Designation: E2821 – 13

Standard Specification for Compacted Mineral-Insulated, Metal-Sheathed Cable Used in Industrial Resistance Thermometers[1]

This standard is issued under the fixed designation E2821; 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 compacted, mineral-insulated, metal-sheathed (MIMS) cables used to manufacture metal-sheathed, industrial resistance thermometers referred to in this document as Resistance Temperature Detectors or RTDs.

1.2 The materials of construction include copper, nickel-clad copper, copper-45 % nickel (constantan), or nickel conductors, an austenitic stainless steel or nickel-chromium alloy sheath, and either magnesia (MgO) or alumina (Al_2O_3) insulation.

1.3 The cable diameter is between 0.093 and 0.500 in. (2.33 and 12.70 mm) and contains between two and eight conductors, set in various design configurations and wire spacings.

1.4 The values of temperature in this specification are based on the International Temperature Scale of 1990 (ITS-90).

1.5 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.6 *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 latest issues of the following documents 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 Due to the similarity between Compacted MIMS Thermocouple Cable and Compacted MIMS Cable, some Thermocouple ASTM Standards may apply.

2.3 *ASTM Standards:*[2]

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

E344 Terminology Relating to Thermometry and Hydrometry

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

E1137/E1137M Specification for Industrial Platinum Resistance Thermometers

E1652 Specification for Magnesium Oxide and Aluminum Oxide Powder and Crushable Insulators Used in the Manufacture of Base Metal Thermocouples, Metal-Sheathed Platinum Resistance Thermometers, and Noble Metal Thermocouples

[1] This specification is under the jurisdiction of ASTM Committee E20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.03 on Resistance Thermometers.

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[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.

2.4 *ANSI Standard:*[3]
ANSI B46.1 Surface Texture, Surface Roughness, Waviness and Lay

3. Terminology

3.1 *Definitions*—The definitions given in Terminology E344 shall apply to this specification.

3.2 *Definitions:*

3.2.1 *lot, n*—a quantity of finished MIMS RTD 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.

3.2.2 *raw material, n*—tubing, insulation, and wires used in fabrication of MIMS RTD cable.

4. Significance and Use

4.1 MIMS RTD cable may be used as follows:

4.1.1 As a cable for attaching the sensing element to a sensor termination within a thermometer (see Specification E1137/E1137M).

4.1.2 As an extension cable connecting a thermometer to another device.

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 MIMS RTD cable or the length of each piece of finished MIMS RTD cable.

5.1.2 The material and number of conductors (see Fig. 1) and the allowable variation in conductor resistances if other than that specified in 6.2. Consult individual manufacturers for the number of conductors which are limited by cable size.

5.1.3 The sheath material (see 7.3) and whether it shall be seamless or welded and drawn. Note that 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 insulating material (either MgO or Al_2O_3) and its respective type (see 7.2). Note that other insulation composition and impurity levels may be used with purchaser and producer agreement.

5.1.6 The seal to be applied to the exposed insulation at the cable end(s) prior to shipment (see 11.1).

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

5.1.8 Any deviations from this specification or the referenced documents.

5.1.9 The Optional Clearance if applicable (see Fig. 1).

6. General Requirements

6.1 *MIMS RTD Cable*—Cable shall be in accordance with this specification (see Fig. 2). Fig. 2 shows a cable with two conductors, but more than two conductors may be specified.

6.2 *Conductor Resistance Match*—The resistance of each conductor shall be measured. The difference between the maximum conductor resistance and minimum conductor resistance shall not exceed 10 % of the minimum conductor resistance.

6.3 *Dimensions*—The dimensional and tolerance requirements for sheath diameter and wall thickness, conductor diameter, and insulation thickness depicted in Fig. 2 and summarized in Table 1 shall be based on the nominal sheath outside diameters. The purchaser need only specify the cables outside diameter and number of conductors required in the ordering documents. The preferred cable sizes are listed in Table 2. For any nominal sheath size:

6.3.1 The outside diameter tolerance, *A*, shall be 0.001 in. (0.025 mm) or ± 1 % of the outside diameter, whichever is greater.

6.3.2 The wall thickness, *B*, shall be at least 8 % of the nominal sheath outside diameter and shall be uniform within 1.6 % of the minimum sheath outside diameter.

6.3.3 The conductor diameter, *D*, shall be at least 8 % of the nominal sheath outside diameter.

6.3.4 The insulation thickness, *C*, either between conductors or between any conductor and the inside surface of the sheath, shall be at least 4 % of the nominal sheath outside diameter.

6.3.5 An optional clearance "*F*" (see Figs. 1 and 2) may be specified when the area between the conductors will be removed to make room for a sensing element. This construction is one that is used when manufacturing Platinum Resistance Thermometers (PRTs) using this cable. Unless otherwise specified, the other dimensional requirements shall be maintained. Consult the cable manufacturer regarding this optional feature.

