.bipm.org.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

3. Terminology

3.1 *Definitions*—The definitions given in Terminology E344 shall apply to this specification.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *dissipation constant, δ, n*—the ratio of the change in energy dissipated per unit time (power) in a thermistor, $\Delta P = P_2 - P_1$, to the resultant temperature change of the thermistor, $\Delta T = T_2 - T_1$.

$$\delta = \frac{\Delta P}{\Delta T} \quad (1)$$

The dimensions of the dissipation constant are ~~W/K.~~watts per kelvin (W/K). Note that many NTC thermistors are very small devices, and as such, the dissipation constant dimensions are frequently expressed in terms of milliwatts per kelvin (mW/K).
For this specification, T_1 is in the range from ~~20~~20 °C to ~~38°C~~38 °C and ΔT ~~= 10°C.~~ = 10 °C.

3.2.2 *dumet, n*—round, copper-coated 42 % nickel-iron wire intended primarily for sealing to soft glass. Also known as CuNiFe in some ~~communities.~~communities; see Specification F29 for additional information.

3.2.3 *insulation resistance, dc, n*—the resistance at a specified direct-current voltage between the insulated leads of a thermistor sensor and the metallic enclosure of the sensor, if such an enclosure is present, or else between the sensor leads and a conductive medium in which the sensor is immersed.

3.2.4 *qualification test, n*—a series of tests conducted by the procuring agency or an agent thereof to determine conformance of thermistor sensors to the requirements of a specification, normally for the development of a qualified products list under the specification.

3.2.5 *response time, n*—the time required for a sensor to change a specified percentage of the total difference between its initial and final temperatures as determined from zero-power resistances when the sensor is subjected to a step function change in temperature.

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

3.2.7 *zero-power resistance, n*—the dc resistance of a device, at a specified temperature, calculated for zero-power.

3.2.7.1 *Discussion*—

Accurate zero-power resistance is obtained by extrapolating to zero-power the resistance values obtained from measurements at three or more levels of power with the sensor immersed in a constant temperature medium. For the purpose of this specification, this is obtained from measurements at a single power level ~~adjusted such that the power is~~that is adjusted or otherwise determined to be not greater than one-fifth the product of the dissipation constant specified in Table 1 (see ~~3.2.1~~3.2.1 and 7.3 ~~and 7.3~~) and the appropriate tolerance requirement of Table 3. Accordingly, the applied power levels required to satisfy the zero-power resistance criterion as defined above can be as little as 2 µW (for a Type W sensor with accuracy class 1) to as much as 600 µW (for Types J, K or P sensors with accuracy class 6). The known excitation current or voltage of the measurement system along with the resistance of the sensor at the selected temperature (from the nominal resistance and ratio values given in Table 2~~. When making stability measurements, the power~~) can be used to compute the actual applied power to the unit under test (UUT) and to determine if this power level meets the zero-power criterion. When making repeat measurements over a specified time period to determine the stability of a sensor, the power level shall be kept constant.

4. Classification

4.1 Thermistor sensors covered by this specification shall be classified with a ~~type designation~~unique identification code that includes the ASTM detailed specification number followed by a descriptive ~~code. See~~type designation code, an operating temperature range code, an accuracy class code, and a calibration type code. (See Fig. 1~~.~~.)

4.2 *ASTM Specification Number*—The ASTM specification number specifies uniquely the design and construction of the sensor including the type designation if more than one type appears in the same specification.

4.2.1 *Type Designation*—The type designation code shall be a letter symbol to indicate the design and construction of the thermistor ~~sensor.~~sensor followed by a number to indicate the subset of specific features as shown on the detailed specification drawing whenever there are design options. (See Fig. 2 through Fig. 10).

4.2.1.1 *Type S*—Silicone rubber-coated glass probe with tinned Dumet extension leads (see Fig. 2).

4.2.1.2 *Type E*—Epoxy-coated glass probe with silver-plated copper extension leads (see Fig. 3).

4.2.1.3 *Type G*—General purpose ~~four wire~~ four-wire sensor in stainless steel housing (see Fig. 4).

4.2.1.4 *Type H*—General purpose two-wire sensor in stainless steel housing (see Fig. 5).

4.2.1.5 *Type V*—Interchangeable sensor enclosed in ~~1.2-mm~~1.2 mm vinyl tube (see Fig. 6).

4.2.1.6 *Type W*—Non-interchangeable sensor enclosed in ~~0.9-mm~~0.9 mm vinyl tube (see Fig. 7).

4.2.1.7 *Type P*—Interchangeable sensor with flexible cable and sealed plastic tip (see Fig. 8).

TABLE ~~3 Letter Symbol Designation of Operating Temperature Ranges (See 4.1 and 4.3)~~

~~Operating Temperature Range~~	~~Letter Symbol~~
~~–10 to 105°C~~	~~A~~
~~–10 to 60°C~~	~~B~~

