



Standard Specification for Compacted Mineral-Insulated, Metal-Sheathed, Base Metal Thermocouple Cable¹

This standard is issued under the fixed designation E585/E585M; 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 establishes requirements for compacted, mineral-insulated, metal-sheathed (MIMS), base metal thermocouple cable,² with at least two thermoelements.³

1.2 This specification describes the required material, processing and testing requirements, optional supplementary testing, quality assurance, and verification choices.

1.3 The material of construction includes standard base metal thermoelements, austenitic stainless steel or other corrosion resistant sheath material, and either magnesia (MgO) or alumina (Al₂O₃) insulation.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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, health, and environmental 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 The following documents of the latest issue form a part of this specification to the extent specified herein. In the event

¹ This specification is under the jurisdiction of ASTM Committee E20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.12 on Thermocouples - Specifications.

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² The terms “MIMS cable”, or “thermocouple cable”, or “MIMS thermocouple cable”, or “cable” will be used herein to describe mineral-insulated, metal-sheathed, base metal thermocouple cable.

³ “Wire” is also used to describe “thermoelements.”

of a conflict between this specification and other specifications referenced herein, this specification shall take precedence.

2.2 ASTM Standards:⁴

[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/A269M 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 Standard Specification for Nickel-Chromium-Aluminum Alloys \(UNS N06699\) Nickel-Chromium-Iron Alloys \(UNS N06600, N06601, N06603, N06690, N06693, N06025, N06045, and N06696\) Nickel-Chromium-Cobalt-Molybdenum Alloy \(UNS N06617\) Nickel-Iron-Chromium-Tungsten Alloy \(UNS N06674\) and Nickel-Chromium-Molybdenum-Copper Alloy \(UNS N06235\) Seamless Pipe and Tube](#)

[B423 Specification for Nickel-Iron-Chromium-Molybdenum-Copper Alloy Seamless Pipe and Tube](#)

[B516 Specification for Welded Nickel-Chromium-Aluminum Alloy \(UNS N06699\) and Nickel-Chromium-Iron Alloy \(UNS N06600, UNS N06601, UNS N06603, UNS N06025, UNS N06045, UNS N06690, and UNS N06693\) Tubes](#)

[E112 Test Methods for Determining Average Grain Size](#)

[E220 Test Method for Calibration of Thermocouples By Comparison Techniques](#)

[E230/E230M Specification for Temperature-Electromotive Force \(emf\) Tables for Standardized Thermocouples](#)

[E235/E235M Specification for Type K and Type N Mineral-Insulated, Metal-Sheathed Thermocouples for Nuclear or](#)

⁴ 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.

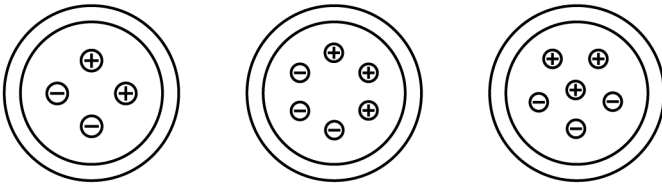


FIG. 1 Examples of Adjacent Configurations

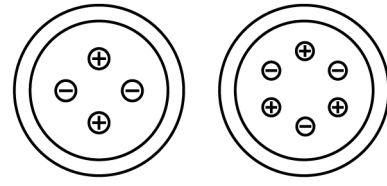


FIG. 2 Examples of Alternating Configurations

for Other High-Reliability Applications

[E344 Terminology Relating to Thermometry and Hydrometry](#)

[E608/E608M Specification for Mineral-Insulated, Metal-Sheathed Base Metal Thermocouples](#)

[E780 Test Method for Measuring the Insulation Resistance of Mineral-Insulated, Metal-Sheathed Thermocouples and Mineral-Insulated, Metal-Sheathed Cable at Room Temperature](#)

[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](#)

2.3 ANSI Standard:

[ANSI B46.1 Surface Texture](#)⁵

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*—thermo-element configuration within a multi-pair 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 cable with a thermoelement in the center must be considered an adjacent configuration.

3.2.2 *alternating thermoelement configuration, n*—thermo-element configuration within a multi-pair 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 around the circular pattern.

