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An American National Standard

Standard Specification for Tungsten-Rhenium Alloy Thermocouple Wire[1]

This standard is issued under the fixed designation E696; 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 bare, solid conductor, tungsten and rhenium alloy thermoelements having diameters of 0.127 mm (0.005 in.) to 0.508 mm (0.020 in.) supplied in matched pairs. These thermoelements shall be suitable for use either in bead-insulated, bare-wire thermocouples, or in compacted metal-sheathed, ceramic insulated thermocouple material or assemblies.

1.2 This specification covers the thermocouple combinations of tungsten-3 % rhenium versus tungsten-25 % rhenium (W3Re/W25Re) and tungsten-5 % rhenium versus tungsten-26 % rhenium (W5Re/W26Re; Type C). All information applies to both combinations unless otherwise noted.

1.3 It is recognized that the alloys described are refractory and are not suitable for use at high temperatures in oxidizing atmospheres. All tests and processes described herein must be performed under conditions that are non-reactive to tungsten-rhenium alloys.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E8/E8M Test Methods for Tension Testing of Metallic Materials

E207 Test Method for Thermal EMF Test of Single Thermoelement Materials by Comparison With Reference Thermoelement of Similar EMF-Temperature Properties

E220 Test Method for Calibration of Thermocouples By Comparison Techniques

E230/E230M Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples

E344 Terminology Relating to Thermometry and Hydrometry

E452 Test Method for Calibration of Refractory Metal Thermocouples Using a Radiation Thermometer

E988 Temperature-Electromotive Force (EMF) Tables for Tungsten-Rhenium Thermocouples (Withdrawn 2011)[3]

E1751/E1751M Guide for Temperature Electromotive Force (emf) Tables for Non-Letter Designated Thermocouple Combinations

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions used in this standard, see Terminology E344.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *dope, vt*—in this specification, to add potassium, silicon and aluminum compounds or other volatile substances to the alloy powders during the preparation to produce a ductile wire. See NASA CR-72884.[4]

3.2.1.1 *Discussion*—Some alloy powders are doped.

3.2.2 *lot, n*—a quantity of wire processed or heat treated as a single continuous length and identified uniquely.

4. Ordering Information

4.1 A purchase order for thermocouple material conforming to this specification shall specify the following:

4.1.1 *Thermocouple Wire Composition*—May be W3Re/W25Re or W5Re/W26Re.

4.1.2 *Wire Size*—Specify size with each order.

4.1.3 *Wire Length*—Specify total amount of each wire and minimum continuous length.

[1] This specification is under the jurisdiction of ASTM Committee E20 on Temperature Measurement and is the direct responsibility of Subcommittee E20.13 on Thermocouples - Materials and Accessories Specifications.

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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.

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

[4] NASA CR-72884, "Some Studies on Behavior of W-Re Thermocouple Materials at High Temperatures." Available from National Aeronautics and Space Administration, 400 Maryland Ave. S.W., Washington, DC 20546.

4.1.4 *Thermocouple Calibration*—Calibration will be in accordance with Section 5.1.4 unless otherwise specified.

4.1.5 *Supplementary Requirements*—See the Supplementary Requirements section of this specification.

4.1.6 *Instructions for Spooling, Packaging, and Labeling*—Packaging will be in accordance with Section 10 unless otherwise specified.

4.1.7 *Tests and Certifications Required from the Processor*—Certification will be in accordance with Section 9 unless otherwise specified.

5. Materials and Manufacture

5.1 *Thermocouple Wire:*

5.1.1 *General*—The thermoelements shall be tungsten-3 % rhenium and tungsten-25 % rhenium or tungsten-5 % rhenium and tungsten-26 % rhenium (Type C), as indicated on the purchase order.