TABLE 1 Specification for ASTM Laboratory Thermistor Sensors

	E879 Type S	E879 Type E	E879 Type G	E879 Type H	E879 Type V	E879 Type W	E879 Type P	E879 Type J	E879 Type K
Description	Silicone Rubber Coated Glass Probe	Epoxy Coated Glass Probe	4-Wire Non-interchangeable Sensor in S.S. Housing	2-Wire Non-interchangeable Sensor in S.S. Housing	Interchangeable Sensor Enclosed in 1.17 mm Plastic Tube	Non-interchangeable Sensor Enclosedin 0.92 mm Plastic Tube	Interchangeable Sensor with flexible cable and plastic tip	Interchangeable Sensor in S.S. Housing	Interchangeable Sensor in S.S. Housing with 1/8-27 NPT body
Design and Construction	Fig. 2	Fig. 3	Fig. 4	Fig. 5	Fig. 6	Fig. 7	Fig. 8	Fig. 9	Fig. 10
Major Applications	General Purpose Laboratory Temperature Measurement	General Purpose Laboratory Temperature Measurement	General Purpose Laboratory Temperature Measurement	General Purpose Laboratory Temperature Measurement	Cuvette Thermometry	Cuvette Thermometry	General Purpose Laboratory Temperature Measurement	General Purpose Laboratory Temperature Measurement	General Purpose Laboratory Temperature Measurement
Design Exposure Temperature Limits									
minimum	–50 °C	–20 °C	–20 °C	–20 °C	–20 °C	–20 °C	–20 °C	–50 °C	–50 °C
maximum	125 °C	105 °C	105 °C	105 °C	70 °C	70 °C	105 °C	105 °C	150 °C
Available Accuracy Classes	1 (±0.01 °C)	1 (±0.01 °C)	1 (±0.01 °C)	1 (±0.01 °C)	. . .	. . .	. . .	. . .	. . .
	2 (±0.02 °C)	2 (±0.02 °C)	2 (±0.02 °C)	2 (±0.02 °C)	. . .	. . .	. . .	. . .	. . .
	3 (±0.05 °C)	3 (±0.05 °C)	3 (±0.05 °C)	3 (±0.05 °C)	. . .	. . .	. . .	. . .	. . .
	4 (±0.10 °C)	4 (±0.10 °C)	4 (±0.10 °C)	4 (±0.10 °C)	4 (±0.10 °C)	4 (±0.10 °C)	4 (±0.10 °C)	4 (±0.10 °C)	4 (±0.10 °C)
	. . .	. . .	. . .	. . .	5 (±0.20 °C)	5 (±0.20 °C)	5 (±0.20 °C)	5 (±0.20 °C)	5 (±0.20 °C)
	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	6 (±0.50 °C)
Available Operating Temperature Ranges	A (–10 °C to 105 °C)	A (–10 °C to 105 °C)	A (–10 °C to 105 °C)	A (–10 °C to 105 °C)	. . .	. . .	A (–10 °C to 105 °C)	A (–10 °C to 105 °C)	A (-10 °C to 105 °C)
	B (–10 °C to 60 °C)	B (–10 °C to 60 °C)	B (–10 °C to 60 °C)	B (–10 °C to 60 °C)	B (–10 °C to 60 °C)	B (–10 °C to 60 °C)	B (–10 °C to 60 °C)	B (–10 °C to 60 °C)	B (–10 °C to 60 °C)
	C (0 °C to 60 °C)	C (0 °C to 60 °C)	C (0 °C to 60 °C)	C (0 °C to 60 °C)	C (0 °C to 60 °C)	C (0 °C to 60 °C)	C (0 °C to 60 °C)	C (0 °C to 60 °C)	C (0 °C to 60 °C)
	D (0 °C to 70 °C)	D (0 °C to 70 °C)	D (0 °C to 70 °C)	D (0 °C to 70 °C)	D (0 °C to 70 °C)	D (0 °C to 70 °C)	D (0 °C to 70 °C)	D (0 °C to 70 °C)	D (0 °C to 70 °C)
	E (0 °C to 100 °C)	E (0 °C to 100 °C)	E (0 °C to 100 °C)	E (0 °C to 100 °C)	. . .	. . .	E (0 °C to 100 °C)	E (0 °C to 100 °C)	E (0 °C to 100 °C)
	. . .	. . .	. . .	. . .	. . .	. . .	. . .	F (-50 °C to 50 °C)	F (-50 °C to 50 °C)
Accuracies for Other Temperatures Within Specified Temperature Range	n/a	n/a	n/a	n/a	Class 3 (±0.05 °C) Over 24 °C to 45 °C	Class 3 (±0.05 °C) Over 24 °C to 45 °C	n/a	n/a	n/a
Calibration Type	Non-interchangeable	Non-interchangeable	Non-interchangeable	Non-interchangeable	Non-interchangeable	Non-nterchangeable	Interchangeable	Interchangeable	Interchangeable
Type of Immersion	water, air	water, oil, air	all fluids compatible with Type 304 S.S.	all fluids compatible with Type 304 S.S.	water	water	water, oil, air	all fluids compatible with Type 304 S.S.	all fluids compatible with Type 304 S.S.
Nominal Resistance at 25 °C in Ohms with applicable Curve (Ratio 25/125)	2500 (19.86)	2500 (19.86)	5000 (19.86)	5000 (19.86)	11 000 (20.37)	10 000 (19.86)	2252 (29.25)	2252 (29.25)	2252 (29.25)
	10 000 (22.73)	10 000 (22.73)	10 000 (22.06)	10 000 (22.06)	44 000 (20.37)	22 000 (20.37)	10 000 (29.25)	10 000 (29.25)	10 000 (29.25)
Dissipation Constant	3.5 ± 0.9 mW/K	5.0 ± 1.2 mW/K	4.8 ± 1.2 mW/K	4.8 ± 1.2 mW/K	1.1 ± 0.3 mW/K	0.8 ± 0.2 mW/K	6.0 ± 1.5 mW/K	6.0 ± 1.5 mW/K	6.0 ± 1.5 mW/K

63.2% Response Time	0.55 ± 0.16 s	0.45 ± 0.11	4.5 ± 1.1 s	4.5 ± 1.1 s	0.5 ± 0.12 s	0.26 ± 0.06 s	4.5 ± 1.1 s	4.5 ± 1.1 s	4.5 ± 1.1 s

TABLE ~~5~~6 Manufacturing Screening Tests

Examination or Test	Requirement Section	Test Method Section
Visual and mechanical	5.1	7.1
Zero-power resistance versus temperature relationship	5.2	7.2
Insulation resistance	5.8	7.8

4.2.1.8 *Type J*—Interchangeable sensor enclosed in stainless steel housing (see Fig. 9).

4.2.1.9 *Type K*—Interchangeable sensor enclosed in stainless steel housing with threaded pipe fitting (see Fig. 10).

4.3 *Operating Temperature Range*—The operating temperature range shall be designated by a letter symbol (see Table ~~3~~4).

4.4 *Accuracy Class*—The accuracy class shall be designated by a single-digit number (see Table ~~2~~3).

4.5 *Calibration Type*—The type of calibration required for each unit shall be designated by a letter symbol. The letter *I* shall be used to denote units that are interchangeable with respect to a single resistance-temperature relationship. The letter *N* shall be used to denote non-interchangeable units for which resistance-temperature information must be furnished for each unit. For Calibration Type N sensors, serial number identification must be provided.

