



# Standard Specification for Mineral-Insulated, Metal-Sheathed Base Metal Thermocouples<sup>1</sup>

This standard is issued under the fixed designation E 608/E 608M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers the requirements for mineral-insulated, metal-sheathed base metal thermocouples for industrial or high-reliability applications. It applies specifically to thermocouples fabricated from sheathed thermocouple material in accordance with Specification E 585/E 585M. Provisions are made for selecting thermoelements, insulation, and sheath material, and measuring junction configuration, thermocouple assembly length, and the type of transition or termination.

1.2 This specification also includes provisions for quality assurance or verification program requirements, or both, as a purchaser's option.

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

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- E 94 Guide for Radiographic Examination
- E 142 Method for Controlling Quality of Radiographic Testing<sup>3</sup>
- E 165 Test Method for Liquid Penetrant Examination
- E 220 Test Method for Calibration of Thermocouples by Comparison Techniques

<sup>1</sup> 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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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Withdrawn.

E 230 Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples

E 344 Terminology Relating to Thermometry and Hydrometry

E 585/E 585M Specification for Compacted Mineral-Insulated, Metal-Sheathed, Base Metal Thermocouple Cable

E 780 Test Method for Measuring the Insulation Resistance of Sheathed Thermocouple Material at Room Temperature

E 839 Test Methods for Sheathed Thermocouples and Sheathed Thermocouple Material

### 2.2 AWS Standards:<sup>4</sup>

A5.9 Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes

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

## 3. Terminology

3.1 *Definitions*—The definitions given in Terminology E 344 shall apply to this specification.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *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.

3.2.2 *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.

3.2.3 *lot, n*—a quantity of thermocouples manufactured from the same continuous length of mineral-insulated, metal-sheathed thermocouple cable.

3.2.4 *sheathed thermocouple material, n*—a combination of two or more continuous thermoelements embedded in ceramic insulation compacted within a metal protecting sheath.

<sup>4</sup> Available from The American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126.

**TABLE 1 Suggested Upper Temperature Limits for Sheathed Thermocouples**

NOTE 1—This table gives the suggested upper temperature limits for the various thermocouples in several common sheath sizes. It does not take into account environmental temperature limitations of the sheath material itself, nor does it address compatibility considerations between the thermoelement materials and the sheath containing them. The actual maximum practical temperature in a particular situation will generally be limited to the lowest temperature among the several factors involved. The purchaser should consult ASTM Manual 12<sup>5</sup> and other literature sources for further applications information.

NOTE 2—The temperature limits given here are intended only as a guide to the purchaser and should not be taken as absolute values nor as guarantees of satisfactory life or performance. These types and sizes are sometimes used at temperatures above the given limits, but usually at the expense of stability or life, or both. In other instances, it may be necessary to reduce the given limits in order to achieve adequate service.

Nominal Sheath Diameter		Upper Temperature Limit for Various Sheath Diameters °C [°F]				
		Thermocouple Type				
mm	in.	T	J	E	K, N	
0.5	0.020	260 (500)	260 (500)	300 (570)	700 (1290)	
...	0.032	260 (500)	260 (500)	300 (570)	700 (1290)	
1.0	0.040	260 (500)	260 (500)	300 (570)	700 (1290)	
1.5	0.062	260 (500)	440 (825)	510 (950)	920 (1690)	
2.0	...	260 (500)	440 (825)	510 (950)	920 (1690)	
...	0.093	260 (500)	480 (900)	580 (1075)	1000 (1830)	
3.0	0.125	315 (600)	520 (970)	650 (1200)	1070 (1960)	
4.5	0.188	370 (700)	620 (1150)	730 (1350)	1150 (2100)	
6.0	0.250	370 (700)	720 (1330)	820 (1510)	1150 (2100)	
8.0	0.375	370 (700)	720 (1330)	820 (1510)	1150 (2100)	

#### 4. Significance and Use

4.1 This specification describes the physical requirements of mineral-insulated, metal-sheathed base metal thermocouples and establishes suitable test criteria for them.

