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Standard Specification for Industrial Platinum Resistance Thermometers[1]

This standard is issued under the fixed designation E1137/E1137M; 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 requirements for metal-sheathed industrial platinum resistance thermometers (PRT's) suitable for direct immersion temperature measurement. It applies to PRT's with an average temperature coefficient of resistance between 0 and 100 °C of 0.385 %/°C and nominal resistance at 0 °C of 100 Ω or other specified value. This specification covers PRT's suitable for all or part of the temperature range −200 to 650 °C. The resistance-temperature relationship and tolerances are specified as well as physical, performance, and testing requirements.

1.2 The values of temperature in this specification are based on the International Temperature Scale of 1990 (ITS-90).[2]

1.3 The values stated in inch-pound units or SI (metric) units may be regarded separately as standard. The values stated in each system are not exact equivalents, and each system shall be independent of the other.

1.4 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

A269 Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service

B167 Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, N06045, and ~~N06045)~~N06696) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Seamless Pipe and Tube

E344 Terminology Relating to Thermometry and Hydrometry

E644 Test Methods for Testing Industrial Resistance Thermometers

E1652 Specification for Magnesium Oxide and Aluminum Oxide Powder and Crushable Insulators Used in the Manufacture of Metal-Sheathed Platinum Resistance Thermometers, Base Metal Thermocouples, and Noble Metal Thermocouples

3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification see Terminology ~~E 344~~E344.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *connecting wire end closure*, *n*—moisture barrier at the connecting wire end of the sheath.

3.2.1.1 *Discussion*—The closure is intended to provide a seal sufficient to prevent the sensor's insulation resistance from dropping below the minimum requirements.

3.2.2 *connecting wires*, *n*—wires that run from the element through the connecting wire end closure and external to the sheath.

3.2.3 *excitation*, *n*—electrical current passing through the element.

3.2.4 *g-level*, *n*—acceleration of an object relative to the local acceleration of gravity.

3.2.4.1 *Discussion*—For example, a g-level of 5 is equivalent to an acceleration of approximately $5 \times 9.8\ m/s^2 = 49.0\ m/s^2$.

3.2.5 *minimum immersion length*, *n*—depth that a thermometer should be immersed, in a uniform temperature environment, such that further immersion does not produce a change in indicated temperature greater than the specified tolerance.

3.2.6 *PRT design*, *n*—generic term used to differentiate between different PRT construction details, such as element and

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[2] Preston-Thomas, H., "The International Temperature Scale of 1990 (ITS-90)," ~~*Metrologia*, Vol 27, No. 1, 1990, pp. 3–10. For errata see *ibid*, Vol 27, No. 2, 1990, p. 107.~~ Metrologia , Vol 27, No. 1. 1990, pp 3– 10, *ibid*, Vol 27, No. 2, 1990, p107

[3] 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.

connecting wire construction, insulation methods, sealing techniques, and mounting methods (for example, spring loaded or direct mounting).

3.2.7 *self-heating*, *n*—change in temperature of the element caused by the heating effect of the excitation.

3.2.8 *sheath*, *n*—cylindrical metal tube with an integral welded closure at the end in which the element is located.

4. Significance and Use

4.1 This specification is written to provide common terminology, resistance versus temperature characteristics, accuracy classification, and inspection requirements for a specified configuration of a typical industrial platinum resistance thermometer (PRT).

4.2 This specification may be used as part of the documentation to support negotiations for the purchase and discussion of such thermometers.

5. Classification of Tolerances

5.1 The PRT shall conform to the resistance-temperature relation (see 9.2.1) within the following tolerances:

$$\text{Grade } A = \pm[0.13 + 0.0017|t|]°C \quad (1)$$

where:

$|t|$ = value of temperature without regard to sign, °C.

5.1.1 The tolerances are given in Table 1 for a PRT with a nominal resistance of 100 Ω at 0 °C.

6. Ordering Information

6.1 The purchase order documents shall specify the following information to ensure that the PRT is adequately described:

6.1.1 The number of this specification,

6.1.2 Sheath diameter and overall length (see Fig. 1),

6.1.3 Sheath material,

6.1.4 Minimum and maximum sensed temperature,

6.1.5 Maximum and minimum temperature at connecting wire end closure,

6.1.6 Connection configuration; 2-Wire, 3-Wire, 4-Wire (potentiometric), and compensating loop (4-Wire) (see Fig. 2),

6.1.7 Tolerance, (Grade A, or Grade B),

6.1.8 Nominal resistance at 0 °C (100 Ω unless otherwise specified), and

6.1.9 Serial Number identification requirement (mandatory if an individual calibration or test record will be maintained).

7. Materials and Manufacture

7.1 All materials used shall be in accordance with the following requirements:

7.1.1 *Sheath Materials*—For temperatures not exceeding 480 °C, austenitic stainless steel tubing, conforming to Specification ~~A 269~~A269. For temperatures not exceeding 650 °C, high-nickel alloy tubing, conforming to Specification ~~B 167~~B167.