5.1.2 *Physical:*

5.1.2.1 The diameter of each wire shall be within ±0.01 mm (0.0005 in.) of the ordered size for 0.5 mm (0.02 in.) diameter wire and smaller. The diameter of each wire shall be uniform end-to-end to within 0.01 mm (0.0005 in.) for 0.5 mm (0.02 in.) diameter wire and smaller.

5.1.2.2 The wires shall be solid, round, smooth and be free of weld joints, slivers, kinks, pits or nicks exceeding 5 % of diameter.

5.1.2.3 The wire surface shall be uniformly clean and free of discoloration.

5.1.2.4 Mechanical or optical methods may be used to verify the requirements of 5.1.2.1, 5.1.2.2, and 5.1.2.3.

5.1.3 *Mechanical:*

5.1.3.1 The wires shall withstand, at a temperature of 20 °C to 35 °C (68 °F to 95 °F), wrapping five turns around a mandrel five times the diameter of the wire without breaking or splitting.

5.1.3.2 The tests shall be made on at least one specimen from each end of each lot of wire.

5.1.4 *Thermoelectric:*

5.1.4.1 The emf versus temperature characteristics of the matched thermoelements shall be determined using procedures described in Test Methods E207, E220, or E452.

5.1.4.2 The emf versus temperature relationship of the matched pair of thermoelements shall comply with the values shown in Guide E1751/E1751M for W3Re/W25Re or Specification E230/E230M for Type C (W5Re/W26Re).

5.1.4.3 The initial calibration tolerance shall be in accordance with Table 1 (W3Re/W25Re). or Specification E230/E230M (W5Re/W26Re), as appropriate.

5.2 *Composition:*

5.2.1 *Positive thermoelement:*

5.2.1.1 The positive thermoelement for the W3Re/W25Re combination shall have a nominal composition of 97 % tungsten and 3 % rhenium.

5.2.1.2 The positive thermoelement for the W5Re/W26Re combination shall have a nominal composition of 95 % tungsten and 5 % rhenium.

5.2.1.3 The positive thermoelement shall be doped to maintain ductility after high temperature use.

5.2.2 Negative thermoelement:

5.2.2.1 The negative thermoelement for the W3Re/W25Re combination shall have a nominal composition of 75 % tungsten and 25 % rhenium.

5.2.2.2 The negative thermoelement for the W5Re/W26Re combination shall have a nominal composition of 74 % tungsten and 26 % rhenium.

6. Lot Identification

6.1 Thermocouple wires, test results and certifications shall be identified by manufacturer's lot number.

7. Lot Designation

7.1 A vendor who purchases wire from processors for repackaging and resale shall supply, for each spool, the wire processor's name, lot number and certification to the customer.

8. Extension Wires

8.1 Due to the high cost of tungsten-rhenium alloys, to difficulties encountered in obtaining long continuous lengths of these alloys and to inherent problems in applications where ductility is important, many users find it advantageous to use compensating extension wires made of base metal alloys.

8.2 Information on upper temperature limits and the suppliers guaranteed limits of error for currently available compensating extension wires for W3Re/W25Re can be found in Table 2. Information on upper temperature limits and the suppliers

TABLE 1 Initial Calibration Tolerances and Suggested Temperature Range for W3Re/W25Re Thermocouples[A]

	Temperature Range		Initial Calibration Tolerance	
Thermocouple Type	°C	°F	°C (whichever is greater)	°F
W3Re/W25Re	0 to 2315 °C	32 to 4200	±4.4 or 1 %	Note 3

[A] Caution—Users should be aware that certain characteristics of thermocouple materials including calibration may change in time with use; consequently, test results obtained at time of manufacture may not necessarily apply throughout an extended period of use.

NOTE 1—Initial calibration tolerances in this table apply to new thermocouple wire, normally in the size range of 0.127 mm (0.005 in.) to 0.508 mm (0.020 in.) in diameter (No. 36 to 24 AWG) and used at temperatures not exceeding the suggested upper temperatures of Table 1. If used at higher temperatures these initial calibration tolerances may not apply.

