Designation: E2820 – 13

Standard Test Method for Evaluating Thermal EMF Properties of Base-Metal Thermocouple Connectors[1]

This standard is issued under the fixed designation E2820; 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 standard describes a thermal emf test method for base-metal thermocouple connectors including Types E, J, K, N and T. Standard connectors such as found in Specifications E1129/E1129M and E1684 as well as non-standard connector configurations and connector components can be evaluated using this method.

1.2 The measured emf is reported as an equivalent temperature deviation or error relative to a reference thermocouple of the same type. This method can be used to verify deviations introduced by the connector greater than or equal to 1°C.

1.3 The connector is tested with thermocouple contacts axially aligned with a temperature gradient using a specified thermal boundary condition. The actual temperature difference developed across the connector and corresponding error will depend on the connector design.

1.4 Connector contacts are often fabricated from raw materials having temperature-emf relationships in accordance with Specification E230. However, verifying Specification E230 tolerances is not within the scope of this method.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this 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 *ASTM Standards:*[2]

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
E563 Practice for Preparation and Use of an Ice-Point Bath as a Reference Temperature
E1129/E1129M Specification for Thermocouple Connectors
E1684 Specification for Miniature Thermocouple Connectors
E2488 Guide for the Preparation and Evaluation of Liquid Baths Used for Temperature Calibration by Comparison

3. Terminology

3.1 *Definitions*—The definitions given in Terminology E344 apply to the terms used in this standard.

4. Summary of Test Method

4.1 The connector is tested as part of a thermocouple circuit and compared to a reference thermocouple of the same type and material lot.

4.2 Measurements are made while the connector is subjected to a temperature gradient established by a specified boundary condition.

4.3 Performance is evaluated at a fixed position within a dry-well furnace or stirred liquid bath (Method 1 or 2A respectively) or variable position within a stirred liquid bath (Method 2B). The latter method can be used to survey the connector to identify a position within the thermal gradient that produces a maximum output deviation.

4.4 Results are interpreted relative to the properties of the reference thermocouple.

5. Significance and Use

5.1 A thermocouple connector, exposed to a temperature difference, contributes to the output of a thermocouple circuit. The output uncertainty allocated to the connector depends on the connector design and temperature gradient.

5.2 Connector performance can be classified based on the results of this method and used as part of a component specification.

[1] This test method is 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] 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.

5.3 The method can be used as an engineering tool for evaluating different connector designs tested under similar thermal conditions.

6. Apparatus

6.1 The apparatus includes a temperature source, thermocouple readout device or voltmeter and ice-bath as shown in Fig. 1 and Fig. 2. An ice-bath is needed only if the readout does not provide cold junction compensation.

6.2 The thermocouple readout device or voltmeter shall have two or more channels and have equivalent temperature resolution of at least 0.1°C. The difference between channels shall not exceed the equivalent of 0.1°C when supplied with the same voltage input.

6.3 The temperature source heats the measuring junctions and produces a temperature gradient across the connector. The source is either a dry-well furnace or stirred liquid bath depending on the specified method.

6.3.1 *Method 1*—a temperature controlled dry-well furnace with an immersion depth of at least 100 mm and the capability of maintaining the specified test temperature within 1°C.

6.3.2 *Method 2*—a temperature controlled stirred liquid bath of non-conductive fluid with an immersion depth of at least 150 mm and the capability of maintaining the specified temperature within 1°C. Comparison calibration baths as described in Guide E2488 are suitable for this test.

7. Hazards

7.1 Review the Material Safety Data Sheet (MSDS) before using a fluid in a temperature-controlled bath. Temperature limits, flammability, vapor pressure, toxicity and chemical stability are important factors in determining a suitable fluid.

8. Preparation of Apparatus

8.1 The apparatus requires a dual thermocouple circuit with a common measuring junction. The circuit shall be fabricated from the same spool of wire. Except for the connector under test, the length of wire shall be continuous without splices or other connections between the measuring junction and the readout device.

8.2 The thermocouple wire shall carry the same letter designation (for example, Type K) as the connector under test. The wire shall conform to the special tolerance in Specification E230 over the range of 0°C to the maximum specified connector test temperature. The wire size shall be 24 gage (0.5 mm) unless specified otherwise.

