



Designation: E608/E608M – 06

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

This standard is issued under the fixed designation E608/E608M; 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 ( $\epsilon$ ) 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 E585/E585M. 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>

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

E585/E585M Specification for Compacted Mineral-Insulated, Metal-Sheathed, Base Metal Thermocouple Cable

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

2.2 *AWS Standards:*<sup>3</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 E344 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.

## 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.

<sup>3</sup> Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, <http://www.aws.org>.

<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.

Current edition approved Nov. 1, 2006. Published November 2006. Originally approved in 1977. Last previous edition approved in 2004 as E608/E608M - 00 (2004). DOI: 10.1520/E0608\_E0608M-06.

<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.

**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)

4.2 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 **E585/E585M** for preferred nominal diameters.

5.3 The type of ceramic insulation (MgO or Al<sub>2</sub>O<sub>3</sub>). See Specification **E585/E585M**.

5.4 The type of sheath material. See **Table 2** or Specification **E585/E585M**.

5.5 The type of measuring junction, Style G (grounded) or Style U (ungrounded). See **Figs. 1 and 2**. If more than one pair of thermoelements is specified, Style U is further subdivided into Style CU (common ungrounded) and Style IU (isolated ungrounded).<sup>4</sup> Do not specify Style G 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 Style U 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.

<sup>4</sup> 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 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 E585/E585M. Style U 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. Style G (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 E230, unless otherwise specified.

6.5 *Special Tolerances*—If specified in the purchase document, the special tolerances (see Table 3) in accordance with Specification E230 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 (Style U Junctions)*—The minimum room temperature electrical insulation resistance between the thermoelement pairs and the sheath for sheathed thermocouples with Style U junctions shall be as specified in Table 4 for the dc test voltage noted. In addition, for Style IU (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 E780.

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 E839 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 E585/E585M. The measuring junction dimensional requirements are as follows:

7.1.1 *Dimension A, End-Closure Diameter, Styles U and G*—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 diametral 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 Style CU and Style IU 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 Style CU and IU junctions, as measured from the junction to the sheath in a radial direction, shall be 5 % of the nominal sheath diameter.

