Designation: E2181/E2181M – 06$^{\varepsilon 1}$

Standard Specification for Compacted Mineral-Insulated, Metal-Sheathed, Noble Metal Thermocouples and Thermocouple Cable[1]

This standard is issued under the fixed designation E2181/E2181M; 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.

ε^1 NOTE—Editorial changes were made in 1.3 and 5.2.1 in November 2006.

1. Scope

1.1 This specification establishes dimensional and material requirements for compacted, mineral-insulated, metal-sheathed, Type S (platinum-10 % rhodium versus platinum), Type R (platinum-13 % rhodium versus platinum), and Type B (platinum-30 % rhodium versus platinum-6 % rhodium) noble metal thermocouples. This specification also establishes dimensional and material requirements for compacted, mineral-insulated, metal-sheathed cable with at least one noble metal thermoelement pair.

1.2 This specification describes both the required processing and testing requirements and also the optional supplementary testing and quality assurance requirements.

1.3 Provisions are made for selecting the type of noble metal thermocouple or thermoelements, either magnesia (MgO) or alumina (Al_2O_3) insulation, and a noble metal alloy or other alternate heat-resistant sheath material. Provisions are also made for selecting a thermocouple measuring junction style and for a transition or termination.

1.4 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 the exact equivalents, and each system shall be used independently of the other.

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 and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 The following documents of the latest issue form a part of this specification to the extent specified herein. In the event of a conflict between this specification and other specifications referenced herein, this specification shall take precedence.

2.2 *ASTM Standards:*[2]

A213/A213M Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes

A249/A249M Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes

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

A632 Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service

B163 Specification for Seamless Nickel and Nickel Alloy Condenser and Heat-Exchanger Tubes

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

B516 Specification for Welded Nickel-Chromium-Iron Alloy (UNS N06600, UNS N06603, UNS N06025, and UNS N06045) Tubes

E165 Practice for Liquid Penetrant Examination for General Industry

E220 Test Method for Calibration of Thermocouples By Comparison Techniques

E230 Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples

E344 Terminology Relating to Thermometry and Hydrometry

E608/E608M Specification for Mineral-Insulated, Metal-Sheathed Base Metal Thermocouples

E839 Test Methods for Sheathed Thermocouples and Sheathed Thermocouple Material

E1652 Specification for Magnesium Oxide and Aluminum

[1] This specification is under the jurisdiction of ASTM Committee E20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.04 on Thermocouples.

Current edition approved May 1, 2006. Published May 2006. Originally approved in 2001. Last previous edition approved in 2001 as E2181/E2181M – 01. DOI: 10.1520/E2181_E2181M-06E01.

[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.

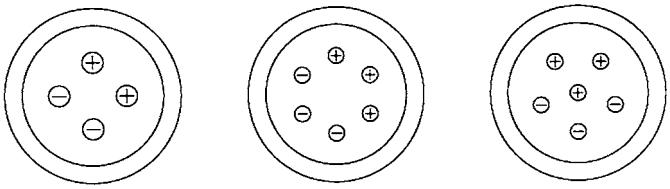

FIG. 1 Examples of Adjacent Configurations

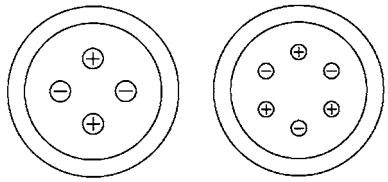

FIG. 2 Examples of Alternating Configurations

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

E1751 Guide for Temperature Electromotive Force (EMF) Tables for Non-Letter Designated Thermocouple Combinations[3]

2.3 *ANSI Standard:*[4]

B46.1 Surface Texture

2.4 *AWS Standard:*[5]

A5.14 Specification for Nickel and Nickel-Alloy Bare Welding Rods and Electrodes

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 *adjacent thermoelement configuration*, *n*—thermoelement configuration within a multi-pair thermocouple or cable where two or more positive thermoelements are immediately adjacent to one another around the circular pattern and two or more negative thermoelements are also immediately adjacent to one another around the circular pattern as shown in Fig. 1 (compare with alternating thermoelement configuration in Fig. 2).

