Designation: E585/E585M – 12

Standard Specification for Compacted Mineral-Insulated, Metal-Sheathed, Base Metal Thermocouple Cable[1]

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, base metal thermocouple cable,[2] with at least two thermoelements.[3]

1.2 This specification describes the required material, processing and testing requirements, and also the optional supplementary testing and 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 (Al_2O_3) 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 and health practices and determine the applicability of regulatory limitations 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:*[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 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), Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617), and Nickel-Iron-Chromium-Tungsten Alloy (UNS N06674) Seamless Pipe and Tube

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

E220 Test Method for Calibration of Thermocouples By Comparison Techniques

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

E235 Specification for Thermocouples, Sheathed, Type K and Type N, for Nuclear or for Other High-Reliability Applications

E344 Terminology Relating to Thermometry and Hydrometry

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

E780 Test Method for Measuring the Insulation Resistance of Mineral-Insulated, Metal-Sheathed Thermocouples and Thermocouple 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 Metal-Sheathed Platinum Resistance

[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, 2012. Published June 2012. Originally approved in 1996. Last previous edition approved in 2009 as E585/E585M-09. DOI: 10.1520/E0585_E0585M-12.

[2] The terms "metal sheathed thermocouple cable" or "cable" will be used to describe the subject description.

[3] "Wire" is also used to describe "thermoelements."

[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.

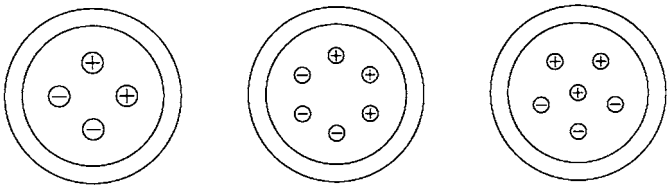

FIG. 1 Examples of Adjacent Configurations

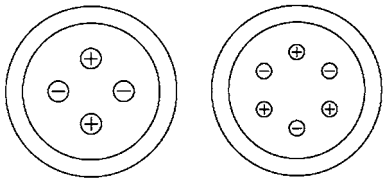

FIG. 2 Examples of Alternating Configurations

Thermometers, Base Metal Thermocouples, 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*—thermoelement 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*—thermoelement 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.

3.2.3 *lot, n*—a quantity of finished mineral-insulated, metal-sheathed 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 sheathed 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).

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

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

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 on 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 kind of sheath material (see 7.3) and whether it shall be seamless or welded and drawn. Note that other sheath material may be used with purchaser and producer agreement.

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

5.1.5 The kind of ceramic insulation (see 7.2). Note that other insulation composition and impurity levels may be used with purchaser and producer agreement.

5.1.6 The intended operating temperature range of the cable (see 9.8).

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

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

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

5.1.10 Any deviations from this specification or the referenced documents.

6. General Requirements

6.1 *Mineral-Insulated, Metal–Sheathed 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.

6.2 *Tolerances on Initial Values of Emf versus Temperature*—The standard tolerances of Specification E230 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. The preferred cable sizes are listed in Table 1. For any nominal sheath size, the outside diameter tolerance, *A*, shall be ±0.025 mm [0.001 in.] or ±1 %, whichever is greater. 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. The thermoelement diameters, *D*, shall be at least 15 % of the nominal sheath outside diameter if two thermoelements are included, at least 12 % of the nominal sheath

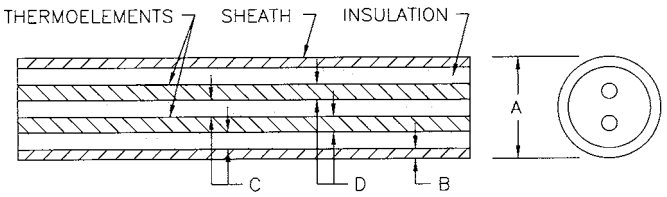

FIG. 3 Sheathed Thermocouple Material Construction (See Table 1)

TABLE 1 Dimensions of Metal Sheathed Thermocouple Cable in SI (Metric) and Inch-Pound Units

Preferred Sizes—Nominal Outside Diameter, A, in millimetres [inches]	
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

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

6.4 *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, shall apply to the supplied lengths. See Test Methods E780 and E839.