4.6 *Zero-power Resistance at 25 °C*—Each of the individual thermistor sensor types shall have nominal zero-power resistance values at 25 °C as specified in Table 1 and as shown on the individual detailed specification drawings. Each nominal resistance value specified shall also have an associated resistance ratio-versus-temperature value that is characteristic of the thermistor material formulation employed in the sensor. The resistance ratio-versus-temperature data for the selected thermistor material formulations are shown in Table 2. Other nominal resistance values at 25 °C, or at another reference temperature, may be agreed upon by the manufacturer and end user provided that this information is clearly communicated in all appropriate documentation; and, that the unique identification code (see Fig. 4.1) is not used under such circumstances.

4.7 *Terminations*—The detailed specification drawings (see Fig. 2 through Fig. 10) show the sensors with the most common type of termination for that type designation. All sensors, regardless of type designation, may be terminated with any suitable electrical connector (as agreed upon by manufacturer and end user) such that it allows the sensor to interface with a specific thermometer system. It is recommended that the zero-power resistance measurements be performed only after any such modifications have taken place. Examples of such terminations shall include (but are not limited to) phone plugs; stereo plugs; multiple pin DIN type plugs; multiple pin "Deutsches Institut für Normung" (DIN) circular connectors; or, gold-plated terminals.

5. Requirements

5.1 *Specifications*—Sensors shall comply with the general requirements specified herein as well as with the applicable detailed specifications of Table 1, Table 2, and Fig. 2 through Fig. 10. In the event of conflict between this requirement ~~paragraph~~subsection and the detailed specification of Table 1, ~~Figs. 2-7~~Table 2, and Fig. 2 through Fig. 10, the latter shall govern.

5.2 *Zero-Power Resistance ~~versus~~Versus Temperature Relationship*—The zero-power resistance versus temperature relationship shall be presented in a form such that any temperature within the specified operating temperature range can be obtained from that relationship and have an uncertainty no greater than one-tenth the specified tolerance in Table ~~2~~3. When tested in accordance with 7.2, the zero-power resistance versus temperature relationship for interchangeable parts shall comply to within the tolerance specified in Table ~~2~~3. The manufacturer of the sensor shall, for non-interchangeable parts, supply this relationship with each part shipped. This relationship may be supplied in the form of data tables, or by providing the constants for one or more of the following thermistor equations, or both.

Equations representing this relationship use the standard curve fitting technique of considering the natural logarithm of the zero-power resistance to be a polynomial in reciprocal temperature, or vice versa. Although the polynomial equation can be of any higher order, historically it has been shown that a third order polynomial (Eq 2 and 3) provides excellent results over the relatively narrow temperature ranges of thermistor sensor applications. Furthermore, Steinhart and Hart have proven in oceanographic research studies over the range of –2 °C to +30 °C that satisfactory results are obtained when the squared term is omitted (Eq 4 and 5).[6]

Eq 4 and 5 have three unknown constants that are derived by the simultaneous solution of three equations based upon three calibration data points. Eq 2 and 3 have four unknown constants and thus a minimum of four calibration data points are required to solve for the constants. Frequently, more than four calibration data points are obtained and a polynomial regression analysis is performed to derive the constants for equations Eq 2 and 3. This has the benefit of statistically improving the accuracy of the data.

$$\ln R_T = \left[A_0 + A_1/T + A_2/T^2 + A_3/T^3\right] \quad (2)$$

$$1/T = a_0 + a_1 \ln(R_T) + a_2 \ln(R_T)^2 + a_3 \ln(R_T)^3 \quad (3)$$

[6] Steinhart, J.S., and Hart, S.R., "Calibration Curves for Thermistors," *Deep Sea Research*, Vol 15, No. 497, 1968.

TABLE 2 Resistance-temperature Data for ASTM Laboratory Thermistor Sensors

Curve Designation	(19.86)	(20.37)	(22.06)	(22.73)	(29.25)
Applicable Nominal Resistance at 25 °C (Ohms)	2500 4000 5000 10 000	11 000 22 000 44 000	5000 10 000	10 000 15 000	2252 10 000
Resistance ratio 25 °C to 125 °C	19.86 ± 10 %	20.37 ± 10 %	22.06 ± 10 %	2.73 ± 10 %	29.25 ± 10 %
Resistance ratio 0 °C to 50 °C	7.04 ± 6 %	7.08 ± 6 %	7.44 ± 6 %	7.58 ± 6 %	9.06 ± 6 %
Resistance ratio 0 °C to 70 °C	13.33 ± 8 %	13.45 ± 8 %	14.37 ± 8 %	14.75 ± 8 %	18.65 ± 8 %
Nominal ratio data:					
–50 °C	40.15	40.07	44.97	46.74	67.01
–40 °C	22.06	22.07	24.16	24.96	33.65
–30 °C	12.59	12.60	13.53	13.89	17.70
–20 °C	7.433	7.448	7.863	8.025	9.707
–10 °C	4.534	4.543	4.728	4.800	5.532
0 °C	2.849	2.853	2.932	2.962	3.265
10 °C	1.840	1.841	1.870	1.881	1.990
20 °C	1.840	1.219	1.224	1.227	1.249
25 °C	1.0000	1.0000	1.0000	1.0000	1.0000
30 °C	0.8262	0.8253	0.8215	0.8197	0.8057
40 °C	0.5725	0.5711	0.5633	0.5600	0.5327
50 °C	0.4048	0.4032	0.3942	0.3906	0.3603
60 °C	0.2917	0.2899	0.2811	0.2776	0.2487
70 °C	0.2138	0.2121	0.2040	0.2008	0.1751
80 °C	0.1593	0.1576	0.1504	0.1477	0.1255
90 °C	0.1206	0.1189	0.1126	0.1102	0.09156
100 °C	0.09245	0.0909	0.08547	0.08346	0.06784
105 °C	0.08138	0.0799	0.07484	0.07298	0.05876
110 °C	0.07186	0.0704	0.06573	0.06402	0.05107
120 °C	0.05654	0.0552	0.05117	0.04971	0.03896
125 °C	0.05036	0.0491	0.04534	0.04400	0.03419
130 °C	0.04487	0.0438	0.04029	0.03905	0.03010
140 °C	0.03619	0.0351	0.03209	0.03100	0.02352
150 °C	0.02953	0.0284	0.02577	0.02485	0.01859