3.2.1.1 *Discussion*—By default, a multi-pair thermocouple or cable with a thermoelement in the center must be considered an adjacent configuration.

3.2.2 *alternating thermoelement configuration*, *n*—thermoelement configuration within a multi-pair thermocouple or cable where positive thermoelements and negative thermoelements alternate around the circular pattern as shown in Fig. 2 (compare with adjacent thermoelement configuration in Fig. 1).

3.2.2.1 *Discussion*—In an alternating thermoelement pattern, there are never two or more positive thermoelements nor two or more negative thermoelements immediately adjacent to one another.

3.2.3 *common ungrounded junction*, *n*—measuring junctions within the same multi-pair thermocouple that are electrically isolated from the sheath but electrically connected to each other.

3.2.4 *isolated ungrounded junction*, *n*—measuring junctions within the same multi-pair thermocouple that are electrically isolated from the sheath and electrically isolated from each other.

3.2.5 *lot*, *n*—quantity of finished mineral-insulated, metal-sheathed thermocouples, or length of thermocouple cable manufactured from tubing from the same heat, wire from the same spool and heat, and insulation from the same batch, then assembled and processed together under controlled production conditions to the required final configuration.

3.2.6 *raw material*, *n*—tubing, insulation, and wires used in fabrication of the sheathed thermocouples or thermocouple cable.

4. Significance and Use

4.1 Type S, R, and B noble metal thermocouples are generally specified for use when temperatures exceed the upper recommended operating temperatures of base metal thermocouples (see Specification E608/E608M).

4.2 To optimize elevated temperature stability, Type S, R, and B thermocouples should be supplied with noble metal sheaths (see 6.3.1). Purchasers and users are cautioned that if Type S, R, and B thermocouples are supplied with base metal sheaths, such as 300 series stainless steels or other heat-resistant nickel-chrome alloys, and are used at temperatures exceeding 600 °C [1100 °F], they will be more susceptible to drift due to contamination and the development of inhomogeneity. The higher the temperature, the faster the contamination, inhomogeneity, and resultant drift develop. In some cases, the elevated temperature performance of a noble metal thermocouple with a base metal sheath will be inferior to that of a base metal thermocouple with a base metal sheath.

5. Ordering Information and Basis for Purchase

5.1 The purchasing documents shall specify the following for both thermocouples and cable:

5.1.1 The nominal outside diameter of the sheath (see Table 1).

5.1.2 The type and quantity of noble metal thermoelements (see 6.1). Note that non-letter designated noble metal thermoelements (that is, other than Types S, R, and B) may be used upon purchaser and producer agreement.

5.1.3 The kind of ceramic insulation (see 6.2). Note that other insulation composition and impurity levels may be used with purchaser and producer agreement.

5.1.4 The kind of sheath material (see 6.3), and whether it shall be seamless or welded and drawn. Note that other sheath material may be used with purchaser and producer agreement.

5.1.5 The intended operating temperature range of the thermocouple or cable (see 8.1.5).

[3] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[5] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126.

TABLE 1 Preferred Outside Diameters, *A*, for Thermocouples and Cable in SI (Metric) and Inch-Pound Units

Diameter	
millimetres	inches
0.50	0.020
. . .	0.032
1.00	0.040
1.50	0.062
2.00	. . .
. . .	0.093
3.00	0.125
4.50	0.188
6.00	0.250
8.00	0.375

5.1.6 The tolerance of initial values of emf versus temperature if other than standard for Types S, R, and B thermocouples, or the emf versus temperature relationship and initial tolerance values if other than Type S, R, or B thermocouples (see 8.1.5 and Guide E1751).

5.1.7 Optional supplementary testing and test sample rates or optional material requirements (see Supplementary Requirements).