3.2.3 *lot, n*—a quantity of finished MIMS 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 outside diameter.

3.2.4 *raw material, n*—tubing, insulation, and wires used in fabrication of the MIMS thermocouple cable.

4. Significance and Use

4.1 *Thermocouple Cable may be used as follows:*

4.1.1 Sheathed thermocouple cable for use in manufacturing thermocouples (see Specification [E608/E608M](#)).

4.1.2 Sheathed thermocouple cable for use as extension cable in extremely harsh environments.

5. Ordering Information and Basis for Purchase

5.1 The purchasing documents shall specify the following options:

5.1.1 The total length of finished thermocouple cable and the length of each piece of finished thermocouple cable.

5.1.2 The type and quantity of thermoelements, the thermoelement configuration (see [3.2.1](#) and [3.2.2](#)), and the tolerance range for initial values of emf versus temperature if other than standard (see [6.2](#)). Consult individual manufacturers for the number of thermoelements limited by cable size.

5.1.3 The sheath material (see [7.3](#)) and whether it shall be seamless or welded and drawn. Note that another sheath material may be used with purchaser and producer agreement.

5.1.4 The nominal outside diameter of the sheath (see [6.3](#)).

5.1.5 The composition of mineral oxide insulation (see [7.2](#)). Note that other insulation composition(s) and impurity levels may be used with purchaser and producer agreement.

5.2 Additional requirements may be specified by the purchaser as follows:

5.2.1 The intended operating temperature range of the cable (see [9.8](#)).

5.2.2 The method used to seal the open ends, prior to shipment (see [11.1](#)).

5.2.3 Supplementary testing or material requirements (see Supplementary Requirements).

5.2.4 The quality assurance or verification program requirements or both (see [Appendix X1](#)).

5.2.5 Any deviations from this specification or the referenced documents.

6. General Requirements

6.1 *MIMS Thermocouple Cable*—Cable shall be in accordance with this specification (see [Fig. 3](#)). This figure describes a cable with two thermoelements, but more than two thermoelements may be specified.

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

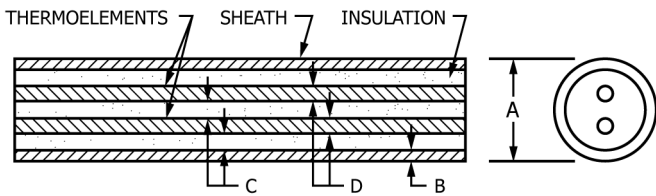


FIG. 3 MIMS Thermocouple Material Construction (See Table 1)

6.2 *Tolerances on Initial Values of Emf versus Temperature*—The standard tolerances of Specification E230/E230M apply unless otherwise stated in the ordering information.

6.3 *Dimensions*—The dimensional and tolerance requirements for sheath diameter and wall thickness, thermoelement diameter, and insulation thickness depicted in Fig. 3 shall be based on nominal sheath outside diameters and number of thermoelements. The preferred cable sizes and sheath diameter tolerances are listed in Table 1. The minimum dimensional requirements for sheath wall thickness, thermoelement diameter, and insulation thickness are summarized in Table 2. The purchaser need only specify the outside diameter and number of thermoelements in the ordering documents.

6.3.1 *Sheath Diameter*—For any nominal sheath size, the outside diameter tolerance, A, shall be ± 0.025 mm [0.001 in.] or $\pm 1\%$, whichever is greater.

6.3.2 *Sheath Wall Thickness*—The wall thickness, B, shall be at least 10% of the nominal sheath outside diameter and shall be uniform within 20% of the minimum required wall thickness.

6.3.3 *Thermoelement Diameter*—The thermoelement diameter, D, shall be at least 15% of the nominal sheath outside diameter if two thermoelements are included, at least 12% of the nominal sheath outside diameter if four thermoelements are included, or at least 9% of the nominal sheath outside diameter if six thermoelements are included. All thermoelement diameters shall be uniform within 20% of their minimum required diameters.