6.6 *Minimum Insulation Density*—The minimum density of the compacted electric 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.[6] See also Supplementary Requirement S6.1.

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, MΩ
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

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.

6.8 *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 as specified in the body of 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 purchasing order requirements, as 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 thermoelectric types: 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 solvents 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:*

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

7.2.1 The insulation shall only be magnesia (MgO) or alumina (Al_2O_3) conforming to Specification E1652. Unless otherwise agreed upon between the purchaser and 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.

7.3.4 Alternate heat-resistant tubing materials may be specified for the sheath by the producer, provided the annealing requirements imposed by 6.7 are satisfied.

7.3.5 Each piece of tubing used in the fabrication of thermocouple material 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.

8. Processing Requirements

8.1 The producer is responsible for raw materials and all processing to ensure that the overall requirements of this 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, he shall so state 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 delineated 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.

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	[A]
9.1.3, 9.8	Calibration	Sample
9.1.4, 9.9	Electrical continuity	[A]

[A] Each length of finished thermocouple cable shall be tested.

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.

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.

10. Certification and Reports

10.1 A certificate of conformance covering the completed mineral-insulated, metal-sheathed 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 at the producer's facility. It is suggested that these records be retained for a minimum of 3 years.

11. Packaging, Marking, and Shipping

11.1 *Sealing*—All open ends of mineral-insulated, metal-sheathed thermocouple cable shall be sealed when processing allows and especially before shipment, in order to prevent entry of moisture inside 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.

TABLE 5 Tolerances on Initial Values of Emf vs. Temperature for MI 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. It should be further noted that due to possible changes in homogeneity, attempting to recalibrate *used* thermocouple cable is likely to yield irrelevant results and is not recommended.

Thermocouple Cable Type	Temperature Range				Tolerances-Reference Junction 0°C (32°F)			
	°C		°F		Standard Tolerances		Special Tolerances	
					°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	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	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 %		[B]	
E[A]	–200	to 0	–328	to 32	The greater of ±2.2 or ±2 %		[B]	
K[A]	–200	to 0	–328	to 32	The greater of ±2.2 or ±2 %		[B]	

[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 justirfy due to limited available information. However, the following 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 %

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. Data for type N thermocuples below 0°C are not currently available.

TABLE 6 Nominal Calibration Temperatures for Standard Thermocouples[A,B,C]

Thermocouple type	Austenitic stainless steel sheath Type TP -		Nickel-chrome sheath type Alloy -
	304, 304L, 316, 316L, 321, 347	310, 310S	600, 601, 625
K	S2	S3	S4
J	S2	S2	S2
E	S2	S2	S2
N	S2	S3	S4
T	S1	S1	S1

[A] Temperature Sequence S1: 100°C, 200°C, 300°C [212°F, 392°F, 572°F]
Temperature Sequence S2: 300°C, 500°C, 700°C [572°F, 932°F, 1292°F]
Temperature Sequence S3: 300°C, 500°C, 700°C, 1000°C [572°F, 932°F, 1292°F, 1832°F]
Temperature Sequence S4: 300°C, 500°C, 900°C, 1093°C [572°F, 932°F, 1652°F, 1999°F]

[B] The nominal calibration temperatures may not be appropriate for establishing upper service temperatures for all sheath diameters. Refer to E608/E 608M Table 1, Suggested Upper Temperature Limits for Sheathed Thermocouples, for assistance in establishing upper service temperatures for specific thermocouple diameters.

[C] The recommended nominal calibration temperatures may reflect industrial use but should not be interpreted as a guarantee of performance of the thermocouple cable at those temperatures under all conditions. Users should confirm suitability of materials for a specific application with the thermocouple cable's supplier or the sheath metal alloy's manufacturer.

11.3 The method of packaging of completed cable shall be per producer's usual practice, unless otherwise requested by the purchaser.