4.2 Standardized dimensional requirements, including acceptable allowances for manufacturing variations, are given.

4.3 A set of standard tests to be applied to all thermocouples covered by this specification are described together with a group of optional tests from which applicable additional requirements may be selected.

4.4 **Warning**—Users should be aware that certain characteristics of thermocouples might change with time and use. If a thermocouple's designed shipping, storage, installation, or operating temperature has been exceeded, the thermocouple's moisture seal may have been compromised and may no longer adequately prevent the deleterious intrusion of water vapor. Consequently, the thermocouple's condition established by test at time of manufacture may not apply later during an extended period of use, and retesting may become necessary. In addition, inhomogeneities can develop in thermoelements because of exposure to temperature, even in cases where maximum exposure temperatures have been lower than the suggested upper temperature limits of Table 1. For this reason, calibration of thermocouples destined for delivery to a customer is not recommended (see S6.1). Because the EMF indication of any thermocouple depends upon the condition of the thermoelements along their entire length, as well as the temperature profile pattern in the region of any inhomogeneity, the EMF output of a used thermocouple will be unique to its installation. Because temperature profiles in calibration equipment are unlikely to duplicate those of the installation, removal of a used thermocouple to a separate apparatus for calibration is not recommended. Instead, in situ calibration by comparison to a similar thermocouple known to be good is often recommended.

#### 5. Ordering Information

5.1 The purchase documents shall specify the following options:

5.1.1 The type and quantity of thermoelement pairs, and the tolerances, if other than standard (see 6.4 and 6.5).

5.2 The nominal sheath diameter. See Table 1 or Specification E 585/E 585M for preferred nominal diameters.

5.3 The type of ceramic insulation (MgO or Al<sub>2</sub>O<sub>3</sub>). See Specification E 585/E 585M.

5.4 The type of sheath material. See Table 2 or Specification E 585/E 585M.

5.5 The type of measuring junction, Class 1 (grounded) or Class 2 (ungrounded). See Figs. 1 and 2. If more than one pair of thermoelements is specified, Class 2 is further subdivided into Class 2A (common ungrounded) and Class 2B (isolated ungrounded). Do not specify Class 1 grounded junctions with Type T thermoelements (see 6.3.2).

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

5.7 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, or termination, and moisture seal should be specified (6.6). For thermocouples with insulated wire attached (Fig. 6) and Class 2 junctions, state the minimum acceptable insulation resistance (6.7).

5.8 Optional supplementary testing requirements and test sample rate (8.2).

5.9 The quality assurance or verification program requirements, or both, including material traceability if required. See Appendix X1.

5.10 Any deviations from this specification or the referenced specifications.

**TABLE 2 Weld Closure Filler Metal**

Sheath Material	Weld Rod AWS Type	AWS Specification
Austenitic Stainless Steels		
TP 304	ER 308	A5.9
TP 304L	ER 308L	A5.9
TP 310	ER 310	A5.9
TP 316	ER 316	A5.9
TP 316L	ER 316L	A5.9
TP 317	ER 317	A5.9
TP 321	ER 347	A5.9
TP 347	ER 347	A5.9
TP 348	ER 348	A5.9
Nickel-chromium-iron alloy	ER NiCrFe-5	A5.14

5.11 Shipping method and straightness criteria, if required (see 10.2).<sup>5</sup>

5.12 The minimum and maximum intended operating temperatures of the thermocouple (see S6.1).

## 6. General Requirements

6.1 *Tagging*—During fabrication, each thermocouple shall be tagged with a unique identification number to keep traceability to materials and test data. The producer's standard tagging method may be used.

6.2 *Welding Rod*—Filler material used for welding or plugging the end closure shall comply with Table 2.

### 6.3 Measuring Junctions:

6.3.1 The end closure 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 measuring junction shall be replaced with dry oxide of the same type that is in accordance with the purity requirements of Specification E 585/E 585M. Class 2 measuring junctions shall be fabricated by welding the thermoelements without filler metal or flux.