TABLE ~~2~~3 Equivalent Temperature Tolerances for Different Class Sensors (See 4.1 and 4.4)

Accuracy Class	Temperature Tolerance, °C
1	±0.02
2	±0.03
3	±0.05
4	±0.1
5	±0.2
6	±0.5

$$\ln R_T = [B_0 + B_1/T + B_3/T^3] \quad (4)$$

$$1/T = b_0 + b_1 \ln(R_T) + b_3 \ln(R_T)^3 \quad (5)$$

where:

A_n, a_n = unique constants derived from calibrations performed at four or more specified data points,
B_n, b_n = unique constants derived from calibrations performed at three specified data points,
T = is the absolute temperature in kelvins, and
R_T = is the zero-power resistance at temperature T.

5.2.1 *Accuracy*—The resistance-temperature relationship, provided in Table ~~1~~2, or with the sensor, or both, shall not differ from that obtained from measurements made in accordance with 7.2 by more than the tolerances specified in Table ~~2~~3 for the applicable intervals specified in Table 1. When additional temperature intervals are specified within the operating temperature range, the accuracy class for each interval shall be clearly indicated by the manufacturer.

5.3 *Thermal Requirements:*

5.3.1 *Dissipation Constant*—When tested in accordance with 7.3, the dissipation constant shall be as specified in the detailed specification.

5.3.2 *Response Time*—When tested in accordance with 7.4, the response time or time constant, or both, shall be as specified in the detailed specification.

5.4 *Environmental Requirements:*

5.4.1 *Operating Temperature Range*—The operating temperature range shall be as specified in the type designation code (see 4.1 and 4.3).

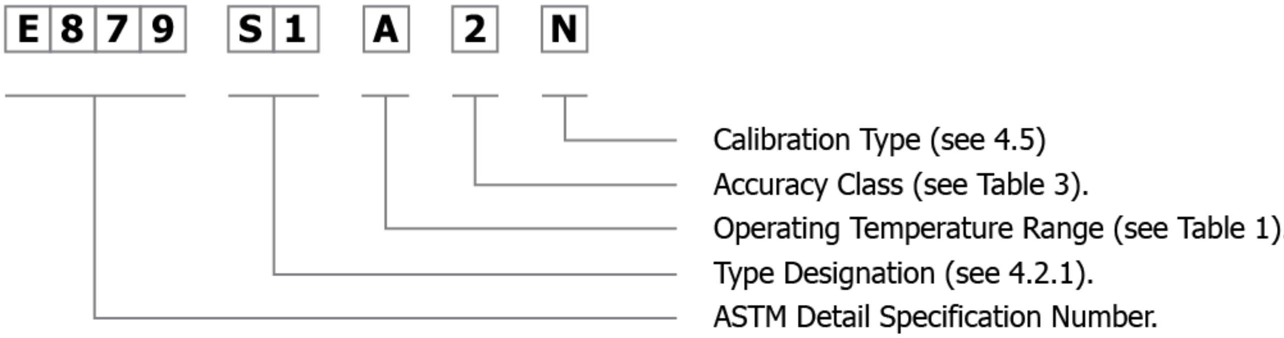
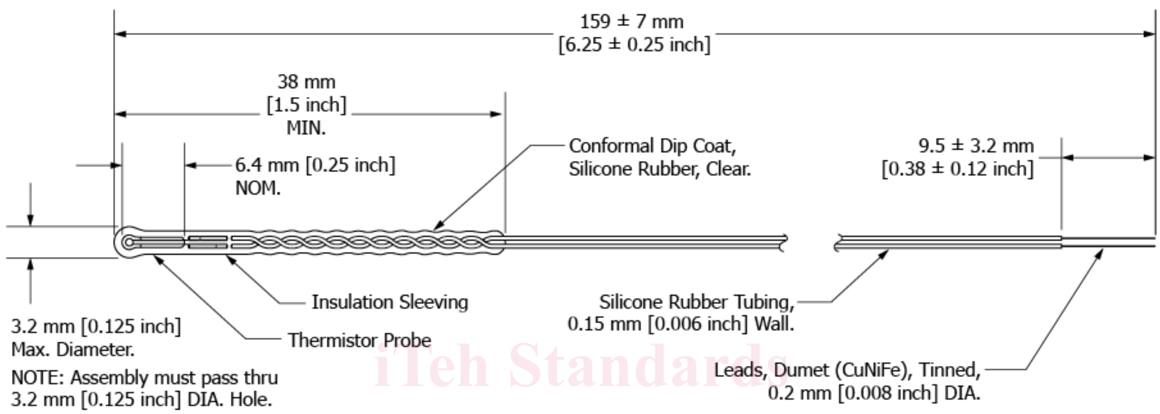


FIG. 1 ~~Classification~~ Thermistor Sensor Type Designation Code



Type Code	Resistance at 25 °C	Curve Ratio
S1	2500 Ohms	19.86
S2	10000 Ohms	22.73

TYPE - S: Silicone rubber-coated glass probe with tinned Dumet extension leads.

NOTE: METRIC [ENGLISH] --- ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE INDICATED.

FIG. 2 Silicone Rubber Coated Glass Probe (Type S)

5.4.2 *Storage Temperature Range*—Sensors shall be capable of meeting all requirements specified herein as well as those listed in the applicable detailed specification after storage at any temperature (or combination thereof) in the range ~~from –40 to 60°C for~~ from –50 °C minimum (or the design limit for minimum exposure temperature, whichever is higher) up to 60 °C maximum (or the design limit for maximum exposure temperature, whichever is lower) for a period of 1 year. Sensors subjected to operation or storage at temperatures that exceed their design limits may experience mechanical damage, degraded stability, or both, as well as unreliable performance.

5.4.3 *Humidity Requirement*—Sensors shall be capable of being operated or stored at relative humidity from 0 to 95 % without condensation.

