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.

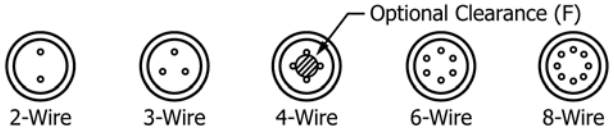

Figure 1: Examples of Conductor Wire Configurations

FIG. 1 Examples of Conductor Wire Configurations

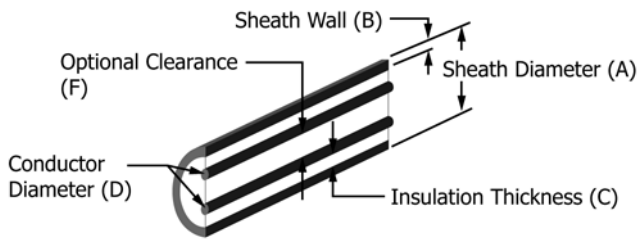

FIG. 2 Sheathed RTD Material Construction

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

initial cleaning, a final cleaning with an acceptable cleaning solvent such as isopropyl alcohol, methanol or ethanol shall be performed.

8. Processing Requirements

8.1 The producer shall be responsible for raw materials and all processing to ensure that the overall requirements of this specification are met.

9. Quality Verification and Test Requirements

9.1 The following tests are required for all MIMS RTD cable furnished under this specification:

9.1.1 Dimensional inspection.

9.1.2 Insulation resistance at room temperature.

9.1.3 Comparison of Conductor Resistances

9.1.4 Dielectric Breakdown Test.

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, they shall so state in the purchasing documents.

9.4 *Standard Tests*—The producer shall perform an inspection and tests in accordance with Table 5, using the methods delineated in Test Methods E839. Sampling shall be performed from each lot.

9.5 *Dimensional Inspection*—The producer shall measure a sample of finished RTD cable to determine conformance to 6.3 for the following: outside diameter, conductor diameter, sheath wall thickness, and insulation thickness. Dimensions shall be measured per Test Methods E839.

9.6 *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.

9.7 *Conductor Resistance Verification*—The electrical resistances of each conductor within the cable shall be measured to ensure that they comply with 6.2.

TABLE 5 Standard Tests

Section	Test	Test Piece
9.1.1 and 9.5	Dimensional Inspection	Sample
9.1.2 and 9.6	Insulation Resistance at Room Temperature	All (A)
9.1.3 and 9.7	Conductor Resistance Match	All (A)

A = Each length of finished RTD cable shall be tested.

10. Certification and Reports

10.1 A certificate of conformance covering the completed MIMS RTD 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 MIMS RTD cable shall be sealed when processing allows and especially before shipment, in order to prevent entry of moisture to the inside the cable. Seal welding, melted plastic, and epoxy seals are examples of acceptable sealing techniques (see 5.1.6).

11.2 *Cleaning Prior to Packaging*—The outer sheath shall be cleaned free of grease, oil, dirt, and other foreign substances.

11.3 The method of packaging of the completed cable shall be per the 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, number of conductors, conductor material, sheath material, insulation material, 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 cable and the quantity of cables in the package,

11.5.3 Purchaser's order number,

11.5.4 Nominal diameter of cable,

11.5.5 Sheath material,

11.5.6 Insulation material and type, and

11.5.7 Conductor material and number of conductors.

12. Keywords

12.1 alumina; compacteds; conductors; constantans; coppers; copper-45 % nickels; industrial resistance thermometers; magnesia; Metal Sheatheds; MIMS; Mineral-Insulateds; nickels; nickel plated coppers; RTD cables

SUPPLEMENTARY REQUIREMENTS

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

S1. Optional Elevated-Temperature Insulation Resistance

S1.1 If this optional requirement is specified, insulation resistance shall be measured at 1202°F (650°C) to indicate whether or not insulation contamination, which cannot be detected at room temperature, is present. This test is intended primarily for high-temperature RTD service. 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.

S1.1 Minimum Insulation Resistance at 1202°F (650°C)

Nominal Sheath Outside Diameter, in. (mm)	Minimum Applied Voltage, VDC	Minimum Insulation Resistance, Ω/1 Ft (300mm) at 650°C
0.093 (2.33) and larger	50	2×10^6 (2 Megohms)

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 of cable.

S2.1.1Close wind the selected section of the sheathed RTD cable three full turns on a mandrel two times the sheath diameter. Check the continuity of each conductor and the insulation resistance between each conductor and the sheath and between conductors 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 conductor, a short between the conductors, or a short between any conductor 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 (Paragraph 8.1.1 of Test Methods E839)

S3.1.2 Basic Sheath Integrity Test Using Water (Paragraph 8.1.2.6 of Test Methods E839)

S3.1.3 Sheath Integrity Mass Spectrometer Method (Paragraph 8.1.3 of Test Methods E839)

S4. Surface Finish

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

S5. Requirements for Measuring Insulation Compaction Density and Insulation Retention

S5.1 *Compaction Density Measurement*—If this optional requirement is specified, compaction density of the mineral insulation shall be determined using the methods specified in Test Methods E839 unless otherwise agreed upon between the purchaser and the producer.

S5.2 *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.

S6. Analysis of the Insulating Material

S6.1 If this optional requirement is specified, a certified analysis of the composition of the insulating material as supplied to the RTD cable producer shall be furnished to the purchaser. The RTD cable producer shall be responsible for maintaining the purity within the specified limits in the finished cable material.

S7. Special Requirements for the Sheath

S7.1 If this optional requirement is specified, standard sheath materials shall be austenitic stainless steels as specified in Specifications A213/A213M, A249/A249M, A3, and A632 or Ni-Cr-Fe alloy. 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.

S7.2 *Additional Requirements*—When special sheath material requirements are specified, the purchaser shall specify the name of the material, any associated grade (if applicable), and any specification to which the material must comply. The purchaser shall also specify any other applicable requirements.

S8. Metallurgical Structure of Sheath

S8.1 If this optional requirement is specified:

S8.1.1 A section from the sample RTD cable shall be examined for grain size of the sheath.

S8.1.2 A section from the sample RTD cable shall be examined for cracks or localized wall thinning in the sheath.

S8.1.3 The test methods and the acceptance levels shall be agreed upon between the purchaser and the producer.

APPENDIXES

(Nonmandatory Information)

X1. Conductor Cleanliness

Cleanliness of the conductors during assembly may be verified by passing a solvent-saturated lint free cloth over the conductor. Isopropyl alcohol, methanol, ethanol, denatured alcohol or acetone followed by alcohol are acceptable solvents. Because it leaves a residual film, using acetone alone is unacceptable. While a heavy discoloration of the cloth is unacceptable, a light discoloration is acceptable unless particles of grit or metallic flakes are visually detectable without use of magnification.

X2. Tube Cleanliness

Acceptable materials for cleaning the inside of the tube during assembly include isopropyl alcohol, methanol, ethanol, denatured alcohol or acetone followed by alcohol. Supplemental Requirement S3 of Specification A632 contains an acceptance procedure and criteria for determining sheath material cleanliness.