6.3.2 The measuring junction end closures shall be seal welded. The use of plugs or filler metals is optional. Class 1 (grounded) measuring junctions on Type T thermocouples are excluded from this specification because of the problems associated with welding the copper thermoelement.

6.4 *Standard Tolerances*—Sheathed thermocouples fabricated to this specification shall conform to the standard tolerances (see Table 3) in accordance with Specification E 230, unless otherwise specified.

6.5 *Special Tolerances*—If specified in the purchase document, the special tolerances (see Table 3) in accordance with Specification E 230 shall apply.

6.6 *Termination*—The sheathed thermocouples shall be terminated at the end opposite the measuring junction in a manner specified by the purchaser. All exposed MgO or Al<sub>2</sub>O<sub>3</sub> shall be sealed from moisture to keep the insulation dry. All connectors, connection heads, or transitions shall include a positive method of preventing strain on the thermoelements emerging from the sheathed material. All transitional wire connections shall be brazed or welded. The moisture seal and termination (see Figs.

3-6) shall be compatible with their intended installation and operating conditions (see 5.7).

6.7 *Room Temperature Insulation Resistance (Class 2 Junctions)*—The minimum room temperature electrical insulation resistance between the thermoelement pairs and the sheath for sheathed thermocouples with Class 2 junctions shall be as specified in Table 4 for the dc test voltage noted. In addition, for Class 2B (isolated ungrounded) junctions, the minimum electrical insulation specified in Table 4 shall also apply between thermoelement pairs. The minimum insulation value shall be negotiated between the purchaser and the producer for Fig. 6 assemblies with purchaser-specified insulated thermocouple extension wire or other devices attached. For Fig. 5 assemblies, the minimum insulation resistance values of Table 4 shall be imposed before the thermocouple is terminated (when it is like Fig. 4). The insulation resistance shall be tested in accordance with Test Method E 780.

6.8 *Sheath Condition*—The surface of the completed thermocouples shall be visually clean, dry, and oxide-free.

6.9 The tests specified in 8.1 are required to determine if the specification requirements have been met. Additional optional requirements are listed in the Supplementary Requirements section, and may be included in the purchase order requirements, as desired by the purchaser.

6.10 All testing and inspection shall be performed in accordance with Test Methods E 839 unless otherwise indicated.

## 7. Measuring Junction Configuration

7.1 The measuring junction configurations are shown in cross section in Figs. 1 and 2. The tip shape is optional as long as the dimensional requirements are maintained. The preferred nominal sheath diameters are listed in Table 1 or Specification E 585/E 585M. The measuring junction dimensional requirements are as follows:

7.1.1 *Dimension A, End-Closure Diameter, Classes 1 and 2*—The end-closure maximum diameter shall be no larger than the nominal sheath diameter plus a weld allowance of 0.05 mm (0.002 in.) or 2 % of the nominal sheath diameter, whichever is larger. Localized reduction of the end-closure diameter caused by weld shrinkage shall not exceed 0.05 mm (0.002 in.) or 2 % of the nominal sheath diameter, whichever is larger. This expanded end-closure diameter tolerance shall apply from the tip of the end closure over a length not exceeding 2× the nominal sheath diameter.

7.1.2 *Dimensions Controlled by Supplementary Radiographic Inspection (see Supplementary Requirement S1):*

7.1.2.1 *Dimension B, Measuring Junction Length*—The measuring junction length on Class 2A and Class 2B junctions shall be a minimum of one and a maximum of four thermoelement diameters long.

7.1.2.2 *Dimension C, Minimum Measuring Junction Insulation Thickness, Radial Dimension*—The minimum insulation thickness on Class 2A and 2B junctions, as measured from the junction to the sheath in a radial direction, shall be 5 % of the nominal sheath diameter.

7.1.2.3 *Dimension D, Minimum Material Thickness, Class 1 and Class 2 Junctions*—The thickness at any point of the end-closure weld interface shall be not less than 10 % of the nominal sheath diameter. Wall thinning caused by welding

<sup>5</sup> "Manual on the Use of Thermocouples in Temperature Measurement," *ASTM Manual 12*, ASTM International, 1993.