8.3 The test connector shall be installed approximately 70 mm from the measuring junction. When testing in a dry-well furnace per Method 1, a thermally and electrically insulating gasket shall be used to seal the furnace entrance, accentuating the temperature gradient across the connector. Placing the gasket between the plug and jack is generally the easiest way to control the position of the connector within the temperature gradient (Fig. 3–a).

8.4 When testing per Method 2 in a liquid bath, the connector and a portion of the thermocouple shall be attached to an insulating rod to support the sample during the test (Fig. 3–b).

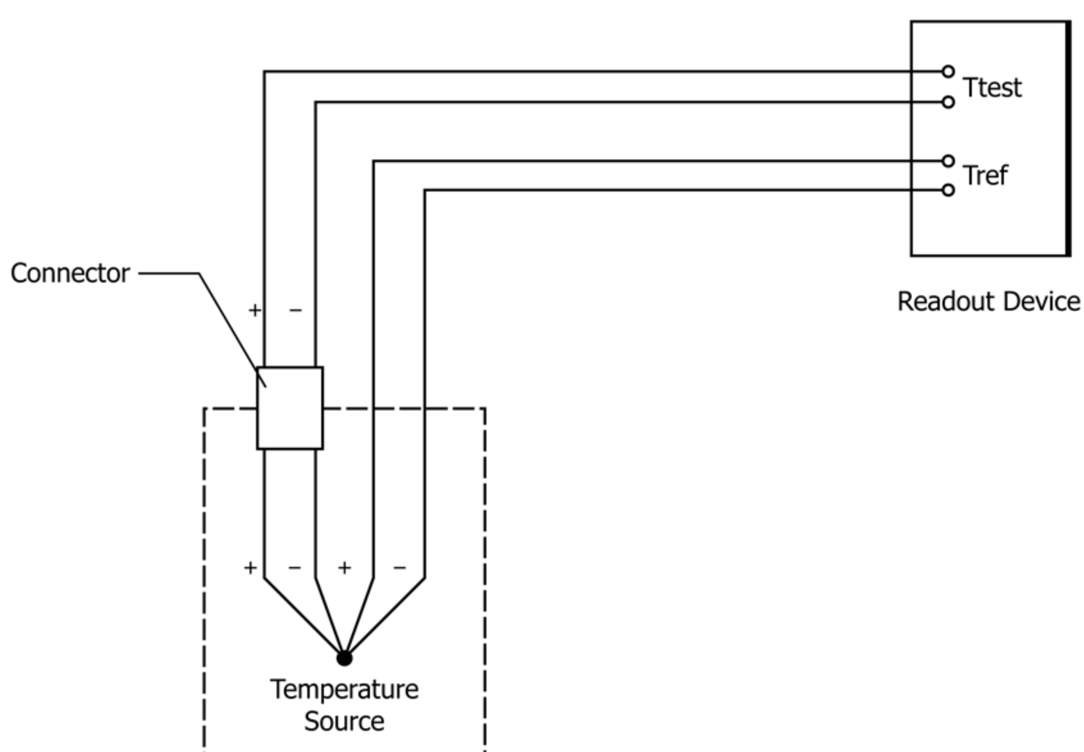

FIG. 1 Test Schematic Using a Readout Device with Cold Junction Compensation, Providing Temperature Indications of the Test Thermocouple T_{test} and Reference Thermocouple T_{ref}