5.5 *Stability:*

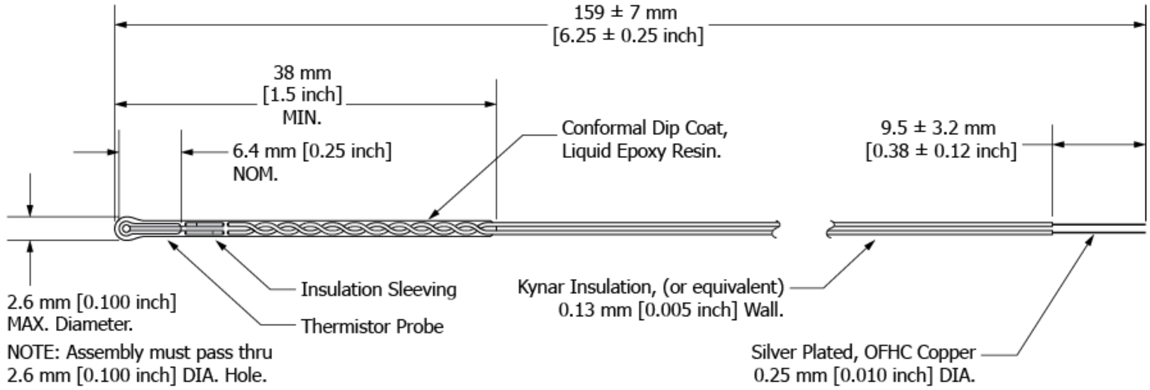
5.5.1 *~~Short-Term~~Short-term Stability* (10 days)—When tested in accordance with 7.5.1, the equivalent temperature shift shall be no greater than 10 % of the tolerance shown in Table ~~2~~3 for the accuracy class specified.

5.5.2 *~~Long-Term~~Long-term Stability* (120 days)—When tested in accordance with 7.5.2, the equivalent temperature shift shall be no greater than 25 % of the tolerance shown in Table ~~2~~3 for the accuracy class specified.

5.6 *~~Low-Temperature~~Low-temperature Storage*—When tested in accordance with 7.6, there shall be no evidence of mechanical damage and the sensor shall comply with the accuracy requirements of 5.2.

5.7 *Thermal Shock*—When tested in accordance with 7.7, there shall be no evidence of mechanical damage and the sensor shall comply with the accuracy requirements of 5.2.

5.8 *Insulation Resistance:*

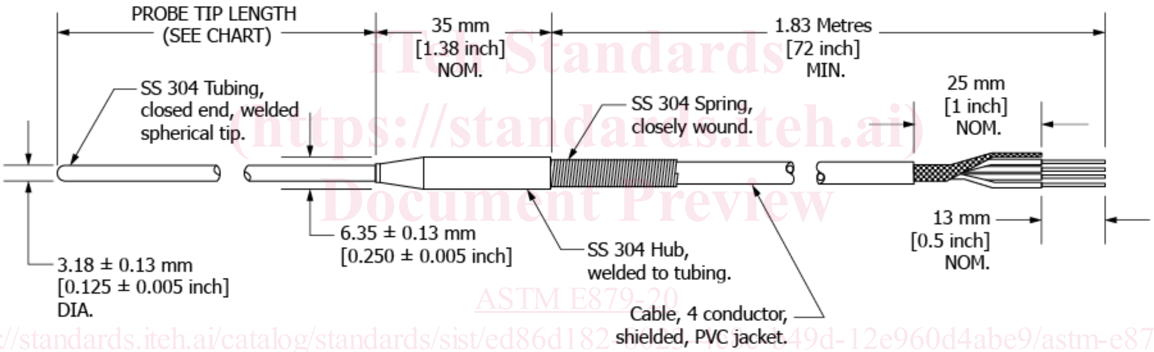


Type Code	Resistance at 25 °C	Curve Ratio
E1	2500 Ohms	19.86
E2	10000 Ohms	22.73

TYPE - E: Epoxy-coated glass probe with silver-plated copper extension leads.

NOTE: METRIC [ENGLISH] --- ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE INDICATED.

FIG. 3 Epoxy Coated Glass Probe (Type E)



Type Code	Probe Tip Length	Resistance at 25 °C	Curve Ratio
G1	114 ± 2 mm [4.5 ± 0.08 inch]	5000 Ohms	19.86
G2	152 ± 2 mm [6.0 ± 0.08 inch]	10000 Ohms	22.06
G3	165 ± 2 mm [6.5 ± 0.08 inch]	5000 Ohms	19.86
G4	229 ± 2 mm [9.0 ± 0.08 inch]	10000 Ohms	22.06

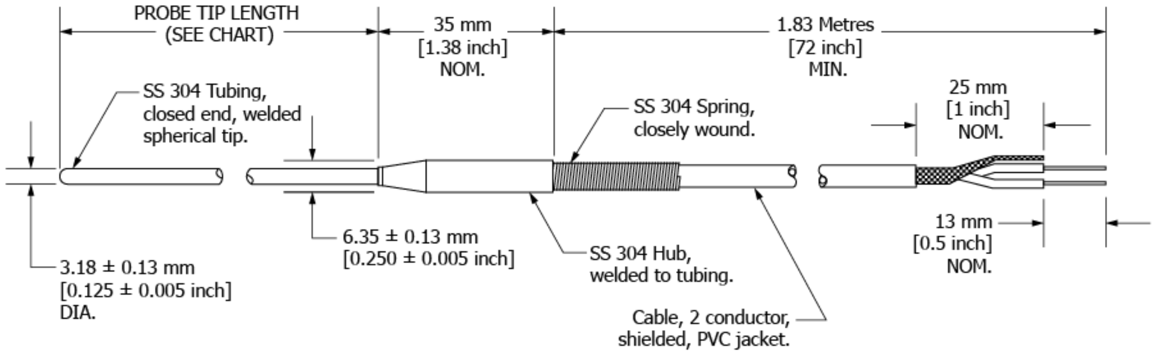
TYPE - G: General purpose four-wire sensor in stainless steel housing.

NOTE: METRIC [ENGLISH] --- ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE INDICATED.