NOTE 2—Initial calibration tolerances apply to new wire as delivered to the user and do not allow for calibration drift during use. The magnitude of such changes depends on such factors as wire size, temperature, time of exposure and environment.

NOTE 3—The °F tolerance is 1.8 times larger than the °C tolerance at the equivalent °C temperature. Note particularly that the percentage tolerance only applies to the temperature that is expressed in °C.

NOTE 4—Tables 1 and 2 describe suggested upper temperature limits for the thermocouple and extension wires. These limits apply to protected thermocouples, that is, thermocouples in atmospheres, and in contact with materials, that are non-reactive to the alloys being used.

TABLE 2 Initial Calibration Tolerances and Suggested Temperature Ranges for Type W3Re/W25Re Thermocouple Compensating Extension Wires

	Temperature Range		
Designation	°C	°F	Standard Tolerance
300P(+) / 300N(-)[A]	0 to 330	32 to 625	±0.125mV
203(+) / 225(-)[B]	0 to 260	32 to 500	±0.110 mV

[A] 97.7Ni Bal Cr, Al, and Si versus 96Ni, 4W; U.S. Patent 3,502,510 assigned to Engelhard Industries.
[B] 90Ni, 10Cr versus 98Ni, 2Cr; Designation of Hoskins Mfg.

guaranteed limits of error for currently available compensating extension wires for W5Re/W26Re can be found in Specification E230/E230M.

9. Certification

9.1 The processor shall supply a certificate with each order stating the wire composition, size, lot identification and calibration information.

10. Packaging and Package Marking

10.1 Wires typically will be supplied on spools of a nominal 100 mm (4 in.) diameter core and boxed individually, unless otherwise requested. Each spool shall be marked to identify the wire composition, diameter, quantity, processor's name, spool designation and customers purchase order number in a manner to identify the pair of wires to be used to form a thermocouple meeting the calibration requirement.

11. Keywords

11.1 rhenium; thermocouple; thermoelement; tungsten

SUPPLEMENTARY REQUIREMENTS

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

S1. Mechanical

S1.1 The wires shall have an elongation measured at a temperature in the range of 20 °C to 35 °C (68 °F to 95 °F) of at least 12 % as measured over a 50 mm (2 in.) gauge length.

S1.2 Elongation shall be determined in accordance with Test Methods E8/E8M using a rate of 0.2 mm/mm/min. (0.2 in./in./min.) maximum and a 50 mm (2 in.) gauge length.

S1.3 The tests shall be made on at least one specimen from each end of each lot of wire.

S2. Thermoelectric

S2.1 The wires shall be thermoelectrically homogeneous so that when joined to form a thermocouple whose measuring junction and reference junction are held at constant temperatures, any short-term (less than 1 h) change in the temperature profile along the wire within the range from 0 °C to 1000 °C (32 °F to 1832 °F) will not produce a change in the thermocouple output signal of more than 100 µV.

S3. Electrical

S3.1 A dc resistance measurement may be used to verify mechanical integrity of tungsten-rhenium alloy wires having diameters of 0.125 mm (0.005 in.) or larger. Defects cited in 5.1.2.2 can cause high local resistance in tungsten alloy wires.

S3.2 A dc resistance measurement at 20 °C (68 °F) shall be made on an accurately measured reference length of each thermoelement using an instrument and range to yield ±1 % accuracy to derive a resistance per meter or foot. The wire size of the reference length and test pieces of known, practical lengths should be within 0.005 mm (0.0002 in.) of each other.

S3.3 The resistance measurement taken according to 12.3.2 shall be compared to the dc resistance measurements of each measured full length of wire.

S3.4 The full length resistance per unit length (ohms per meter or foot) of each of the test lengths shall be within 10 % of the value obtained from the reference length.

NOTE S1—The resistivity of W25Re and that of W26Re is more than double that of either W3Re or W5Re, and all of these alloys have high temperature coefficients of resistance.