5.1.8 Packaging method and straightness criteria, if required (see 11.3).

5.1.9 The quality assurance and verification program requirements (see Appendix X1).

5.1.10 Any deviations from this specification or its Referenced Documents.

5.2 In addition, the purchasing documents shall specify the following if purchasing thermocouples:

5.2.1 The style of measuring junction, Style G (grounded) or Style U (ungrounded). See Figs. 8 and 9. If more than one pair of thermoelements is specified, Style U is further subdivided into Style CU (common ungrounded) and Style IU (isolated ungrounded).[6]

5.2.2 The quantity, sheath length, and sheath length tolerance of each thermocouple. See Figs. 3-6 for examples.

5.2.3 The type and configuration of connection head, connector, transition piece, or termination, and moisture seal required on the end opposite the measuring junction. See Figs. 3-6 for examples. The minimum and maximum intended operating temperature of the connection head, transition, termination, or moisture seal should be specified (see 6.5). For thermocouples with insulated wire attached (see Fig. 6) and Style U junctions, state the minimum acceptable insulation resistance (see 8.1.3.2).

5.3 In addition, the purchasing documents shall specify the following if purchasing thermocouple cable:

5.3.1 The thermoelement configuration (see 3.2.1 and 3.2.2). Consult individual manufacturers for the available number of thermoelements within a cable size.

5.3.2 The total length and tolerance of finished thermocouple cable, and the length and length tolerance of each piece of finished thermocouple cable.

[6] Style G, Style U, Style CU and Style IU measuring junctions were previously termed Class 1, Class 2, Class 2A and Class 2B measuring junctions respectively.

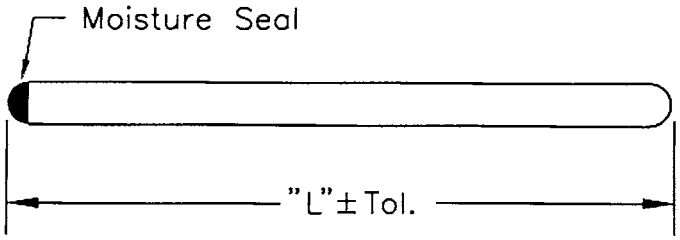

FIG. 3 Sheathed Thermocouple Cable

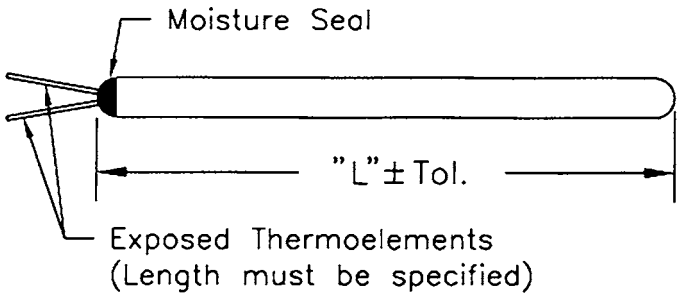

FIG. 4 Sheathed Thermocouple with Exposed Thermoelements

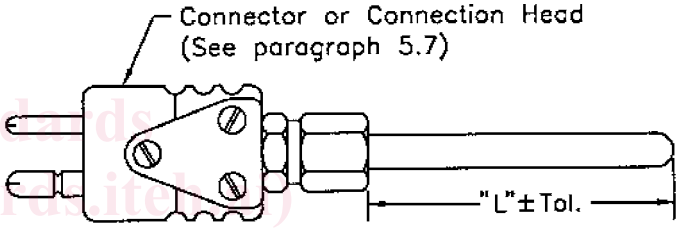

FIG. 5 Sheathed Thermocouple Assembly with Connector or Connection Head (any Type Specified)