FIG. 4 General Purpose ~~Four-Wire~~Four-wire Sensor in Stainless Steel Housing (Type G)

5.8.1 *Dry Test*—This requirement shall apply to sensors that have exposed metallic surfaces, but are not designed for immersion in conductive fluids. When tested in accordance with 7.8.1, there shall be no evidence of mechanical damage and the insulation resistance shall be sufficiently high that its shunting effect will not prevent the unit from complying with the accuracy requirement of Table ~~2~~3. In no case shall the insulation resistance be less than 10^8 ~~ohms.~~ Ω.

5.8.2 *Wet Test*—This requirement shall apply to sensors that are designed for use in conductive solutions. When tested in accordance with 7.8.2, there shall be no evidence of mechanical damage and the insulation resistance shall be sufficiently high that its shunting effect will not prevent the unit from complying with the accuracy requirement of Table ~~2~~3. In no case shall the insulation resistance be less than 10^8 ~~ohms.~~ Ω.

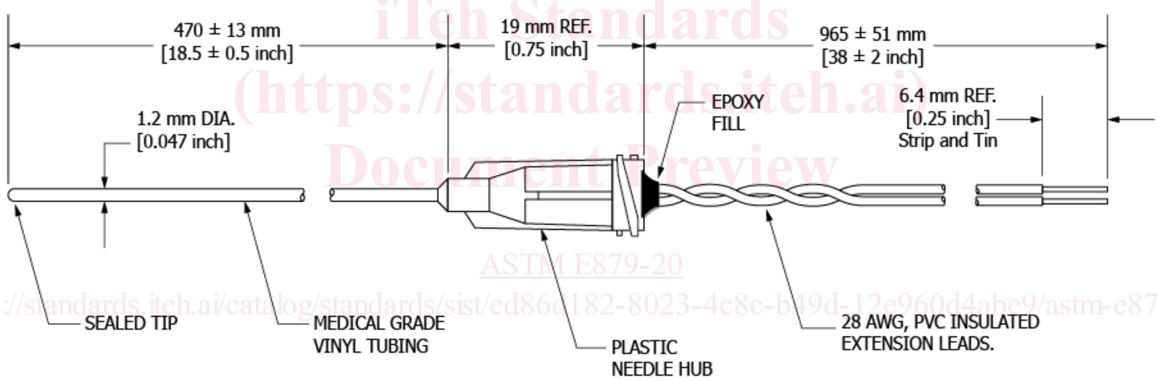


Type Code	Probe Tip Length	Resistance at 25 °C	Curve Ratio
H1	114 ± 2 mm [4.5 ± 0.08 inch]	5000 Ohms	19.86
H2	152 ± 2 mm [6.0 ± 0.08 inch]	10000 Ohms	22.06
H3	165 ± 2 mm [6.5 ± 0.08 inch]	5000 Ohms	19.86
H4	229 ± 2 mm [9.0 ± 0.08 inch]	10000 Ohms	22.06

TYPE - H: General Purpose two-wire sensor in stainless steel housing.

NOTE: METRIC [ENGLISH] --- ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE INDICATED.

FIG. 5 General Purpose ~~Two-Wire~~Two-wire Sensor in Stainless Steel Housing (Type H)



Type Code	Resistance at 25 °C	Curve Ratio
V1	11000 Ohms	20.37
V2	44000 Ohms	20.37

TYPE - V: interchangeable sensor enclosed in 1.2 mm sealed vinyl tubing.

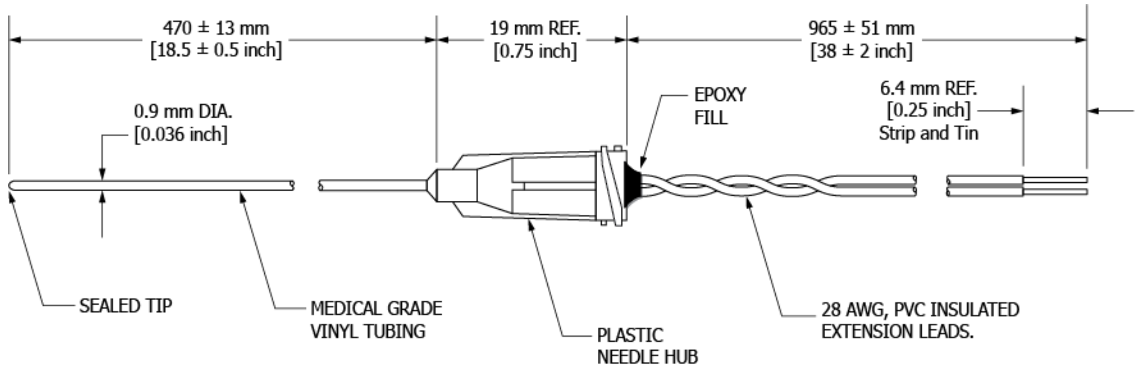
NOTE: METRIC [ENGLISH] --- ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE INDICATED.

FIG. 6 Interchangeable Sensor Enclosed in 1.2 mm Vinyl Tube (Type V)

6. Quality Assurance Provisions

6.1 *General*—The methods of examination and tests con-tained in Section 7 are to be used to determine the conformance of sensors to the requirements of this specification. Each manufacturer or distributor who represents his products as conforming to this specification may, as agreed upon between the purchaser and seller, use statistically based sampling plans that are appropriate for each inspection lot. Records shall be kept as necessary to document the claim that all of the requirements of this specification are met. The tests specified in this section are intended as minimum requirements. Additional sampling and testing of the product, as may be agreed upon between the purchaser and the seller, are not precluded by this section.

