~~Designation:E2181/E2181M–06ε1~~ Designation: E2181/E2181M – 11

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 (MIMS), 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~~compacted MIMS 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.

~~1.3Provisions~~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)~~(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~~(UNS N06600, N06601, N06603, N06690, N06693, N06025, N06045, and ~~N06696),~~N06696), Nickel-Chromium-Cobalt-Molybdenum Alloy ~~(UNS N06617),~~(UNS N06617), and Nickel-Iron-Chromium-Tungsten Alloy ~~(UNS N06674)~~(UNS N06674) Seamless Pipe and Tube

B516 Specification for Welded Nickel-Chromium-Iron Alloy ~~(UNS~~(UNS N06600, UNS N06601, UNS N06603, UNS N06025, UNS N06045, UNS N06690, and UNS ~~N06693)~~N06693) 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

[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.

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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.

E839 Test Methods for Sheathed Thermocouples and Sheathed Thermocouple Cable
E1652 Specification for Magnesium Oxide and Aluminum Oxide Powder and Crushable Insulators Used in the Manufacture of Base Metal Thermocouples, Metal-Sheathed Platinum Resistance Thermometers, and Noble Metal Thermocouples
E1751/E1751M Guide for Temperature Electromotive Force ~~(EMF)~~(emf) Tables for Non-Letter Designated Thermocouple Combinations
2.3 *ANSI Standard:*[3]
B46.1 Surface Texture
~~2.4 *AWS Standard:*~~
~~A5.14Specification 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 and 3.2.2).
3.2.1.1 *Discussion*—By default, a multi-pair thermocouple or cable with a thermoelement in the center ~~must~~shall 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 and 3.2.1).
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~~junction within the same multi-pair thermocouple that ~~are~~is electrically isolated from the sheath but electrically connected to ~~each other.~~ another ungrounded junction.
3.2.4 *isolated ungrounded junction*, *n*—measuring ~~junctions~~junction within the same multi-pair thermocouple that ~~are~~is electrically isolated from the sheath and electrically isolated from ~~each other.~~ all other junctions.
3.2.5 *lot*, *n*—quantity of finished ~~mineral-insulated, metal-sheathed~~ MIMS thermocouples, or length of MIMS thermocouple cable manufactured from tubing or other sheath material from the same heat, wire from the same spool and heat, and insulation from the same batch, then assembled and processed ~~together~~at the same time under controlled production conditions to the required final configuration.
3.2.6 *raw material*, *n*—~~tubing,~~ sheath, insulation, and wire materials used in the fabrication of the sheathed thermocouples or thermocouple cable.

4. Significance and Use

4.1 Types 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, Types S, R, and B thermocouples should be supplied with noble metal sheaths (see 6.3.1). Purchasers and users are cautioned that if Types 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 will 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:

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

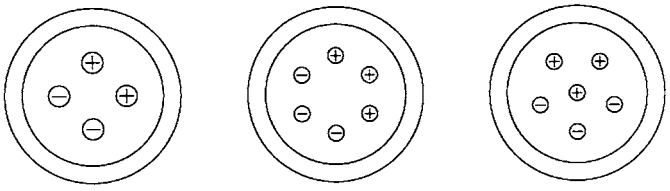

FIG. 1 Examples of Adjacent Configurations

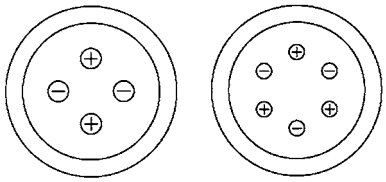

FIG. 2 Examples of Alternating Configurations

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~~with 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.

~~5.1.4The kind of sheath material (see~~

5.1.4 The 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).

5.1.6 The tolerance of initial values of emf versus temperature if other than standard for Types S, R, and B thermocouples (see Table 2), or the emf versus temperature relationship and initial tolerance values if other than Types S, R, or B thermocouples (see 8.1.5 and Guide ~~E1751~~E1751/E1751M).

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~~when purchasing thermocouples:

~~5.2.1The~~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).[4]

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 temperatures 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) shall be stated.

5.3 In addition, the purchasing documents shall specify the following ~~if~~when 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.

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

~~[4] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126.~~

[4] 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.

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

TABLE 5 2 Tolerances on Initial Values of EMF versus Temperature for Types S, R, and B MIMS Thermocouples and MIMS Thermocouple Cable

NOTE 1—Tolerances in this table apply to new Platinum sheathed MIMS thermocouples and thermocouple cable.
NOTE 2—Tolerances apply to new material as produced and do not allow for changes in thermoelectric characteristics of the materials during use. The magnitude of such changes depends upon such factors as sheath and thermoelement size, temperature, time of exposure, and environment.
NOTE 3—Where tolerances are given in percent, the percentage applies to the temperature being measured when expressed in degrees Celsius.
NOTE 4—To determine the tolerance in degrees Fahrenheit, multiply the tolerance in degrees Celsius by 9/5.