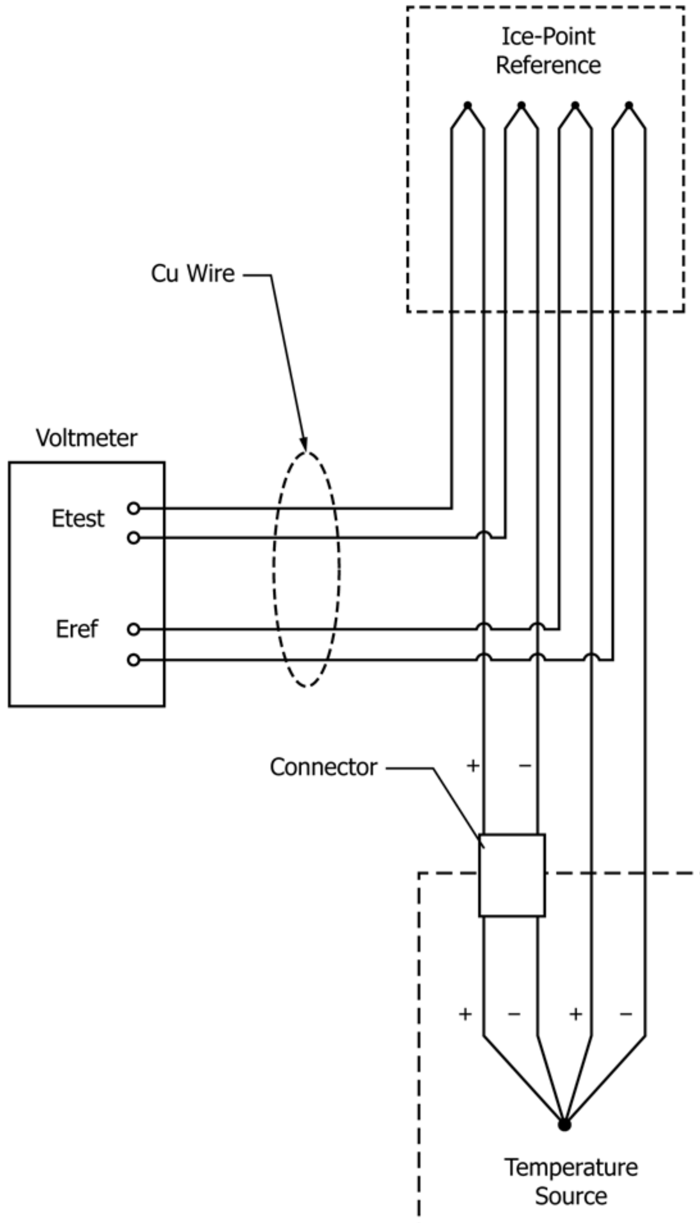

FIG. 2 Test Schematic Using a Voltmeter and Reference Junctions at 0°C

8.5 The 0°C reference junctions (if needed) shall be prepared using the same approach used for thermocouple calibration per Test Method E220. The copper wires shall be thermocouple type TP per Specification E230 and shall all be cut from the same spool.

8.6 The 0°C ice-bath (if needed) shall be prepared in accordance Practice E563.

9. Procedure

9.1 Set up the temperature source for the specified test condition (Table 1).

9.2 Connect both thermocouple circuits to the readout device or meter. With the common measuring junction and connector at room temperature, verify the difference between circuits is within the equivalent of 0.1°C. For voltage outputs, the difference expressed in °C is determined as follows.

$$\Delta T = (E_{test} - E_{ref})/S \tag{1}$$

where:

E_{ref} = voltage output of reference thermocouple, mV
E_{test} = voltage output of test thermocouple (with connector), mV
S = nominal Seebeck coefficient (see Appendix X1), mV/°C

9.3 *Method 1*—using a dry-well furnace at fixed depth.

9.3.1 Insert the thermocouples into the furnace with the connector positioned at the furnace entrance with an insulating gasket.

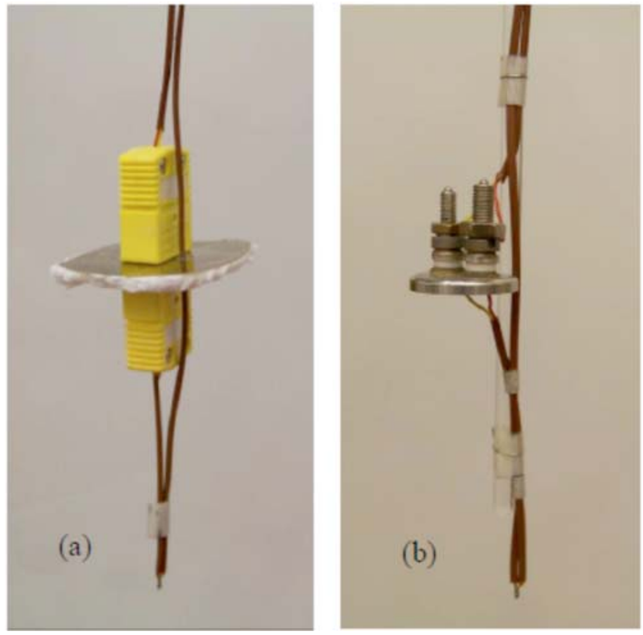

FIG. 3 Connector Hook-Up Examples: (*a*) E1129 Connector Prepared for Method 1 Testing in a Dry-Well Furnace and (*b*) A Terminal Assembly Prepared for Method 2 Testing in a Stirred Liquid Bath