6.3.4 *Insulation Thickness*—The insulation thickness, C, either thermoelement to thermoelement or thermoelement to inside surface of the sheath, shall be at least 7% of the nominal sheath outside diameter if two thermoelements are included, at least 5.5% of the nominal sheath outside diameter if four thermoelements are included, or at least 4% of the nominal sheath outside diameter if six thermoelements are included.

6.3.5 *Sheath Inside Diameter*—The inside sheath diameter is equal to Diameter A minus two times dimension B. Dimensions shall be measured in accordance with Test Methods E839.

6.4 *Materials*—The thermocouple cable shall be fabricated from component parts specified in Section 7.

6.5 *Insulation Resistance at Room Temperature*—The minimum electric insulation resistance between thermoelements and between each thermoelement and the sheath (at room temperature) shall be as specified in Table 3, for the voltages noted. The values of insulation resistance, given in megohms,

TABLE 1 Dimensions and Tolerances of MIMS Cable in SI (Metric) and U.S. Customary Units

Preferred Sizes—Nominal Outside Diameter, A	
Diameters listed below are commonly available sizes.	
Diameter, millimetres	
0.50	
1.00	
1.50	
2.00	
3.00	
4.50	
6.00	
8.00	
9.50	
Diameter, inches	
0.020	
0.032	
0.040	
0.062	
0.093	
0.125	
0.188	
0.250	
0.313	
0.375	

TABLE 2 Summary of Thermocouple Cable Dimensional Requirements (Percent of Nominal Outside Diameter)

Number of Thermoelements	2	4	6
Minimum Sheath Thickness	10 %	10 %	10 %
Minimum Thermoelement Diameter	15 %	12 %	9 %
Minimum Insulation Thickness	7 %	5.5 %	4 %

TABLE 3 Room-Temperature Insulation Resistance Requirements in SI (Metric) and Inch-Pound Units

Nominal Sheath Outside Diameter	Applied Voltage, min, V, dc	Insulation Resistance, min, M Ω
Less than 0.80 mm [0.030 in.]	50	1000
0.80 to 1.45 mm [0.030 to 0.057 in.]	50	5000
Larger than 1.45 mm [0.057 in.]	500	10 000

shall apply to the supplied cables over their entire lengths. See Test Methods E780 and E839.

6.6 *Minimum Insulation Density*—The minimum density of the compacted electrical insulation shall be 70% of the maximum theoretical density which is 3580 kg/m³ [0.129 lb/in.³] for MgO, and 3970 kg/m³ [0.144 lb/in.³] for Al₂O₃.⁶ See also Supplementary Requirement S6.1.

6.7 *Sheath Condition*—The sheath shall be free of visible surface contaminants and oxidation. The sheath shall be in the fully annealed state for Type E, J, K, and N thermocouple material. For Type T material, the sheath shall be annealed to the extent that the thermoelements will permit. Tests for proving conformance are in Supplementary Requirement S2 or S9.

⁶ Handbook of Chemistry and Physics, Chemical Rubber Publishing Co., No. 76 (1995) edition.

6.8 *Sheath Integrity*—The sheath of the finished thermocouple 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 Requirement S3.

6.9 Quality verification requirements are specified on an optional basis. The purchaser may require material traceability, as desired (see [Appendix X1](#)).

6.10 The tests in this specification are the minimum to determine if the specification requirements have been met. Additional optional supplementary requirements are listed in the Supplementary Requirements section and may be included in the purchase order requirements, if desired by the purchaser.

7. Material Requirements

7.1 Thermoelements:

7.1.1 The thermoelements shall be solid wire, round in cross section.

7.1.2 The thermoelements shall only be of Type E, J, K, N, or T. All wire used for fabrication shall meet the supplemental cleanliness requirements of Specification [A632](#), except that acetone or any other solvent that might leave a harmful residue shall not be used for final cleaning.

7.1.3 The emf-versus-temperature relationship shall meet the initial calibration tolerance of [6.2](#).

7.2 Insulation:

7.2.1 The insulation shall only be magnesia (MgO) or alumina (Al₂O₃) conforming to Specification [E1652](#). Unless otherwise agreed upon between the purchaser and the producer, only Type 1 magnesia or Type 1 alumina shall be used.