6.2 *Classification of Inspection:*

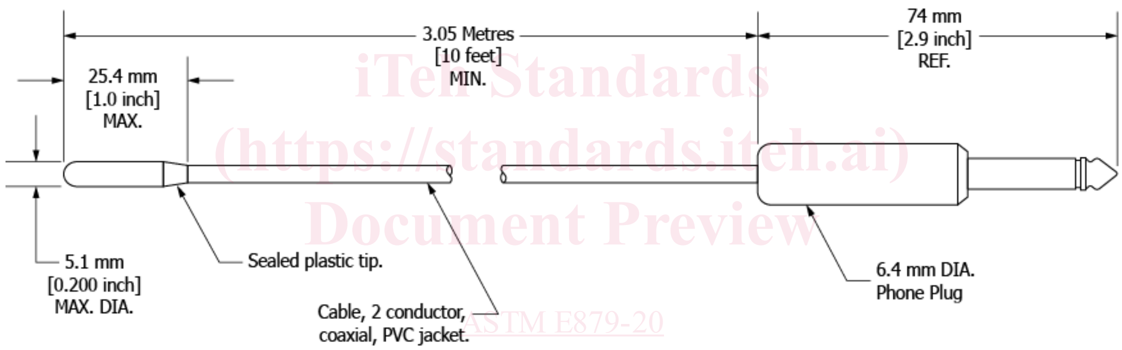


Type Code	Resistance at 25 °C	Curve Ratio
W1	10000 Ohms	19.86
W2	22000 Ohms	20.37

TYPE - W: Non-interchangeable sensor enclosed in 0.9 mm sealed vinyl tubing.

NOTE: METRIC [ENGLISH] --- ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE INDICATED.

FIG. 7 Non-Interchangeable Sensor Enclosed in 0.9 mm Vinyl Tube



Type Code	Resistance at 25 °C	Curve Ratio
P1	2252 Ohms	29.25
P2	10000 Ohms	29.25

TYPE - P: General Purpose interchangeable sensor with flexible cable and sealed plastic tip.

NOTE: METRIC [ENGLISH] --- ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE INDICATED.

FIG. 8 Interchangeable Sensor with Flexible Cable and Sealed Plastic Tip (Type P)

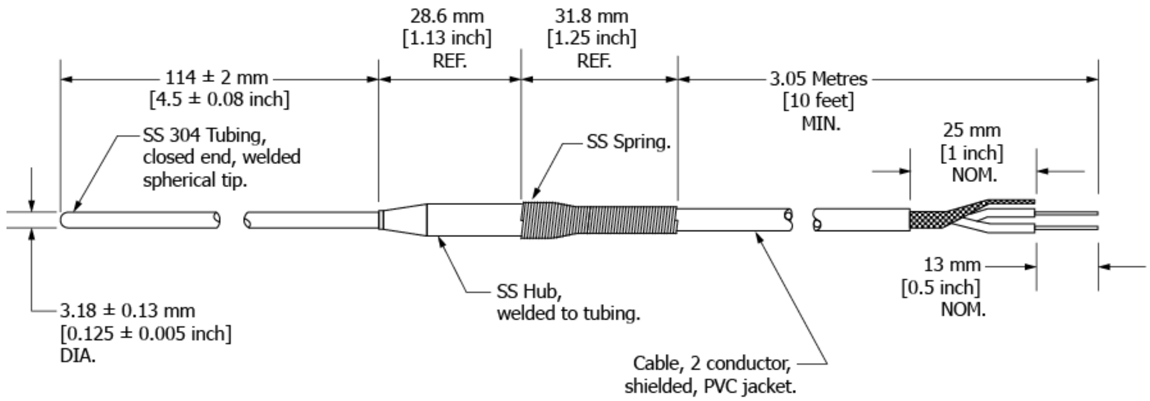
6.2.1 *Qualification Tests*—Qualification tests shall be performed for each basic design manufactured in accordance with this specification. The sample size required for the tests conducted shall be in accordance with Table ~~4~~5. In order for a design to qualify, there shall be no failures resulting from any of the tests.

6.2.2 *Responsibility for Qualification Testing*—The manufacturer shall perform qualification testing, at least once, for each basic design for which this specification applies. If a basic design incorporates more than one resistance value of a specific material formulation or a particular style of thermistor, or both, different resistance values may be combined for the qualification sample. The highest and lowest resistance values for a specified thermistor design (type, material formulation, and geometry) must be included in the qualification sample. Qualification testing, by the manufacturer, must be repeated whenever a design change ~~is introduced~~ which may affect the performance of the sensor with regard to Section 5 of this ~~specification.~~specification is introduced..

6.2.3 *Manufacturing Screening Tests*—During manufacture, all parts produced in accordance with this specification shall receive 100 % testing for compliance with the requirements of Table ~~5~~6.

7. Methods of Examination and Test

7.1 *Visual and Mechanical Examination*—Examine sensors to verify that their design, construction, physical dimensions, markings, and workmanship comply with the detailed specification.

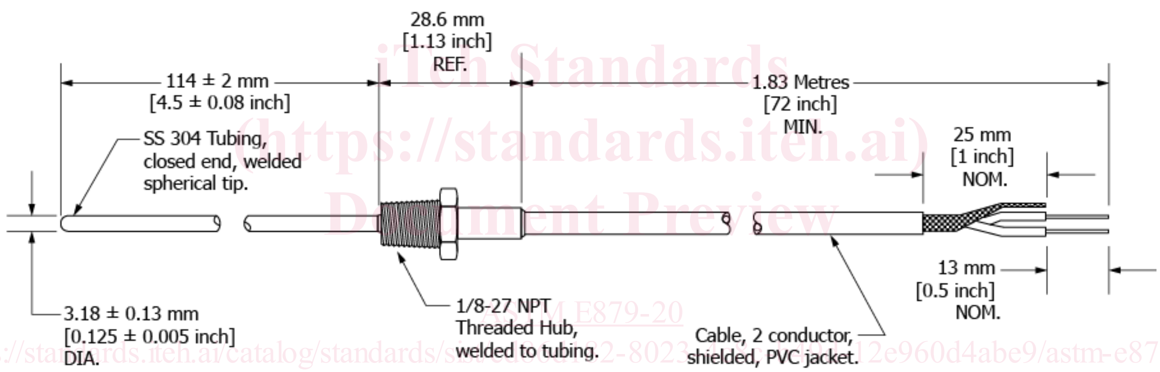


Type Code	Resistance at 25 °C	Curve Ratio
J1	2252 Ohms	29.25
J2	10000 Ohms	29.25

TYPE - J: General Purpose interchangeable sensor in stainless steel housing.

NOTE: METRIC [ENGLISH] --- ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE INDICATED.