TABLE 1 Standard Test Conditions

Condition	Nominal Test Temperature (°C)
A	65
B	100
C	200
D	260
or user specified	

9.3.2 Adjust the furnace temperature until the reference thermocouple channel indicates the specified test temperature within ± 1°C.

9.3.3 Allow the thermocouple and connector to equilibrate as indicated by a stable output difference between the reference and test thermocouples. This typically requires 15 to 30 min, depending on connector design.

9.3.4 Record the output of the test and reference thermocouples.

9.4 *Method 2A*—using a stirred liquid bath at fixed depth.

9.4.1 Insert the thermocouple into the bath with the connector suspended just above the bath surface (approximately 70 mm).

9.4.2 Adjust the bath temperature until the reference thermocouple channel indicates the specified test temperature within ± 1°C.

9.4.3 Lower the thermocouple to the specified connector immersion depth.

9.4.4 Allow the thermocouple and connector to equilibrate as indicated by a stable output difference between the reference and test thermocouples. This typically requires 15 to 30 min, depending on connector design.

9.4.5 Record the output of the test and reference thermocouples.

9.5 *Method 2B*—using a stirred liquid bath at variable depth.

9.5.1 Insert the thermocouple into the bath with the connector suspended just above the bath surface (approximately 70 mm).

9.5.2 Adjust the bath temperature until the reference thermocouple channel indicates the specified test temperature within ± 1°C.

9.5.3 Allow the thermocouple and connector to equilibrate as indicated by a stable output difference between the reference and test thermocouples. This typically requires 15 to 30 min, depending on connector design.

9.5.4 Record the output of the test and reference thermocouples.

9.5.5 Repeat the stabilization step of 9.5.3 and the measurement of 9.5.4 at incrementally increasing depths until the connector is completely immersed. Each step shall not exceed 25 % of the connector length.

10. Calculation and Interpretation of Results

10.1 The connector error is calculated from the difference between the test and reference thermocouple outputs.

10.1.1 When using a temperature readout device:

$$Error = T_{test} - T_{ref} \quad (2)$$

where:

T_{test} = temperature indicated by the test thermocouple (with connector), °C
T_{ref} = temperature indicated by the reference thermocouple, °C

10.1.2 When using a voltmeter:

$$Error = (E_{test} - E_{ref})/S \quad (3)$$

where:

E_{test} = output of test thermocouple (with connector), mV
E_{ref} = output of reference thermocouple, mV

S = nominal Seebeck coefficient (see Appendix X1), mV/°C

10.2 The connector error can be positive or negative. When testing at a fixed position or depth, the connector error typically changes linearly with test temperature as shown in Fig. 4.

10.3 When surveying the connector at multiple immersion depths (Method 2B), the connector is characterized by the maximum error without regard to sign.

10.4 When the connector is completely immersed in the bath, the connector will be approximately isothermal and the resulting error should be zero.

11. Report

11.1 The report shall include the following minimum information:

11.1.1 Connector identification,

11.1.2 Test method and specified connector immersion depth, if applicable, and

11.1.3 Test condition (Table 1) or specified test temperature and corresponding connector error expressed in °C.

12. Precision and Bias

12.1 The precision of this test method is based on an interlaboratory study of ASTM E2820, Standard Test Method for Evaluating Thermal EMF Properties of Base Metal Thermocouple Connectors, conducted in 2012. Six laboratories participated in the study, testing three different types of connectors. Every analyst was instructed to report three replicate test results in this study. Practice E691 was followed for the study design; the details are given in ASTM Research Report No. E20-1003.[3]

12.1.1 *Repeatability limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same part, obtained by the same operator using the same equipment on the same day in the same laboratory.