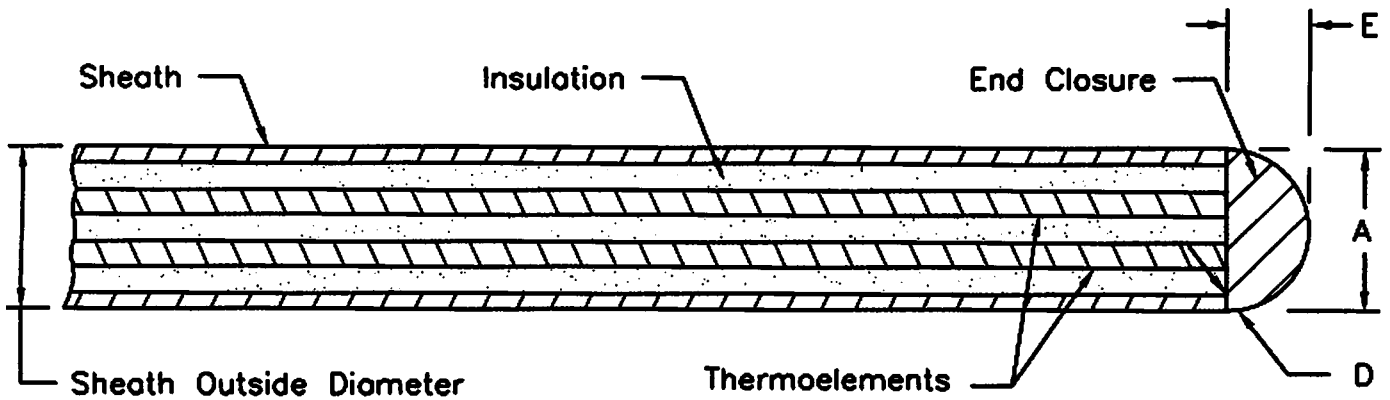


FIG. 1 Grounded Measuring Junction, Class 1

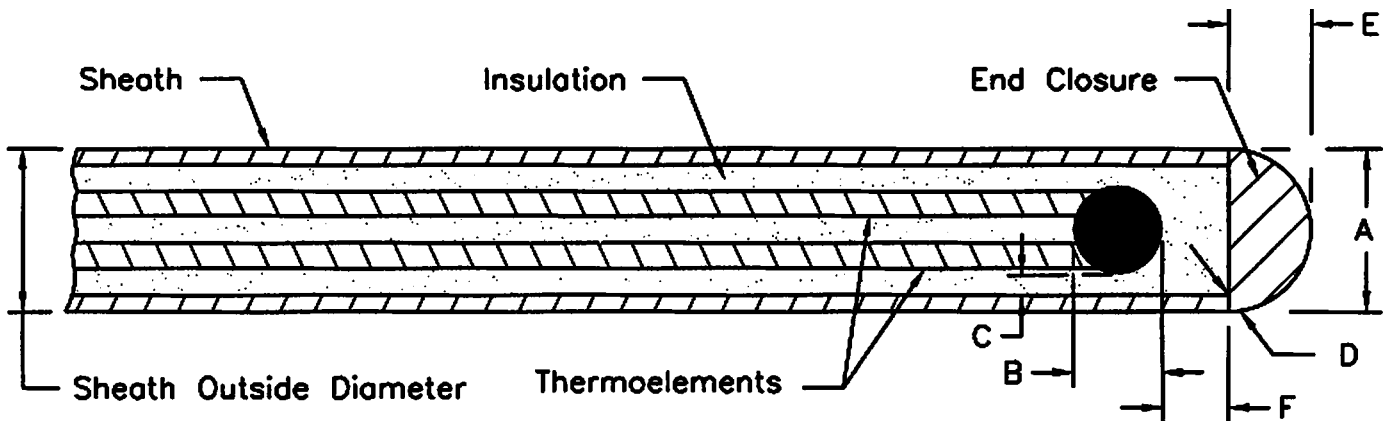


FIG. 2 Ungrounded Measuring Junction, Class 2

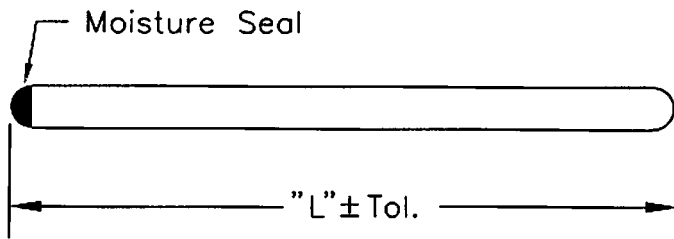


FIG. 3 Sheathed Thermocouple

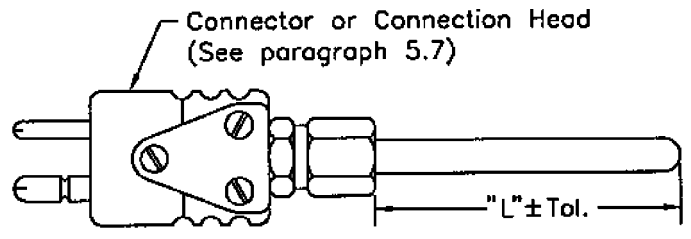


FIG. 5 Sheathed Thermocouple Assembly with Connector or Connection Head (Any Type Specified)

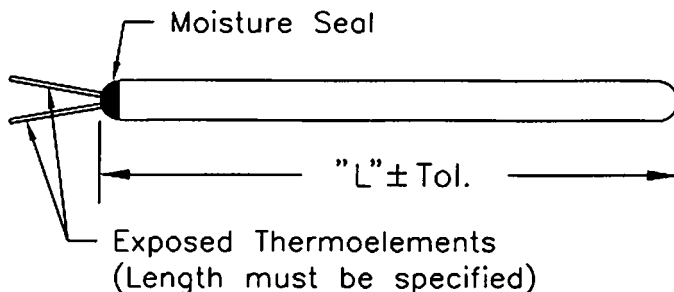


FIG. 4 Sheathed Thermocouple with Exposed Wires

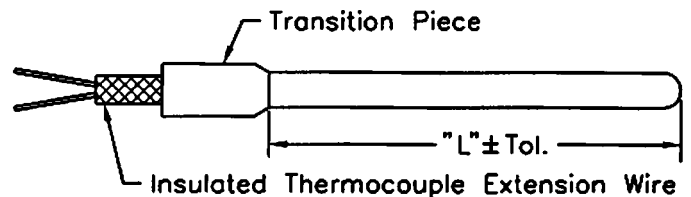


FIG. 6 Sheathed Thermocouple Assembly with Transition Piece

shall be limited to the minimum material sheath wall thickness requirement of 10 % of the nominal diameter.

7.1.2.4 *Dimension E, End-Closure Thickness*—The end-closure thickness, on both Class 1 and Class 2 junctions, shall be a minimum of 10 % and a maximum of 80 % of the nominal sheath diameter.

7.1.2.5 *Dimension F, Measuring Junction Location*—The measuring junction or junctions of Class 2A and 2B thermocouples, respectively, shall be located a minimum of 10 % of the sheath diameter and a maximum of either 0.75 mm (0.030 in.) or 50 % of the nominal sheath diameter, whichever is greater, from the inside surface of the end closure. Dimension F is defined as the shortest axial distance between end closure and measuring junction.



**TABLE 3 Tolerances on Initial Values of EMF versus Temperature for Sheathed Thermocouples**

NOTE 1—Tolerances in this table apply to new sheathed thermocouple material when used at temperatures not exceeding the recommended limits of Table 1. If used at higher temperatures, these tolerances may not apply.