6.3.6 Dimensions shall be measured in accordance with Test Methods E839.

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

6.5 *Insulation Resistance at Room Temperature*—The minimum insulation resistance between conductors and between each conductor and the sheath (at room temperature) shall be as specified in Table 3 when tested in accordance with Test

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

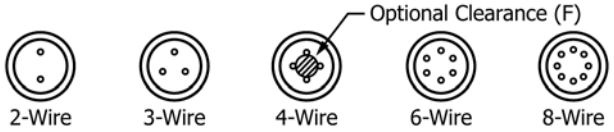

Figure 1: Examples of Conductor Wire Configurations

FIG. 1 Examples of Conductor Wire Configurations

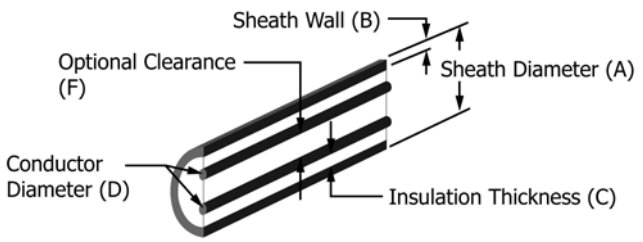

FIG. 2 Sheathed RTD Material Construction

TABLE 1 Summary of RTD Cable Dimensional Requirements (Percentage of Outside Diameter)

	2, 3, 4, 6, or 8 Wires
Minimum Sheath Thickness "B"	8 %
Minimum Conductor Diameter "D"	8 %
Minimum Insulation Thickness "C"	4 %
Optional Clearance "F"	25 %

TABLE 2 Dimensions of Metal Sheathed RTD Cable in SI and Inch-Pound Units

Preferred Sizes—Nominal Outside Diameter "A"	
Millimetres	Inches
3.00	0.125
4.50	0.188
6.00	0.250
8.00	0.313
9.50	0.375

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

Nominal Sheath Outside Diameter	Applied Voltage Minimum VDC	Insulation Resistance (Megohms) Minimum
Less than 3.2 mm	500	5000
3.2 mm and larger	500	10 000
Less than 125 in.	500	5000
125 in. and larger	500	10 000

Method E780 for the voltages noted. The values of insulation resistance, shall apply to the supplied lengths.

6.6 *Minimum Insulation Density*—The minimum density of the compacted mineral oxide insulation shall exceed the value which represents 70 % of the maximum theoretical density of the material. This 70 % value is 0.090 lb/in.^{3} (2506 kg/m^3) for MgO, and 0.101 lb/in.^{3} (2780 kg/m^3) for Al_2O_3.[4] See also Supplementary Requirement S5.

6.7 *Sheath Condition*—The sheath shall be free of visible surface contaminants and oxidation and shall be annealed s to the extent that the conductors will permit. Tests for proving conformance are in Supplementary Requirement S2 or S8.

6.8 *Sheath Integrity*—The sheath of the finished RTD 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 Additional optional supplementary requirements are listed in the Supplementary Requirements section and may be included in the purchasing order requirements, if desired by the purchaser.

7. Material Requirements

7.1 *Conductors:*

7.1.1 The conductors shall be solid, round wire of copper, nickel, nickel clad copper, or copper-45 % nickel (constantan) with maximum operating temperatures as specified in Table 4.

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

TABLE 4 Recommended Maximum Conductor Operating Temperatures

Conductor Type	°C	°F	Specification
Copper	250	482	ASTM B286, UNS C11000, or UNS C01200
Nickel Clad Copper	400	752	ASTM B366
Nickel 201	650	1200	UNS N02201
Copper-45 % Nickel (Constantan)	650	1200	ASTM B367 Class 5 UNS N04401

7.1.2 All conductors used in a specific cable shall be from the same lot of material in order to minimize the generation of spurious Electromotive Forces (EMF) when placed in a temperature gradient.

7.1.3 Prior to assembly, the producer shall verify all conductors used are free of visible surface oxides, scale and contaminates such as drawing compounds, carbon, dirt and dust. The absence of scale and contaminants can be verified by wiping the wire with a solvent-saturated lint-free cloth. Acetone, isopropyl alcohol, methanol and ethanol are all acceptable solvents. A light discoloration of the cloth is acceptable unless particles of grit or metal flakes are visually detectable without use of magnification. If acetone or any other solvent that may leave a residual film is used for initial cleaning, a final cleaning with an acceptable cleaning solvent, such as isopropyl alcohol, methanol or ethanol shall be performed.

7.2 *Insulation:*

7.2.1 The insulation shall be magnesia (MgO) or alumina (Al_2O_3) conforming to Specification E1652.

7.3 *Sheath Material:*

7.3.1 The sheath material shall be austenitic stainless steel, or heat-resistant nickel-chrome alloy. If tubing is used, either seamless or welded is acceptable.

7.3.2 A nickel-chrome-iron sheath, as in Specifications B163, B167, or B516, is recommended for fresh water service and for applications with exposure to temperatures greater than 896°F (480°C). There are high molybdenum stainless steels that are specifically made for use in salt water, such as type 316 and proprietary alloys.

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

7.3.4 Prior to assembly, the producer shall verify that each piece of sheath material used in the fabrication of RTD cable is free of visible surface oxides, scale and contaminants such as drawing compounds, carbon, dirt and dust. The absence of scale and contaminants can be verified by passing a solvent-saturated swatch of lint-free yarn or cloth against the inner surface of the sheath material. Acetone, isopropyl alcohol, methanol and ethanol are all acceptable solvents. A light discoloration of the swatch or plug is acceptable unless particles of grit or metal flakes are visually detectable without the use of magnification. If acetone or any other solvent that leaves a harmful residual film upon evaporation is used for