FIG. 9 Interchangeable Sensor In Stainless Steel Housing (Type J)



Type Code	Resistance at 25 °C	Curve Ratio
K1	2252 Ohms	29.25
K2	10000 Ohms	29.25

TYPE - K: General Purpose interchangeable sensor in stainless steel housing with pipe fitting body.

NOTE: METRIC [ENGLISH] --- ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE INDICATED.

FIG. 10 Interchangeable Sensor In Stainless Steel Housing With Pipe Fitting (Type K)

7.2 *~~Zero-Power~~Zero-power Resistance versus Temperature ~~Relationship~~Relationship:*[7,8,9]~~:~~

7.2.1 *Traceability*—All measurements shall be traceable to the ~~National Institute~~ International System of Units (SI) through a National 4,5,6. Metrology Institute (NMI) such as the National Institute of Standards and Technology (NIST) ~~through the use of~~ using suitable reference standards with documentation.

7.2.1.1 *Measurement System Uncertainties*—Uncertainties exist in all measurements and these must be properly evaluated in order to have confidence in the measurement results. An uncertainty budget is an analysis tool that should be used before the zero-power measurements are taken in order to determine if the measurement system is capable of achieving the desired results. The uncertainty budget will identify the sources of uncertainty and their individual contributions to the overall uncertainty of the

[7] Mangum, B. W., "Platinum Resistance Thermometer Calibration," *NBS Special Publication ~~250-22~~250-22,* ~~(1987).~~1987.

[8] Mangum, B. W., and Furukawa, G. T., "Guidelines for Realizing the International Temperature Scale of 1990 ~~(ITS-90)~~(ITS-90)," *NIST Technical Note 1265*, ~~(1990).~~1990.

[9] Riddle, J. L., Furukawa, G. T., and Plumb, H. H., "Platinum Resistance Thermometry," *NBS Monograph 126*, ~~(1973).~~1973.

TABLE 4 Letter Symbol Designation of Operating Temperature Ranges (See 4.1 and 4.3)

Operating Temperature Range	Letter Symbol
−10 °C to 105 °C	A
−10 °C to 60 °C	B
0 °C to 60 °C	C
0 °C to 70 °C	D
0 °C to 100 °C	E
−50 °C to 50 °C	F

TABLE 45 Qualification Tests Required for Each Basic Design

Examination or Test	Requirement Section(s)	Method Section(s)	Sample Size
Visual and mechanical	5.1	7.1	10
Zero-power resistance versus temperature relationship	5.2	7.2	10
Dissipation constant	5.3.1	7.3	5
Response time	5.3.2	7.4	5
Short-term stability	5.5.1	7.5.1	10
Long-term stability	5.5.2	7.5.2	10
Low-temperature storage	5.6	7.6	10
Thermal shock	5.7	7.7	10
Insulation resistance	5.8	7.8	10

measurement system. The result of the analysis is a combined expanded uncertainty, symbol U, for the measurement system. Typically, U is given at a coverage factor of 2, approximating to a 95 % confidence level. For the purpose of performing the zero-power resistance-versus-temperature measurements herein, it is recommended that the resulting combined expanded uncertainty for the measurement system in use should not exceed 25 % of the allowable tolerance for the accuracy class of the sensor to be tested. This provides a desired test uncertainty ratio, TUR, of 4:1 and thus there is a reasonable degree of confidence in the measurement data. Refer to Appendix X2 for a more in-depth discussion of the concepts and sources of measurement uncertainty, as well as examples. Also refer to ANSI/NCSL Z540.3 for additional guidance on requirements for calibration of measuring and test equipment.

7.2.2 *Temperature-Controlled Medium—Temperature-controlled Medium:* Make all measurements in a temperature-controlled liquid bath (such as a water bath). The volume of the liquid should be at least 1000 times the volume of the sensor(s) under test, but shall not be less than 1 L. Baths having volumes as large as 100 L have been found to be convenient to use and to be satisfactory with respect to temperature control. Ensure that the bath medium is sufficiently well-stirred that temperature gradients are small compared with the temperature accuracy required. Survey the bath with a thermometer to ensure that its temperature is uniform to the extent necessary to perform the tests. If the operating temperature range of the thermistor sensor includes the ice-point temperature, the water triple-point temperature, or the gallium melting-point temperature, then an ice-point bath, a water triple-point cell, or a gallium melting-point cell may be used as the temperature-controlled medium at that respective temperature.

7.2.2.1 *Comparison Baths*—Make all zero-power resistance versus temperature relationship measurements in a temperature-controlled liquid bath (such as a water bath). The volume of the liquid should be at least 1000 times the volume of the sensor(s) under test, but shall not be less than 1 L. Baths having volumes as large as 100 L have been found to be convenient to use and to be satisfactory with respect to temperature control. Ensure that the bath medium is sufficiently well-stirred so that temperature gradients are small compared with the temperature accuracy required. Survey the bath with a thermometer to ensure that its temperature is uniform and stable to the extent necessary to perform the tests. For further information refer to Guide E2488 which describes methods to define the working space of a bath and to evaluate the temperature uniformity and stability within this space. Ideally, the working space will be as close as possible to isothermal. If needed, a thermal integrating block (equalization block) can be utilized to enhance performance and thus minimize the uncertainty contributed by the comparison bath.

7.2.2.2 *Fixed-point temperatures*—If the operating temperature range of the thermistor sensor includes the ice-point temperature, the water triple-point temperature, or the gallium melting-point temperature, then an ice-point bath, a water triple-point cell, or a gallium melting-point cell may be used as the temperature-controlled medium at that respective temperature. Refer to Practice E563 and Guides E1502 and E1750 for additional guidance and information on the use of fixed-point temperatures.

7.2.3 *Temperature Monitoring and Control*—Determine the temperature While performing the zero-power resistance versus temperature measurements, observe the temperature fluctuations of the bath with a check standard thermometer having a response time that is shorter than or equal to that of the unit under test. The thermometer used to monitor the bath shall have a maximum uncertainty of one-third of the tolerance specified in Table 2. The total uncertainty resulting from the combined uncertainties of the monitor check standard thermometer and the bath temperature (due to temperature fluctuations and bath gradients within the