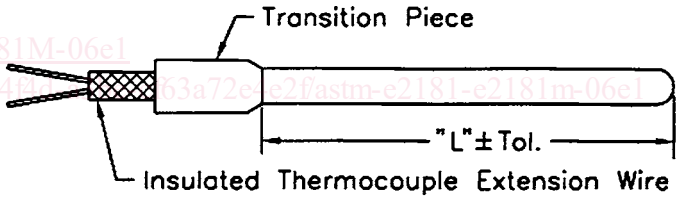

FIG. 6 Sheathed Thermocouple Assembly with Transition Piece

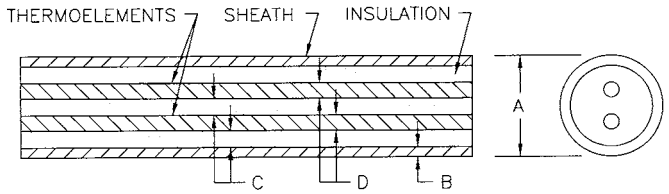

FIG. 7 Sheathed Thermocouple Construction

5.3.3 The kind of end seal applied to the open ends, prior to shipment (see 11.1).

6. Material and Manufacturing Requirements

6.1 *Thermoelements*:

6.1.1 The thermoelements shall only be noble metal, and shall be of thermoelectric types S, R, or B unless otherwise agreed upon between purchaser and producer.