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. 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]			
	°C	°F	Standard Tolerances		Special Tolerances	
			°C	°F	°C	°F
T	0 to 350	32 to 700	±1 or 0.75 %	Note 3	±.5 or 0.4 %	Note 3
J	0 to 750	32 to 1400	±2.2 or 0.75 %		±1.1 or 0.4 %	
E	0 to 900	32 to 1600	±1.7 or 0.5 %		±1 or 0.4 %	
K	0 to 1250	32 to 2300	±2.2 or 0.75 %		±1.1 or 0.4 %	
T <sup>A</sup>	-200 to 0	-328 to 32	±1 or 1.5 %		<sup>B</sup>	
E <sup>A</sup>	-200 to 0	-328 to 32	±1.7 or 1 %		<sup>B</sup>	
K <sup>A</sup> , N	-200 to 0	-328 to 32	±2.2 or 2 %		<sup>B</sup>	

<sup>A</sup> Sheathed thermocouples and thermocouple material 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 sub-zero tolerances given in the second section of the table. If materials are required to meet the sub-zero limits, the purchase order must so state. Selection of materials will be required.

<sup>B</sup> Little information is available to justify establishing special tolerances for sub-zero temperatures. Such special sub-zero tolerances, if required, shall be agreed upon between the purchaser and the producer.

**TABLE 4 Room-Temperature Insulation Resistance for Thermocouples with Class 2 (Ungrounded) Measuring Junctions**

Nominal Sheath Outside Diameter	Applied Voltage, min, V, dc	Insulation Resistance, min, MΩ
Less than 0.80 mm [0.030 in.]	50	100
0.80 to 1.45 mm [0.030 to 0.057 in.]	50	500
Larger than 1.45 mm [0.057 in.]	500	1000

## 8. Test Requirements

8.1 *Standard Tests*—There are certain minimum inspection requirements for each thermocouple fabricated to this specification. Perform the standard tests in accordance with the producer's established procedures in accordance with 8.4. These tests, noted as standard tests, are listed as follows:

8.1.1 *Visual and Envelope Dimensional Inspection,*

8.1.2 *Room Temperature Insulation Resistance Measurement on Class 2 Junctions Only,*

8.1.3 *Thermocouple Polarity Test, and*

8.1.4 *Electrical Continuity Test.*

8.2 *Optional Tests*—The optional tests listed below may be specified in whole or part in the purchase documents by the purchaser. The sample rate shall also be specified by the purchaser. Perform the optional tests in accordance with the following Supplementary Requirements:

S1—Radiographic Inspection

S2—End-Closure Weld Integrity Test Using the Dye Penetrant Method

S3—End-Closure Weld and Sheath Integrity Test Using the Helium Mass Spectrometer Method

S4—End-Closure Weld and Sheath Integrity Test Using Water (thermocouples with Class 2 measuring junctions only)

S5—Elevated Temperature Insulation Resistance (thermocouples with Class 2 measuring junctions only)

S6—Calibration

8.3 *Documentation*—Copies of the documented test results shall be supplied to the purchaser, along with a certification of conformance in accordance with Section 9.

8.4 *Standard Tests*—The producer shall perform the following measurements and checks on each thermocouple, using the test and inspection methods described in Test Methods E 839 to ensure that the product conforms to the ordering documents.

8.4.1 *Visual and Envelope Dimensional Inspection*—Examine each thermocouple to ensure that the length is within the length tolerance ordered, and that the connector or termination is of the type, size, or configuration, or a combination of these, specified. Examine each thermocouple to ensure that a moisture seal is present, that the measuring junction end-closure weld is within dimensional limits, and that surface finish, straightness, and cleanliness are acceptable.