7.3 Sheath Material:

7.3.1 The sheath material may be seamless or welded and drawn tubing of austenitic stainless steel (typically type TP304, TP304L, TP310, TP310S, TP316, TP316L, TP321, or TP347) or heat-resistant nickel-chrome alloy (typically type Alloy 600, Alloy 601, or Alloy 625).

7.3.2 The producer's customary tubing specification shall be applicable for the sheath material. See Supplementary Requirement S8.

7.3.3 A nickel-chrome-iron sheath, as in Specifications [B163](#), [B167](#), or [B516](#), is recommended for fresh water service. There are high molybdenum stainless steels that are specifically made for use in salt water, such as type 316 and proprietary alloys. UNS N08825 or other proprietary alloys, as in Specification [B423](#), may be recommended for chloride-containing environments above 60 °C

7.3.4 Alternative heat-resistant tubing materials may be specified for the sheath by the producer, provided the annealing requirements in [6.7](#) are satisfied.

7.3.5 Each piece of tubing used in the fabrication of thermocouple material shall have its inside diameter meet the supplemental cleanliness requirements of Specification [A632](#), except that acetone or any other solvent that might leave a harmful residue shall not be used for final cleaning.

8. Processing Requirements

8.1 The producer is responsible for raw materials and all processing to ensure that the overall requirements of this

TABLE 4 Standard Tests

Section	Test	Test Piece
9.1.1 , 9.6	Dimensional inspection	Sample
9.1.2 , 9.7	Insulation resistance at room temperature	Sample ^A
9.1.3 , 9.8	Calibration	Sample
9.1.4 , 9.9	Electrical continuity	Sample ^A

^A Each length of finished thermocouple cable shall be tested.

specification are met. The producer is also responsible for the quality of the finished product.

9. Quality Verification and Test Requirements

9.1 The following tests are required for all thermocouple cable furnished under this specification:

- 9.1.1 Dimensional inspection,
- 9.1.2 Insulation resistance at room temperature,
- 9.1.3 Calibration, and
- 9.1.4 Electrical continuity.

9.2 *Documentation*—Certificate of conformance in accordance with Section [10](#).

9.3 Optional testing is defined in the Supplementary Requirements section. If the purchaser desires that these tests be performed in whole, or in part, it shall be stated on the purchasing documents.

9.4 A quality assurance or verification program or both, is defined in [Appendix X1](#). The purchaser may choose this program or any part thereof, as an optional requirement.

9.5 *Standard Tests*—The producer shall perform inspection and tests in accordance with [Table 4](#), using the methods described in Test Methods [E839](#). Sampling shall be performed from each lot.

9.6 *Dimensional Inspection*—The producer shall measure a sample of finished thermocouple cable to determine conformance to [6.3](#) for the following: outside diameter, thermoelement diameter, sheath wall thickness, and insulation thickness. Dimensions shall be measured per Test Methods [E839](#).

9.7 *Insulation Resistance at Room Temperature*—The insulation resistance of each length of cable shall be tested to determine conformance to [Table 3](#) and [6.5](#).

9.8 *Calibration*—Compliance with the tolerances on initial values of emf versus temperature shall be demonstrated by calibration of a sample of finished cable. The sample shall be fabricated into a thermocouple and calibrated using the general procedures outlined in Test Method [E220](#). The tolerances on initial values of emf versus temperature are defined in [Table 5](#). The calibration shall be performed in order of increasing temperature at temperatures that represent the minimum, intermediate, and maximum intended operating conditions of the finished cable. If this information is not furnished by the purchaser, calibration shall be performed at the temperatures specified in [Table 6](#). The actual temperature of the heat source used for calibration may deviate up to 25 °C [45 °F] from the calibration temperature specified. The purchaser may specify other calibration temperatures; see Supplementary Requirement S5.

TABLE 5 Tolerances on Initial Values of Emf vs. Temperature for MIMS Thermocouple Cable

NOTE 1—At a given temperature that is expressed in °C, the tolerance expressed in °F is 1.8 times larger than the tolerance expressed in °C. Where tolerances are given in percent, the percentage applies to the temperature being measured when expressed in degrees Celsius. To determine the tolerance in degrees Fahrenheit, multiply the tolerance in degrees Celsius by 1.8.

