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# Standard Test Methods for Sheathed Thermocouples and Sheathed Thermocouple Cable[1]

This standard is issued under the fixed designation E839; 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.

ε1 NOTE—Added references to Tables X1.7 and X1.8 to 10.7.4 editorially in December 2016.

## 1. Scope

1.1 This document lists methods for testing Mineral-Insulated, Metal-Sheathed (MIMS) thermocouple assemblies and thermocouple cable, but does not require that any of these tests be performed nor does it state criteria for acceptance. The acceptance criteria are given in other ASTM standard specifications that impose this testing for those thermocouples and cable. Examples from ASTM thermocouple specifications for acceptance criteria are given for many of the tests. These tabulated values are not necessarily those that would be required to meet these tests, but are included as examples only.

1.2 These tests are intended to support quality control and to evaluate the suitability of sheathed thermocouple cable or assemblies for specific applications. Some alternative test methods to obtain the same information are given, since in a given situation, an alternative test method may be more practical. Service conditions are widely variable, so it is unlikely that all the tests described will be appropriate for a given thermocouple application. A brief statement is made following each test description to indicate when it might be used.

1.3 The tests described herein include test methods to measure the following properties of sheathed thermocouple material and assemblies.

1.3.1 *Insulation Properties:*

1.3.1.1 *Compaction*—direct method, absorption method, and tension method.

1.3.1.2 *Thickness.*

1.3.1.3 *Resistance*—at room temperature and at elevated temperature.

1.3.2 *Sheath Properties:*

1.3.2.1 *Integrity*—two water test methods and mass spectrometer.

1.3.2.2 *Dimensions*—length, diameter, and roundness.

1.3.2.3 *Wall thickness.*

1.3.2.4 *Surface*—gross visual, finish, defect detection by dye penetrant, and cold-lap detection by tension test.

1.3.2.5 *Metallurgical structure*.

1.3.2.6 *Ductility*—bend test and tension test.

1.3.3 *Thermoelement Properties:*

1.3.3.1 *Calibration*.

1.3.3.2 *Homogeneity*.

1.3.3.3 *Drift*.

1.3.3.4 *Thermoelement diameter, roundness, and surface appearance*.

1.3.3.5 *Thermoelement spacing*.

1.3.3.6 *Thermoelement ductility*.

1.3.3.7 *Metallurgical structure*.

1.3.4 *Thermocouple Assembly Properties:*

1.3.4.1 *Dimensions*—length, diameter, and roundness.

1.3.4.2 *Surface*—gross visual, finish, reference junction end moisture seal, and defect detection by dye penetrant.

1.3.4.3 *Electrical*—continuity, loop resistance, and connector polarity.

1.3.4.4 *Radiographic inspection*.

1.3.4.5 *Thermoelement diameter*.

1.3.4.6 *Thermal response time*.

1.3.4.7 *Thermal cycle*.

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.*

[1] These test methods are under the jurisdiction of ASTM Committee E20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.04 on Thermocouples.

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## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

E3 Guide for Preparation of Metallographic Specimens
E94 Guide for Radiographic Examination
E112 Test Methods for Determining Average Grain Size
E165 Practice for Liquid Penetrant Examination for General Industry
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E207 Test Method for Thermal EMF Test of Single Thermoelement Materials by Comparison with a Reference Thermoelement of Similar EMF-Temperature Properties
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
E585/E585M Specification for Compacted Mineral-Insulated, Metal-Sheathed, Base Metal Thermocouple Cable
E608/E608M Specification for Mineral-Insulated, Metal-Sheathed Base Metal Thermocouples
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E780 Test Method for Measuring the Insulation Resistance of Mineral-Insulated, Metal-Sheathed Thermocouples and Thermocouple Cable at Room Temperature
E1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology
E1129/E1129M Specification for Thermocouple Connectors
E1350 Guide for Testing Sheathed Thermocouples, Thermocouples Assemblies, and Connecting Wires Prior to, and After Installation or Service
E1684 Specification for Miniature Thermocouple Connectors
E1751 Guide for Temperature Electromotive Force (EMF) Tables for Non-Letter Designated Thermocouple Combinations (Withdrawn 2009)[3]
E2181/E2181M Specification for Compacted Mineral-Insulated, Metal-Sheathed, Noble Metal Thermocouples and Thermocouple Cable

2.2 *ANSI Standard*

B 46.1 Surface Texture[4]

2.3 *Other Standard*

USAEC Division of Reactor Development and Technology RDT Standard C 2-1T Determination of Insulation Compaction in Ceramic Insulated Conductors August 1970

## 3. Terminology

3.1 *Definitions*—The definitions given in Terminology E344 shall apply to these test methods.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bulk cable, n*—a single length of thermocouple cable produced from the same raw material lots after completion of fabrication.

3.2.2 *cable lot, n*—a quantity of finished mineral–insulated, metal-sheathed thermocouple cable manufactured from tubing or other sheath material from the same heat, wire from the same spool and heat, and insulation from the same batch, then assembled and processed together under controlled production conditions to the required final outside diameter.

3.2.3 *cold-lap, n*—sheath surface defect where the sheath surface has been galled and torn by a drawing die and the torn surface smoothed by a subsequent diameter reduction.

3.2.4 *insulation compaction density, n*—the density of a compacted powder is the combined density of the powder particles and the voids remaining after the powder compaction. Sometimes the insulation compaction density is divided by the theoretical density of the powder particles to obtain a dimensionless fraction of theoretical density as a convenient method to express the relative compaction.