7.1.2 *Sensing Element*—Sensing element shall be platinum.

7.1.3 *Insulation*—The insulating material within the PRT shall be compatible with the temperature range −200 °C to 650 °C or as specified in 6.1.4. Magnesium oxide (MgO) and aluminum oxide (Al_2O_3) powders and crushable insulators conforming to Specification ~~E 1652~~E1652 satisfy this requirement.

7.1.4 *Connecting Wire End Closure Materials*—Closure materials shall provide a barrier against water and other liquids and generally prevent the penetration of water vapor. Any material used shall be compatible with the ambient temperatures specified for the application (see 6.1.5).

TABLE 1 Classification Tolerances[A, B]

Temperature, *t*, °C	Grade A		Grade B	
	°C	Ω	°C	Ω
– 200	0.47	0.20	1.1	0.47
– 100	0.30	0.12	0.67	0.27
0	0.13	0.05	0.25	0.10
100	0.30	0.11	0.67	0.25
200	0.47	0.17	1.1	0.40
300	0.64	0.23	1.5	0.53
400	0.81	0.28	1.9	0.66
500	0.98	0.33	2.4	0.78
600	1.15	0.37	2.8	0.89
650	1.24	0.40	3.0	0.94

[A] The table represents values for 3-wire and 4-wire PRT's. Caution must be exercised with 2-wire PRT's because of possible errors caused by connecting wires.

[B] Tabulated values are based on elements of 100.0 Ω (nominal) at 0 °C.

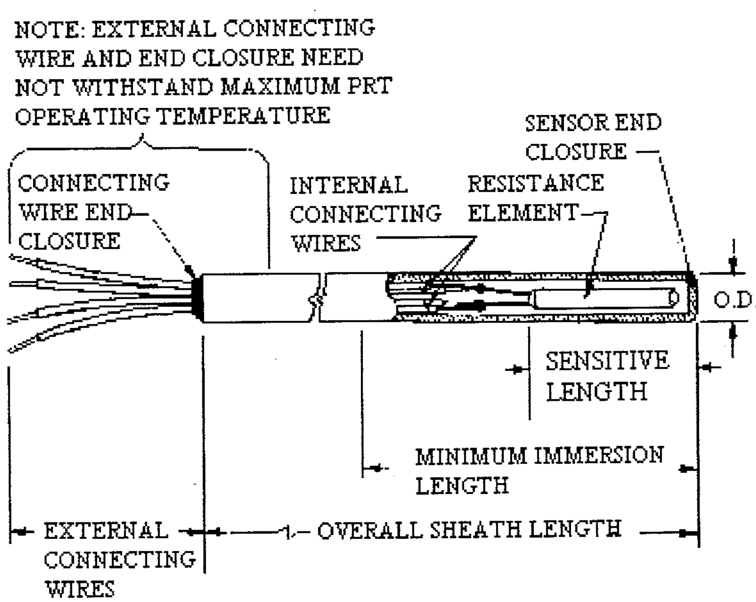

FIG. 1 Typical Industrial Platinum Resistance Thermometer

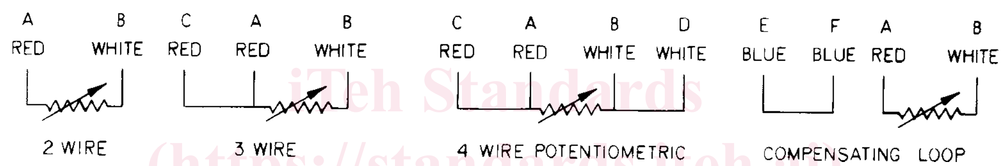

FIG. 2 Connection Configurations

7.1.4.1 Typically, epoxy materials are used for ambient temperatures less than 200 °C and moisture impervious ceramic adhesives are used over 200 °C, but the connecting wire end closure shall not be limited to these materials if the end closure meets all other requirements of this specification.

7.1.5 *Connecting Wires*—Typically, materials of connecting wires are: nickel plated copper, nickel, platinum, constantan, or manganin. Individual connecting wires may be comprised of two or more different materials and sizes over their length to accommodate different requirements internal and external to the sensor sheath. Where different materials are used, care must be exercised in their selection to minimize thermoelectrically induced measurement error (see 9.6). Any material used in joining the connecting wires to the PRT element must withstand the maximum operating temperature of the PRT.

8. Other Requirements

8.1 *Pressure*—The PRT shall withstand an external pressure of 21 MPa (3000 psig) and shall be tested in accordance with Test Methods ~~E 644~~E644 pressure test. The PRT shall remain within the tolerance specified in 5.1.

8.2 *Vibration*:

8.2.1 The PRT shall withstand vibration testing as described in Test Methods ~~E 644~~E644 using the test parameters in Table 2.

8.2.2 The PRT shall be mounted by installation in the thermowell or by threaded connection to simulate normal mounting procedure as limited by Table 2.