12.1.1.1 Repeatability limits are listed in Table 2.

12.1.2 *Reproducibility limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the critical difference between two test results for the same part, obtained by different operators using different equipment in different laboratories.

12.1.2.1 Reproducibility limits are listed in Table 2.

12.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

12.1.4 Any judgment in accordance with statements 12.1.1 and 12.1.2 would have an approximate 95 % probability of being correct.

12.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method; therefore no statement on bias is being made.

12.3 The precision statement was determined through statistical examination of 51 test results, from a total of six laboratories, on three types of connectors.

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:E20-1003. Contact ASTM Customer Service at service@astm.org.

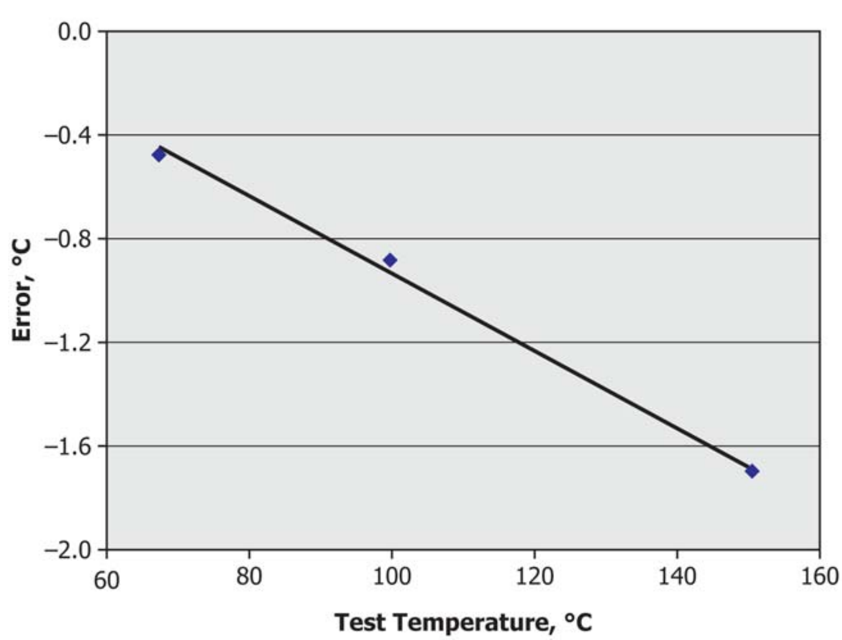

FIG. 4 Example of Connector Error Versus Temperature for an E1129 Type K Connector Tested per Method 1

TABLE 2 Connector Error (°C)

Material	Average[A] $\bar{X}$	Repeatability Standard Deviation S_r	Reproducibility Standard Deviation S_R	Repeatability Limit r	Reproducibility Limit R
E1129A	-0.3134	0.1249	0.2558	0.3497	0.7161
E1129B	-0.4103	0.0601	0.2522	0.1683	0.7061
E1684	-0.8553	0.0891	0.5811	0.2493	1.6271

[A] The average of the laboratories' calculated averages.

13. Keywords

13.1 connector emf; thermocouple connector; thermocouple contact; thermocouple pin; thermocouple socket; thermocouple terminal

APPENDIX

(Nonmandatory Information)

X1. SEEBECK COEFFICIENT CALCULATION

X1.1 The Seebeck coefficient describes the rate of change of thermal emf with temperature at a given temperature. This standard uses the nominal Seebeck coefficient for the specified thermocouple type.

X1.2 The Seebeck coefficient can be estimated from the tabulated values of emf versus temperature included in Specification E230.

$$S = (E_2 - E_1)/(T_2 - T_1) \quad \text{(X1.1)}$$

where:

T_t = nominal test temperature, °C
T_2 = T_t + 1°C
T_1 = T_t − 1°C
E_2 = nominal emf at T_2 per Specification E230, mV
E_1 = nominal emf at T_1 per Specification E230, mV

X1.2.1 For example, the Seebeck coefficient for a Type K thermocouple tested at 100°C is calculated as follows:

T_2 = 101°C
T_1 = 99°C
E_2 = 4.138 mV
E_1 = 4.055 mV
S = (4.138 – 4.055)/(101 – 99) = 0.041 mV/°C