11.4 Each individual length of product shall be marked with the producer's name, unique lot identification number, cable diameter, type of thermoelements, kind of sheath, quantity of thermoelements, kind of insulation, and the purchaser's order number.

11.5 Each shipping container shall be legibly marked with at least the following information:

11.5.1 Producer's name and address,

11.5.2 Length of each piece of finished thermocouple cable and quantity of cables in the package,

11.5.3 Purchaser's order number,

11.5.4 Nominal diameter of material,

11.5.5 Sheath type,

11.5.6 Insulation type, and

11.5.7 Quantity of thermoelements and type of each thermoelement.

12. Keywords

12.1 sheathed thermocouple material; thermocouple; thermoelement

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order.

TABLE S1.1 Minimum Insulation Resistance at 1000°C (1832°F)

NOTE 1—Apply the dc voltage using both direct and reversed polarity, and average the two readings.

NOTE 2—At elevated temperatures, such as 1000°C, insulation resistance is inversely proportional to the length in the elevated temperature.

Nominal Sheath Outside Diameter, mm (in.)	Applied Voltage min, V, dc	Insulation Resistance, min, Ω/300 mm (1 ft) at 1000°C
0.5 (0.020) to 1.45 (0.057)	50	5 000
Larger than 1.45 (0.057)	100	100 000

S1. Optional Elevated-Temperature Insulation Resistance

S1.1 If this optional requirement is specified, insulation resistance shall be measured at 1000°C (1832°F) to indicate if insulation contamination, which cannot be detected at room temperature, is present. This test is intended primarily for Type K and N cables. This is a destructive test, and material tested for high-temperature insulation resistance shall not be considered usable. Perform this high temperature insulation resistance test in accordance with Paragraph 7.5.2 of Test Methods E839. The insulation resistance requirements are shown in Table S1.1.

S1.2 The purchaser and the producer shall agree upon the sample plan and the disposition of tested material.

S2. Sheath Condition and Flexibility

S2.1 If this optional requirement is specified, the condition of the annealed sheath shall be demonstrated on one sample selected from each lot.

S2.1.1 Close wind the selected section of the sheathed thermocouple cable three full turns around a mandrel twice the sheath diameter. Check the continuity of each thermoelement and the insulation resistance between each thermoelement and the sheath and between thermoelements before and after winding. The following is cause for rejection of the lot of material: a reduction in the insulation resistance by a factor of 10 or more, an open thermoelement, a short between the thermoelements, or a short between any thermoelement and the sheath.

S2.1.2 Cut the center turn from the section and examine under 30× magnification. Any visual evidence of sheath cracking shall be cause for rejection of the lot.

S3. Sheath Integrity Tests

S3.1 If this option is specified, the sheath integrity shall be inspected using one of the following tests from 8.1 of Test Methods E839:

S3.1.1 Fast Sheath Integrity Test Using Water,

S3.1.2 Basic Sheath Integrity Test Using Water,

S3.1.3 Sheath Integrity Mass Spectrometer Method, and

S3.1.4 Dye Penetrant Method.

S4. Surface Finish

S4.1 If this optional requirement is specified, the outside surface of all finished thermocouple cable shall have a bright appearance with a finish no rougher than 0.81 µm [32 µin.] rms. A visual comparison made with roughness standards in accordance with ANSI B46.1 shall be acceptable.

S5. Calibration of Sample Thermocouple at Other Temperatures

S5.1 The purchaser may specify calibration tests at other temperatures in addition to, or instead of, the temperatures specified in Table 6. The upper-use temperature of both the sheath and the thermoelements should be taken into consideration. For more information, see ASTM MNL 12.[7]

S6. Requirements for Measuring Insulation Compaction Density and Insulation Retention

S6.1 *Compaction Density Measurement*—If this optional requirement is specified, compaction density of the mineral insulation shall be determined using methods specified in Test Methods E839 unless otherwise agreed upon between the purchaser and the producer.

S6.2 *Insulation Retention Requirement*—If this optional requirement is specified, the test method and the acceptance levels for minimum insulation retention shall be agreed upon between the purchaser and the producer.