TABLE 2 Vibration Test Parameters

NOTE 1— The values in Table 2 apply to a PRT mounted in a thermowell with nominal diametral clearance of less than 0.25 mm (0.01 in.). If the PRT is not mounted in a thermowell, the values in Table 2 apply to a PRT with an unsupported stem length less than 100 mm (4 in.).

Frequency	5 to 500 Hz
Test Level	1.27-mm (0.05-in.) double amplitude displacement or peak g-level of 3, whichever is less
Resonant Dwell Time	30 min for each resonant point
Cycling Time	3 h per axis less the time spent at resonant dwells at the axis.
Mounting	As normally mounted including the mating thermowell, if applicable.

8.2.3 The PRT shall be continuously energized with an oscilloscope-monitored 1.0-mA dc excitation. There shall be no discontinuity of the monitored trace during the test.

8.2.4 After the PRT is tested for vibration the insulation resistance of the PRT shall remain within the tolerance of Table 3 and the resistance at 0 °C within the tolerance specified in 5.1.

8.3 *Mechanical Shock*:

8.3.1 The PRT shall withstand mechanical shock testing as described in Test Methods ~~E 644~~E644. The half-sine pulse shall have a peak g-level of 50 and duration of 11 ms.

8.3.2 The PRT shall be continuously energized with an oscilloscope-monitored 1.0-mA dc excitation. There shall be no discontinuity of the monitored trace during the test.

8.3.3 After the PRT is tested for mechanical shock, the insulation resistance of the PRT shall remain within the tolerance of Table 3 and the resistance at 0 °C within the tolerance in 5.1.

8.4 *Thermal*:

8.4.1 The PRT shall be capable of continuous operation over the specified temperature range (see 6.1).

8.4.2 The connecting wire end closure and external connecting wires need not withstand the entire PRT operating temperature range. As a minimum, these materials must withstand the ambient temperature limits specified for the application (see 6.1.5).

9. Performance

9.1 *Excitation*:

9.1.1 The PRT must be constructed such that it is usable in ac or dc measurement systems. In ac measuring systems, reactance effects shall be considered.

9.1.2 The PRT shall be capable of operating with continuous excitation of 10 mA. However, excitation of 1 mA or less is recommended to minimize measurement errors associated with self-heating (see 9.4).

9.2 *Resistance versus Temperature Relation*:

9.2.1 *Resistance-Temperature Equations*—Within the specified tolerances (see 5.1), the PRT shall have resistance-temperature characteristics defined as follows:
for the range $-200\ °C \leq t < 0\ °C$:

for the range $0\ °C \leq t \leq 650\ °C$:

where:

t = temperature (ITS-90), °C,
R_t = resistance at temperature (t),
R_o = resistance at 0 °C,
A = $3.9083 \times 10^{-3}\ °C^{-1}$,
B = $-5.775 \times 10^{-7}\ °C^{-2}$, and
C = $-4.183 \times 10^{-12}\ °C^{-4}$.

9.2.2 *Resistance Table*—Resistance values of the PRT versus temperature using the equations of 9.2.1 and R_o of 100 Ω are given in Table 4.

9.2.3 Inverse equations that may be used to compute values of temperature (°C) as a function of resistance are given in Appendix X1.

9.3 *Insulation Resistance*—The insulation resistance between each connecting wire and the sheath shall meet the requirements of Table 3 when tested in accordance with Test Methods ~~E 644~~E644. The PRT shall be tested with at least the minimum immersion length exposed to the temperature environment.

9.4 *Self-Heating*—A power of at least 33 mW shall be required to produce a self-heating of 1 °C when the PRT is tested in water in accordance with Test Methods ~~E 644~~E644.

9.5 *Thermal Response Time*—The 63.2 % response time shall not exceed the values in Table 5 when determined in accordance with Test Methods ~~E 644~~E644. The step change in temperature shall be from 20 ± 5 °C air to 77 ± 5 °C water flowing at 0.9 ± 0.09 m/s (3.0 ± 0.3 ft/s).

9.6 *Thermoelectric Effect*— When tested in accordance with Test Methods ~~E 644~~E644 at the upper operating temperature, the PRT shall remain within the tolerances specified in 5.1 with an excitation current of 1-mA dc ± 15 %, regardless of polarity.

NOTE 1—Internal and external connecting wire composition, wire inhomogeneity, and temperature gradients within the PRT can be sources for generation of thermoelectric EMF. Some resistance determination error can result from this EMF. The magnitude and sense of this thermoelectric effect error depends on the excitation current, temperature distribution, and construction of the PRT. For a given PRT, the thermoelectric effect can be minimized by using an alternating polarity excitation with a suitable measurement circuitry.

TABLE 3 Insulation Resistance

Applied dc Voltage, Volts dc		Minimum Insulation Resistance	
min	max	°C	MΩ
10	50	25 ± 5	100
10	50	300 ± 10	10
10	50	650 ± 15	2