Thermocouple Type	Temperature Range		Tolerances – Reference Junction 0°C [32°F]			
	~~Thermocouple Type~~ °C	°F	~~Nominal Calibration Tems~~ °C	°F	~~Sperature~~ Standard Tolerances	Special Tolerances
°C	°F	°C			°F	
~~S, R~~	~~300~~	~~600~~	~~700~~	~~1300~~		
S, R	0 to 1480	32 to 2700	The greater of ±1.5°C or ±0.25 %	~~1300~~		
	1100	2000				
Note 4	The greater of ±0.6°C or ±0.1 %	Note 4				
~~B~~	~~900~~	~~1650~~	~~1100~~	~~2000~~		
B	870 to 1700 1300 ±0.25 %	1600 to 3100 2400	±0.50 %	~~2000~~		

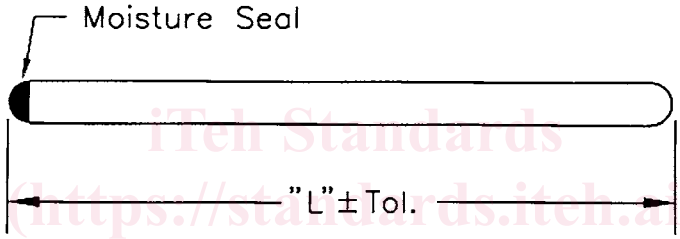

FIG. 3 Sheathed Thermocouple Cable

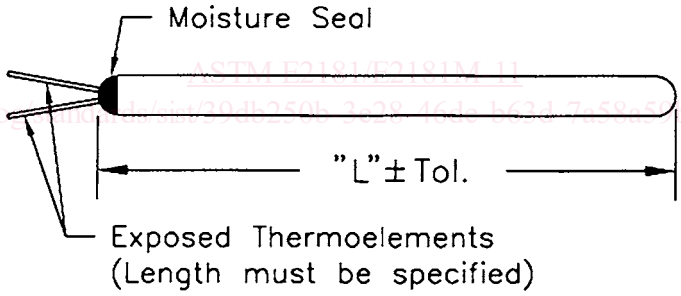

FIG. 4 Sheathed Thermocouple with Exposed Thermoelements

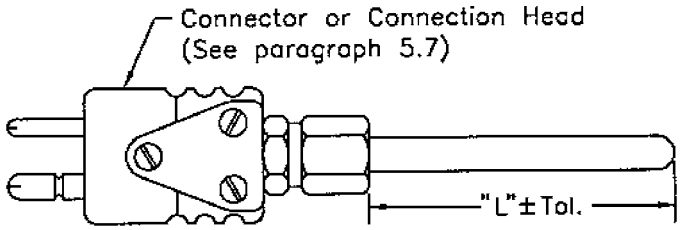

FIG. 5 Sheathed Thermocouple Assembly with Connector or Connection Head (any Type Specified)

6. Material and Manufacturing Requirements

6.1 *Thermoelements*:

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

~~6.1.2The thermoelements shall be solid wire, round in cross section. All wire used for fabrication shall meet the supplemental~~