NOTE 2—**Warning**—Users should be aware that certain characteristics of thermocouple materials, including the emf-versus-temperature relationship, may change with time in use; consequently, test results and performance obtained at the time of manufacture may not necessarily apply throughout an extended period of use. Tolerances given in this table apply only to new cable as delivered to the user *and do not allow for changes in characteristics with use*. The magnitude of such changes will depend on such factors as thermoelement and cable size, temperature, time of exposure, and environment.

Thermocouple Cable Type	Temperature Range				Tolerances-Reference Junction 0 °C (32 °F)			
	°C		°F		Standard Tolerances		Special Tolerances	
	°C	°C	°F	°F	°C	°F	°C	°F
T	0	to 370	32	to 700	The greater of ±1.0 or ±0.75 %	Note 1	The greater of ±0.5 or ±0.4 %	Note 1
J ^C	0	to 760	32	to 1400	The greater of ±2.2 or ±0.75 %		The greater of ±1.1 or ±0.4 %	
E	0	to 870	32	to 1600	The greater of ±2.2 or ±0.75 %		The greater of ±1.0 or ±0.4 %	
K or N ^C	0	to 1260	32	to 2300	The greater of ±2.2 or ±0.75 %		The greater of ±1.1 or ±0.4 %	
T ^A	-200	to 0	-328	to 32	The greater of ±1.0 or ±1.5 %		<i>B</i>	
E ^A	-200	to 0	-328	to 32	The greater of ±2.2 or ±2 %		<i>B</i>	
K ^A	-200	to 0	-328	to 32	The greater of ±2.2 or ±2 %		<i>C</i>	

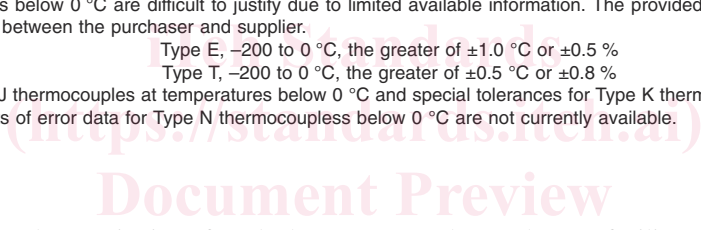
^A Thermocouples and thermocouple materials are normally supplied to meet the tolerances specified in the table for temperatures above 0 °C. The same materials, however, may not fall within the tolerances for temperatures below 0 °C in the second section of the table. If materials are required to meet the tolerances stated for temperatures below 0 °C the order shall so state. Selection of materials usually will be required.

^B Special tolerances for temperatures below 0 °C are difficult to justify due to limited available information. The provided values for Types E and T thermocouples are suggested as a guide for discussion between the purchaser and supplier.

Type E, -200 to 0 °C, the greater of ±1.0 °C or ±0.5 %

Type T, -200 to 0 °C, the greater of ±0.5 °C or ±0.8 %

^C Initial values of tolerance for Type J thermocouples at temperatures below 0 °C and special tolerances for Type K thermocouples below 0 °C are not given due to the characteristics of the materials. Limits of error data for Type N thermocouples below 0 °C are not currently available.



9.9 *Electrical Continuity*—The continuity of each thermoelement of each length of finished thermocouple cable shall be verified using the producer's routine techniques.

at the producer's facility. It is suggested that these records be retained for a minimum of three years.

10. Certification and Reports

10.1 A certificate of conformance covering the completed MIMS thermocouple cable and the data taken during the testing by the producer shall be provided to the purchaser upon request. The certificate shall state that the product has been manufactured from materials specified in the purchase order, that the material was tested in accordance with this specification, that the results are in accordance with this specification, and that the test data and certifications are on file

11. Packaging, Marking, and Shipping

11.1 *Sealing*—All open ends of MIMS thermocouple cable shall be sealed when processing allows and especially before shipment, in order to prevent the entry of moisture into the cable. Seal welding and epoxy seals are examples of techniques used for sealing.

11.2 *Cleaning Prior to Packaging*—The outer sheath shall be cleaned free of grease, oil, dirt, and other foreign substances.