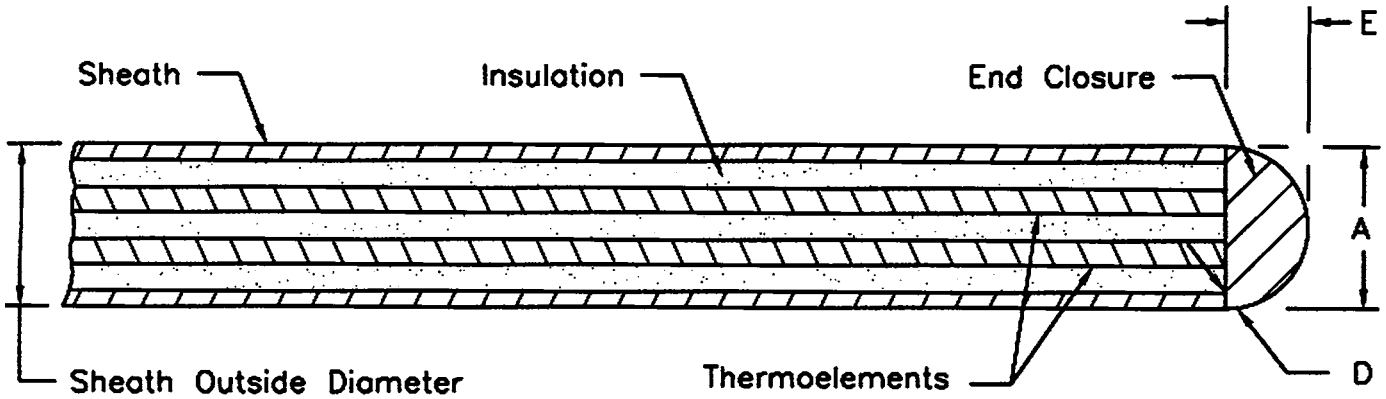

FIG. 8 Grounded Measuring Junction, Style G

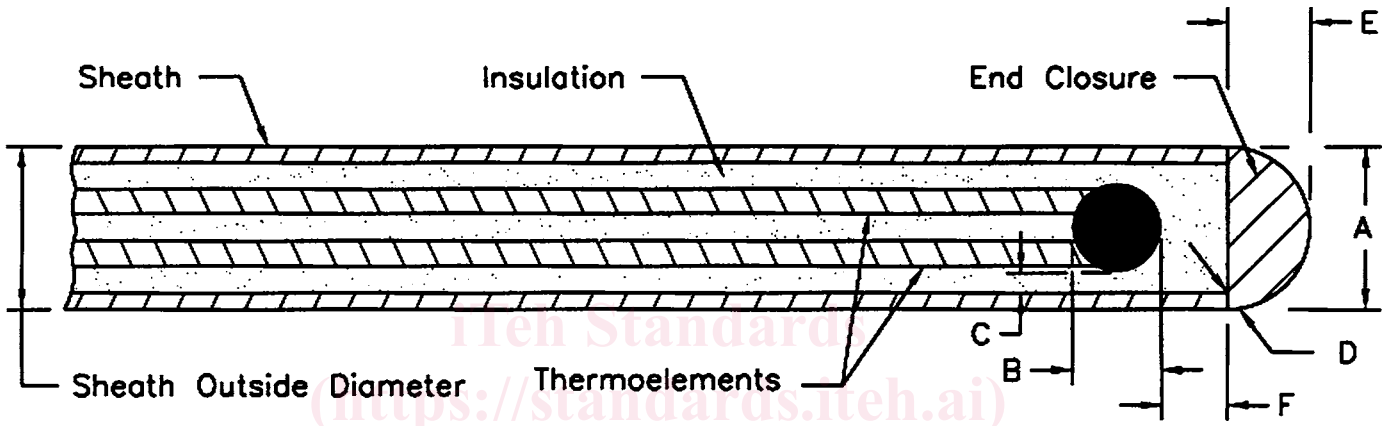

FIG. 9 Ungrounded Measuring Junction, Style U

6.1.2 The thermoelements shall be solid wire, round in cross section. All wire used for fabrication shall meet the supplemental cleanliness requirements of Specification A632, except that acetone or any other solvents that might leave a harmful residue shall not be used for final cleaning.

6.1.3 The initial emf versus temperature relationship for Type S, R, and B thermoelements shall satisfy the standard tolerance specified by Specification E230 unless otherwise stated in the ordering information.

6.2 *Insulation*:

6.2.1 The insulation shall only be magnesia (MgO) or alumina (Al_2O_3) conforming to Specification E1652. Unless otherwise agreed upon between purchaser and producer, only Type 1 magnesia or Type 1 alumina shall be used. See 8.2.13 and Supplementary Requirement S11.

6.2.2 The minimum density of the compacted insulation shall be 70 % of the maximum theoretical density which is 3580 kg/m^3 [0.129 lb/in.^{3}] for MgO, and 3970 kg/m^3 [0.144 lb/in.^{3}] for Al_2O_3.[7] See 8.2.12 and Supplementary Requirement S10.

6.3 *Sheath*:

6.3.1 The sheath material may be seamless or welded and drawn tubing of platinum, platinum-10 % rhodium, platinum-20 % rhodium, or platinum-30 % rhodium. The producer's customary tubing specification may be used.

6.3.2 Alternately, heat-resistant nickel-chrome alloy tubing per Specifications B163, B167, or B516; or 310 or 321 stainless steel tubing per Specifications A213/A213M, A249/A249M, A269, or A632 may be supplied as sheath materials provided there is an agreement between purchaser and producer (see 4.2) and the annealing requirements imposed by 6.3.4 are satisfied. The producer's customary tubing specification may be used.

6.3.3 Each piece of tubing shall meet the supplemental cleanliness requirements of Specification A632, except that acetone or any other solvents that might leave a harmful residue may not be used for final cleaning.

6.3.4 The sheath shall be free of visible surface contaminants and oxidation and shall be in the fully annealed state. Tests for proving conformance are in Supplementary Requirement S7 or S12.

6.3.5 The sheath of the finished thermocouple or cable shall exclude gases and liquids. There shall be no holes, cracks, or other void defects that penetrate through the sheath wall. Tests for proving conformance to this requirement are in Supplementary Requirements S2, S3, S4, and S5.

6.4 The end closure of thermocouples shall be seal welded and shall be impervious to gases and liquids. There shall be no cracks, holes, or void defects that penetrate through the metal wall. Any mineral oxide removed during fabrication of the

[7] Handbook of Chemistry and Physics, Chemical Rubber Publishing Co., No. 76 (1995) edition.