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

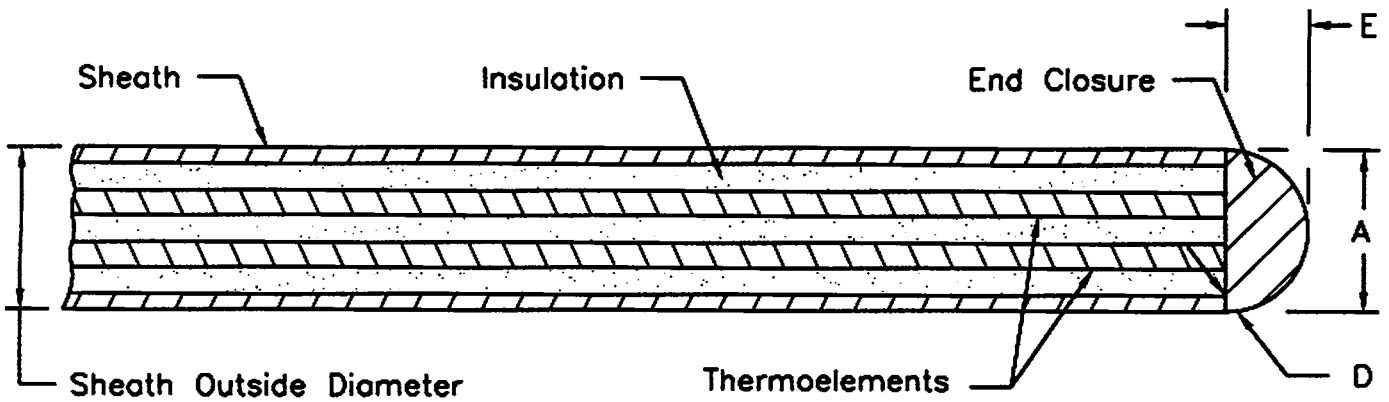


FIG. 1 Grounded Measuring Junction, Style G

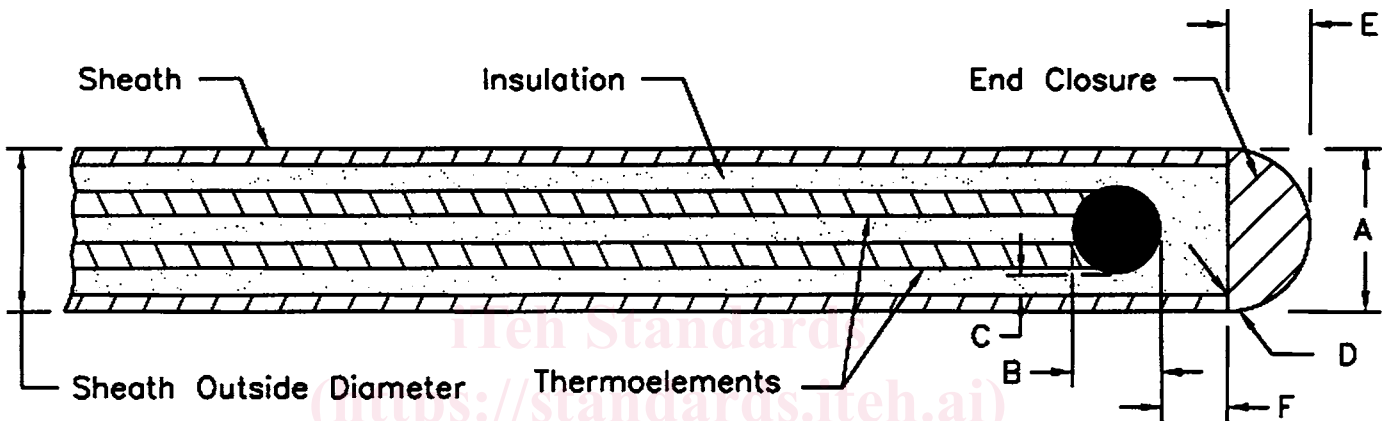


FIG. 2 Ungrounded Measuring Junction, Style U

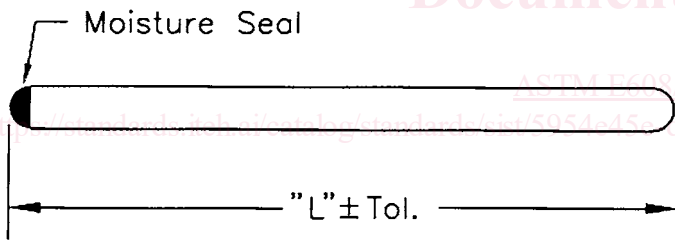


FIG. 3 Sheathed Thermocouple

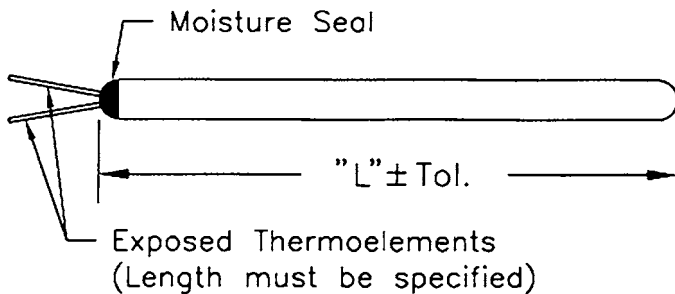


FIG. 4 Sheathed Thermocouple with Exposed Wires

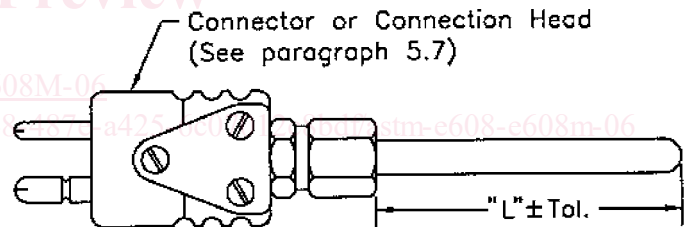


FIG. 5 Sheathed Thermocouple Assembly with Connector or Connection Head (Any Type Specified)

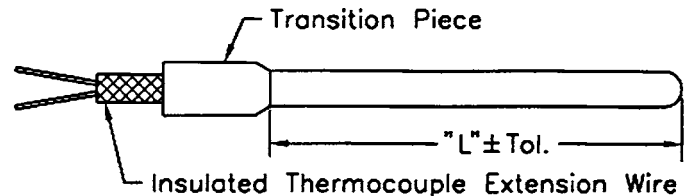


FIG. 6 Sheathed Thermocouple Assembly with Transition Piece

7.1.2.3 *Dimension D, Minimum Material Thickness, Style G and Style U 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

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 Style G and Style U 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 Style CU and IU thermocouples, respectively, shall be located a minimum of 10 % of