8.4.2 *Room-Temperature Insulation Resistance*—Measure the insulation resistance of each Class 2 (ungrounded) thermocouple between all thermoelements and sheath for conformance with Table 4 with the applied voltage specified (both direct and reversed polarity). In addition, measure the insulation resistance of each Class 2B (isolated ungrounded) thermocouple between thermoelement pairs for conformance with Table 4 with the applied voltage specified (both direct and reversed polarity). Document measured values. Measure Class 2 thermocouples with thermocouple extension wire attached (Fig. 6) before and after attachment. Use the values measured prior to termination to judge conformance. The values measured after termination shall exceed the values agreed upon between the purchaser and the producer. This test can also apply to Class 1 (grounded junction) thermocouples if both producer and purchaser agree that the purchaser can select a sample thermocouple from the lot, remove the junction, exercising caution to prevent moisture pick-up, and measure insulation resistance. In the event that this sample thermocouple has insulation resistance less than that specified in Table 4, or, in the case of thermocouples with extension wire attached, less than that agreed upon between the purchaser and the producer, the entire lot shall be deemed to be not in conformance with this specification.

8.4.3 *Thermocouple Assembly Polarity Test*—Check each thermocouple assembly that has a connection head, connector, transition piece, or termination device of any kind for proper polarity by heating the measuring junction and noting the polarity of the electromotive force at the termination.

8.4.4 *Electrical Continuity Test*—Verify the continuity of each of the thermocouple's thermoelement pairs with an ohmmeter. Also check Class 1 (grounded) junctions for thermoelement-to-sheath continuity. No quantitative measurements are required. The continuity test is not a substitute for the polarity test.

## 9. Certification and Test Reports

9.1 A Certificate of Conformance covering the finished thermocouple and the data taken during the testing by the producer shall be provided to the purchaser upon request. The Certificate of Conformance shall state that the finished thermocouple has been manufactured from the material specified in the purchase order, that the material has been tested in accordance with this specification, that the results of the tests are in accordance with the specification, and that the test data

and material certifications will remain on file at the producer's facility for a minimum period of 3 years.

## 10. Packaging, Marking, and Shipping

10.1 *Cleaning*—Prior to packaging, the sheaths shall be cleaned of grease, oil, dirt, scale, and other foreign matter.

10.2 *Packaging*—The thermocouples shall be shipped straight or in coils with diameters agreed upon by both purchaser and producer. The thermocouples shall be packed in dust-tight containers, and bound together, if coiled, to prevent abrasion. When shipped straight, they shall be packaged in dust-tight containers and boxed or supported to prevent bending.

10.3 *Item Identification*—Each thermocouple shall be identified with the producer's name, unique identification number, and the purchaser's order number.

## 11. Keywords

11.1 base-metal thermocouples; junction; metal-sheathed; moisture seal; sheathed thermocouples; termination; thermocouple; thermoelement

## SUPPLEMENTARY REQUIREMENTS

The following requirements shall apply when specified by the purchaser in the ordering documents:

### S1. Radiographic Inspection

S1.1 **Warning**—The requirements of this section necessitate the use of techniques more sophisticated than normally used in radiography.

S1.2 Examine a length of the fabricated thermocouple extending a minimum of 75 mm (3 in.) from the measuring junction, including the end closure, by radiography to determine that the dimensions are in accordance with 7.1.2, and that the defects do not exceed the following limits:

S1.2.1 Cracks, voids, or inclusions in the end closure weld or sheath wall, or thinning of the sheath wall greater than 25 % of the sheath wall thickness, or 0.05 mm (0.002 in.), whichever is greater.

S1.2.2 Cracks, voids, inclusions, or local reduction of the conductors in or near the measuring junction greater than 25 % of the thermoelement diameter or 0.05 mm (0.002 in.), whichever is greater.

S1.2.3 Voids or inclusions in the insulation greater than 50 % of the thermoelement-to-sheath or thermoelement-to-thermoelement separation.

#### S1.3 *Radiographic Method:*

S1.3.1 Perform radiographic inspection in accordance with Test Methods E 839.

S1.3.2 Use single-coated, ultra-fine grain film.

S1.3.3 The radiograph shall have appropriate means to identify the image with the thermocouple.

S1.3.4 Supply radiograph to the purchaser upon request with appropriate means to identify the thermocouple with its radiograph.

### S2. End-Closure Weld Integrity Test Using the Dye Penetrant Method

S2.1 The thermocouple's end-closure weld and a minimum of 25 mm (1 in.) of sheath length shall be free of cracks, seams, holes, or other defects on the surface when tested with dye penetrant in accordance with Procedure A-2 of Test Method E 165.