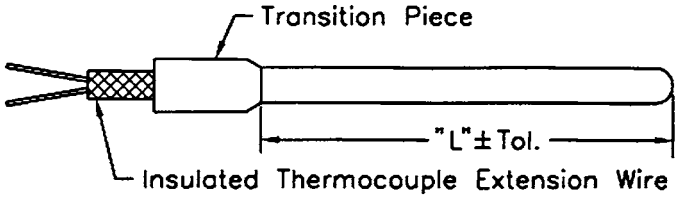

FIG. 6 Sheathed Thermocouple Assembly with Transition Piece

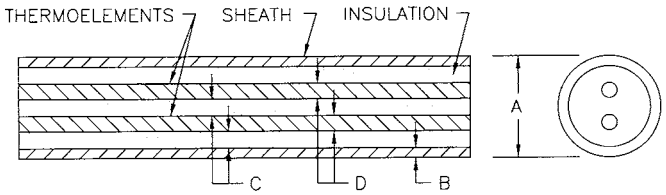

FIG. 7 Sheathed Thermocouple Construction

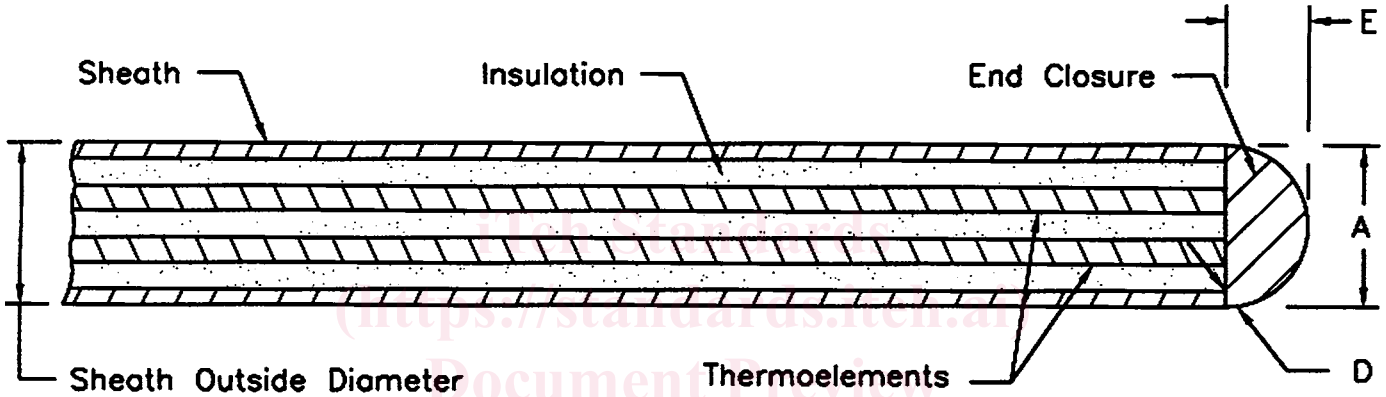

FIG. 8 Grounded Measuring Junction, Style G

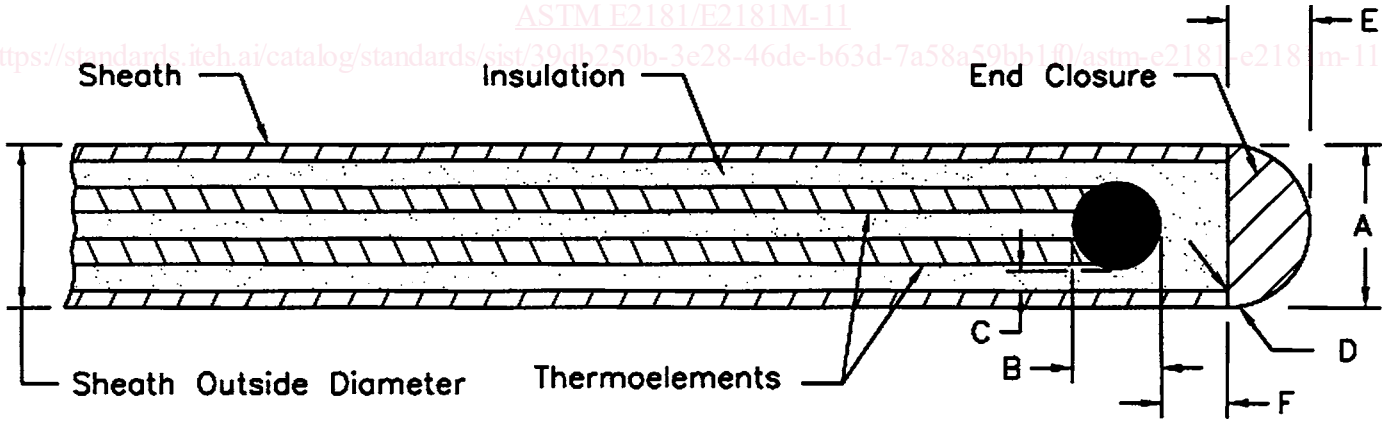

FIG. 9 Ungrounded Measuring Junction, Style U

~~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.~~

~~6.1.3The initial emf versus temperature relationship for Type S, R, and B thermoelements shall satisfy the standard tolerance specified by Specification E230~~

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

6.1.2 The thermoelements shall be solid wire, round in cross section. The thermocouple or cable producer shall ensure that all wire used for fabrication shall be free of visible surface oxides, scale, and contaminants, such as drawing compounds, carbon, dirt, and dust. The absence of scale and contaminants can be verified by wiping the wire with a solvent-saturated lint-free cloth. Acetone, isopropyl alcohol, methanol, and ethanol are all acceptable solvents. A light discoloration of the cloth is acceptable unless

particles of grit or metal flakes are visually detectable without the use of magnification. If acetone or any other solvent that leaves a harmful residual film upon evaporation is used for initial cleaning, a final cleaning with an acceptable cleaning solvent, such as isopropyl alcohol, methanol, or ethanol is required.

6.1.3 The initial emf versus temperature relationship for Types S, R, and B thermoelements shall satisfy the standard tolerance specified in Table 2 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 the 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.[5] See 8.2.12 and Supplementary Requirement S10.

~~[5] 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.~~

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