S7. Analysis of the Insulating Material

S7.1 If this optional requirement is specified, a certified analysis of the composition of the insulating material as supplied to the thermocouple cable producer shall be furnished to the purchaser. The thermocouple cable producer shall be responsible for maintaining the purity within the specified limits in the finished thermocouple material.

S8. Special Requirements for the Sheath

S8.1 If this optional requirement is specified, standard sheath materials shall be austenitic stainless steels as specified in Specifications A213/A213M, A249/A249M, A269, and A632 or Ni-Cr-Fe alloy. Unless otherwise specified, the thermocouple cable producer's normal specification shall apply.

NOTE S8.1—The supplemental cleanliness requirements (S3) of Specification A632 shall apply to all material supplied to this specification, except that acetone or any other solvents that might leave a harmful residue shall not be used for final cleaning.

[7] *Manual on the Use of Thermocouples in Temperature Measurement, ASTM MNL-12*, Fourth Edition, ASTM, April 1993. (Revision of STP 407B.)

S8.2 *Additional Requirements* —The purchaser shall specify the name of the material and the grade. The purchaser may also specify any other options called for by the ASTM specifications.

S8.3 *Deviations*—This specification may be used for material not herein specified but any and all specifications and deviating requirements shall be agreed upon by the purchaser and the producer in the purchasing documents.

S9. Metallurgical Structure of the Sheath

S9.1 If this optional requirement is specified:

S9.1.1 A section from the sample thermocouple shall be examined for grain size of the sheath.

S9.1.2 A section from the sample thermocouple shall be examined for cracks or localized wall thinning in the sheath.

S9.1.3 The test methods and the acceptance levels shall be agreed upon between the purchaser and the producer. Specification E235 may be used as a guide.

APPENDIX

(Nonmandatory Information)

X1. IDENTIFICATION AND DOCUMENTATION OF QUALITY ASSURANCE AND QUALITY VERIFICATION

X1.1 Scope

X1.1.1 This appendix shall apply only when the requirement is specified by the purchaser in the inquiry, contract, or purchase order. This appendix has been prepared as a guide for the purchaser, to determine what specific requirements should be covered by the purchaser's quality assurance documents.

X1.1.2 If specified, the producer shall be responsible for observing the requirements of the purchaser's quality assurance and verification program specifications during the manufacturing and testing of the sheathed thermocouple material. This may also include the verification of all raw materials used in their manufacture.

X1.2 Identification and Documentation

X1.2.1 Identification and documentation shall make it possible to trace any finished thermocouple material length back through production and testing to the raw materials used in that length. The producer shall identify all raw materials and thermocouple material through all phases of production, storage, and shipment. For this, the producer shall use the identification methods submitted to the purchaser for approval (and approved by the purchaser), for positive identification by labeling, tagging, and coding.

X1.3 Test Procedures

X1.3.1 All tests shall be performed in accordance with written test procedures prepared in accordance with the purchaser's quality assurance and verification program specification.

X1.3.1.1 The purchaser shall state in the ordering documents whether he will accept the producer's standard test procedures, or whether specific test procedures for the purchase order shall be prepared and submitted to the purchaser for approval.

X1.3.1.2 If the test procedures are to be submitted to the purchaser for approval, the producer shall itemize and specify the test procedure required, referencing the appropriate sections of this specification and the supplementary requirements of this specification.

X1.3.1.3 If the procedures shall include raw material procurement, then the purchaser shall so state in the ordering documents.

X1.4 Documentation

X1.4.1 All documentation shall be submitted in accordance with purchaser's quality assurance and verification program specification. It is suggested that the documentation include the following:

X1.4.1.1 The certifications covering all raw materials,

X1.4.1.2 The in-process certifications and results, and

X1.4.1.3 Certifications and test results for all routine tests stated in this specification.

X1.5 In-Process Surveillance

X1.5.1 Any in-process surveillance by the purchaser shall be determined by agreement between the purchaser and the producer and shall be covered by the purchase documents.