3.2.5 *raw material, n*—tubing or other sheath material, insulation and wires used in the fabrication of sheathed thermocouple cable.

3.2.6 *short range ordering, n*—the reversible short-ranged, order-disorder transformation in which the nickel and chromium atoms occupy specific (ordered) localized sites in the Type EP or Type KP thermoelement alloy crystal structure.

3.2.7 *thermal response time, n*—the time required for a sheathed thermocouple signal to attain the specified percent of the total voltage change produced by a step change of temperature at the sheath's outer surface.

## 4. Summary of Test Methods

4.1 *Insulation Properties:*

4.1.1 *Compaction*—These tests ensure that the insulation is compacted sufficiently *(1)* to prevent the insulation from shifting during use with the possibility of the thermoelements shorting to each other or to the sheath, and *(2)* to have good heat transfer between the sheath and the thermoelements.

4.1.2 *Insulation Resistance*—The insulation shall be free of moisture and contaminants that would compromise the voltage-temperature relationship or shorten the useful life of the sheathed thermocouple. Measurement of insulation resistance is a useful way to detect the presence of unacceptable levels of impurities in the insulation.

4.2 *Sheath Properties:*

4.2.1 *Integrity*—These tests ensure that *(1)* the sheath will be impervious to moisture and gases so the insulation and thermoelements will be protected, *(2)* surface flaws and cracks that might develop into sheath leaks are detected, and *(3)* the sheath walls are as thick as specified.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

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

4.2.2 *Dimensions*—Determination of length, diameter, and sheath roundness are often necessary to assure proper dimensional fit.

4.2.3 *Sheath Ductility*—The sheath shall be ductile enough to bend the required amount without breaking or cracking.

4.3 *Thermoelement Properties Service Life:*

4.3.1 *Calibration*—This test ensures that the temperature-emf relationship initially corresponds to standardized tolerances.

4.3.2 *Size*—The thermocouple sheath and thermoelement sizes are related to the service life and the thermoelement spacing is related to possible low insulation resistance or shorting.

4.3.3 *Thermoelement Ductility*—Ductility of the thermoelements shall be sufficient to allow the assembly to be bent during assembly or service without significant damage to the thermoelements.

4.4 *Thermocouple Assembly Properties*—The criteria listed above shall apply to both thermocouple assemblies and to bulk cable. In addition, the following tests are important for thermocouple assemblies.

4.4.1 *Continuity*—The loop continuity test assures that the thermocouple assembly has a completed circuit.

4.4.2 *Loop Resistance*—The loop resistance test can detect shorted or damaged thermoelements.

4.4.3 *Polarity*—The connector polarity test indicates whether the connector is correctly installed.

4.4.4 *Moisture Seal*—The moisture seal at the reference junction end of the thermocouple, if faulty, may allow contamination of the insulation with moisture or gases.

4.4.5 *Radiography*—Radiographic examination of the junction and sheath closure weld can indicate faulty junctions and sheath closures that will lead to early failure. Most internal dimensions can also be measured from the radiograph.

4.4.6 *Response Time*—The thermal response time gives an indication of the quickness with which an installed thermocouple will signal a changing temperature under the test conditions.

4.4.7 *Thermal Cycle*—The thermal cycle test will offer assurance that the thermocouple will not have early failure because of strains imposed from temperature transients.

## 5. Significance and Use

5.1 This standard provides a description of test methods used in other ASTM specifications to establish certain acceptable limits for characteristics of thermocouple assemblies and thermocouple cable. These test methods define how those characteristics shall be determined.

5.2 The usefulness and purpose of the included tests are given for the category of tests.

5.3 **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, that 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 the time of manufacture may not apply later. In addition, inhomogeneities can develop in thermoelements because of exposure to higher temperatures, even in cases where maximum exposure temperatures have been lower than the suggested upper use temperature limits specified in Table 1 of Specification E608/E608M. For this reason, calibration of thermocouples destined for delivery to a customer is not recommended. 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.

## 6. General Requirements

6.1 All the inspection operations are to be performed under clean conditions that will not degrade the insulation, sheath, or thermoelements. This includes the use of suitable gloves when appropriate.

6.2 During all process steps in which insulation is exposed to ambient atmosphere, the air shall be clean, with less than 50 % relative humidity, and at a temperature between 20 and 26°C (68 and 79°F).

6.3 All samples which are tested shall be identified by material code, and shall be traceable to a production run.

## 7. Insulation Properties

7.1 *Insulation Compaction Density*—The thermal conductivity of the insulation, as well as the ability of the insulation to lock the thermoelements into place, will be affected by the insulation compaction density.

7.1.1 A direct method for measuring insulation compaction density is applicable if a representative sample can be sectioned so that the sample ends are perpendicular to the sample length and the sheath, thermoelements, and insulation form a smooth surface free of burrs. The procedure is as follows:

7.1.1.1 Weigh the sample section,

7.1.1.2 Measure the sheath diameter and length with a micrometer,

7.1.1.3 Separate the insulation from the thermoelement and sheath with the use of an air abrasive tool,

7.1.1.4 Weigh the thermoelements and sheath, and

7.1.1.5 Determine the sheath and thermoelements densities either by experiment or from references.

7.1.1.6 Determine the percentage of the maximum theoretical insulation density $\rho$ as follows:

$$\%\rho = 100(A - B)/\{[0.785\, C^2\, D - (E/F + G/H)]J\} \quad (1)$$

where:

A = total specimen mass, kg or lb,
B = sheath and wires mass, kg or lb,
C = sheath diameter, m or in.,
D = specimen length, m or in.,
E = sheath mass, kg or lb,