### S3. End-Closure Weld and Sheath Integrity Test Using the Helium Mass Spectrometer Method

S3.1 This test shall be performed in accordance with the section titled "Sheath Integrity—Mass Spectrometer Method" in Test Methods E 839. The length of sheath to be included in the test shall be specified by the purchaser.

### S4. End-Closure Weld and Sheath Integrity Test Using Water

S4.1 Compliance will be demonstrated by examining Class 2 finished thermocouples for cracks, holes, and voids in accordance with the section titled "Sheath Integrity Test Using Water" in Test Methods E 839.

### S5. Elevated Temperature Insulation Resistance

S5.1 This test is performed on assemblies at a temperature of 1000°C (1832°F) to measure contamination effects that cannot be evaluated at room temperature. This test is performed primarily on Type K and N Class 2 (ungrounded junction) thermocouples. This is a destructive test, and sensors tested for high-temperature insulation resistance tests shall not be considered deliverable for installation as a new thermocouple assembly. The resistance requirements are shown in

**TABLE S1 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.

NOTE 3—This test is for Type K and N thermocouples with Class 2 ungrounded junctions.

Nominal Sheath Outside Diameter	Applied Voltage, min, V, dc	Insulation Resistance, min $\Omega$ per 300 mm [1 ft] at 1000°C
0.5 mm [0.020 in.] to 1.45 [0.057 in.]	50	5000
Larger than 1.45 mm [0.057 in.]	100	100 000

Table S1. Perform this high temperature insulation resistance test in accordance with 7.5.2.2 on Elevated Temperature, Contaminants Other than Moisture of Test Methods E 839 except that a test specimen length of 300 mm (12 in.) may be used.

S5.2 The purchaser and the producer shall agree upon the sample plan and the disposition of tested specimens.

## S6. Calibration

S6.1 Demonstrate compliance with the requirements of 6.4 or 6.5 by randomly selecting finished thermocouples manufactured from the same lot of cable and calibrating them in accordance with the general procedures in Test Method E 220. Perform this calibration in order of increasing temperature at temperatures that represent the minimum, intermediate, and maximum intended operating conditions of the thermocouples (see 5.12). If the intended operating conditions are not indicated by the purchaser, use the calibration temperatures defined in Specification E 585/E 585M. Subjecting the thermocouples to thermal treatment during calibration testing may cause the thermoelements to become inhomogeneous. Therefore, calibration of every thermocouple from a lot is not recommended. See 4.4.

S6.2 The producer and purchaser shall agree upon a sample plan and disposition of the calibration specimens.

## APPENDIX

### (Nonmandatory Information)

## X1. QUALITY ASSURANCE AND QUALITY VERIFICATION

### X1.1 Scope

X1.1.1 This appendix shall apply only when required by the purchaser.

X1.1.2 This appendix has been prepared as a guide for the purchaser in determining what specific requirements should be covered by the purchaser's quality assurance documents.

X1.1.3 If specified, the producer shall be responsible for observing the requirements of the purchaser's quality assurance/verification program specifications during the manufacturing and testing of the sheathed thermocouples. 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 back through production and testing to the materials used in it. The producer shall identify all raw materials, components, and thermocouple material through all phases of production, storage, and shipment. For this, the producer shall use identification methods 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, and, when required, prepared in

accordance with the purchaser's quality assurance/verification program specification.

X1.3.2 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.

X1.3.3 If the test procedures must be submitted to the purchaser for approval, the purchaser shall itemize and specify the test procedures required, referencing the appropriate sections of this specification and the Supplementary Requirements of this specification.

X1.3.4 If the procedures 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 the purchaser's quality assurance/verification program specification. It is suggested that the documentation include the following:

X1.4.1.1 Certifications covering all raw materials,

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

X1.4.1.3 Certifications and test results for all tests called for in this specification and the purchase documents.

### 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.

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