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An American National Standard

Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples[1]

This standard is issued under the fixed designation E230/E230M; 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 contains reference tables (Tables 8 to 25) that give temperature-electromotive force (emf) relationships for Types B, C, E, J, K, N, R, S, and T thermocouples.[2] These are the thermocouple types most commonly used in industry. The tables contain all of the temperature-emf data currently available for the thermocouple types covered by this standard and may include data outside of the recommended upper temperature limit of an included thermocouple type.

1.2 In addition, the specification includes standard and special tolerances on initial values of emf versus temperature for thermocouples (Table 1), thermocouple extension wires (Table 2), and compensating extension wires for thermocouples (Table 3). Users should note that the stated tolerances apply only to the temperature ranges specified for the thermocouple types as given in Tables 1, 2, and 3, and do not apply to the temperature ranges covered in Tables 8 to 25.

1.3 Tables 4 and 5 provide insulation color coding for thermocouple and thermocouple extension wires as customarily used in the United States.

1.4 Recommendations regarding upper temperature limits for the thermocouple types referred to in 1.1 are provided in Table 6.

1.5 Tables 26 to 45 give temperature-emf data for single-leg thermoelements referenced to platinum (NIST Pt-67). The tables include values for Types BP, BN, JP, JN, KP (same as EP), KN, NP, NN, TP, and TN (same as EN).

1.6 Tables for Types RP, RN, SP, and SN thermoelements are not included since, nominally, Tables 18 to 21 represent the thermoelectric properties of Type RP and SP thermoelements referenced to pure platinum. Tables for the individual thermoelements of Type C are not included because materials for Type C thermocouples are normally supplied as matched pairs only.

1.7 Polynomial coefficients which may be used for computation of thermocouple emf as a function of temperature are given in Table 7. Coefficients for the emf of each thermocouple pair as well as for the emf of most individual thermoelements versus platinum are included. Coefficients for type RP and SP thermoelements are not included since they are nominally the same as for types R and S thermocouples, and coefficients for type RN or SN relative to the nominally similar Pt-67 would be insignificant. Coefficients for the individual thermoelements of Type C thermocouples have not been established.

1.8 Coefficients for sets of inverse polynomials are given in Table 46. These may be used for computing a close approximation of temperature (°C) as a function of thermocouple emf. Inverse functions are provided only for thermocouple pairs and are valid only over the emf ranges specified.

1.9 This specification is intended to define the thermoelectric properties of materials that conform to the relationships presented in the tables of this standard and bear the letter designations contained herein. Topics such as ordering information, physical and mechanical properties, workmanship, testing, and marking are not addressed in this specification. The user is referred to specific standards such as Specifications E235, E574, E585/E585M, E608/E608M, E1159, or E2181/E2181M for guidance in these areas.

1.10 The temperature-emf data in this specification are intended for industrial and laboratory use.

1.11 Thermocouple color codes per IEC 584–3 are given in Appendix X1.

1.12 The values stated in either SI units or inch-pound units are to be regarded separately as standard.

1.12.1 The values stated in brackets are not conversions to the values they succeed and therefore shall be used independently of the preceding values.

1.12.2 The values given in parentheses are conversions of the values they succeed.

1.12.3 Combining values from the two systems may result in non-conformance with the standard.

1.13 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the*

[1] This specification is under the jurisdiction of ASTM Committee E20 on Temperature Measurement and are the direct responsibility of Subcommittee E20.11 on Thermocouples - Calibration.

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[2] These temperature-emf relationships have been revised as required by the international adoption in 1989 of a revised International Temperature Scale (ITS-90).

responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.

1.14 *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:*[3]

E235 Specification for Type K and Type N Mineral-Insulated, Metal-Sheathed Thermocouples for Nuclear or for Other High-Reliability Applications

E574 Specification for Duplex, Base Metal Thermocouple Wire With Glass Fiber or Silica Fiber Insulation

E585/E585M Specification for Compacted Mineral-Insulated, Metal-Sheathed, Base Metal Thermocouple Cable

E608/E608M Specification for Mineral-Insulated, Metal-Sheathed Base Metal Thermocouples

E1159 Specification for Thermocouple Materials, Platinum-Rhodium Alloys, and Platinum

E2181/E2181M Specification for Compacted Mineral-Insulated, Metal-Sheathed, Noble Metal Thermocouples and Thermocouple Cable

2.2 *NIST Monograph:*

NIST Monograph 175 Temperature-Electromotive Force Reference Functions and Tables for the Letter-Designated Thermocouple Types Based on the ITS-90[4]

2.3 *IEC Standard:*

IEC 584–3 Thermocouples – Part 3: Extension and Compensating Cables Tolerances and Identification System, 1989

3. Source of Data

3.1 The data in these tables are based upon the SI volt[5] and the International Temperature Scale of 1990 (ITS-90).

3.2 The temperature-emf data in Tables 8 to 23 and 26 to 45, together with the corresponding equations in Tables 7 and 46 for all thermocouple types except Type C, have been extracted from NIST Monograph 175. Temperature-emf data in Tables 24 and 25 and the coefficients for Type C in Tables 7 and 46 have been developed from curves fitted to wire manufacturers' data.

NOTE 1—It is beyond the scope of this standard to discuss the origin of these tables. If further information is required, the reader should consult NIST Monograph 175.

3.3 These tables give emf values to three decimal places (1 μV) at temperature intervals of one degree. The tables are satisfactory for most industrial uses but may not be adequate for computer and similar applications. If greater precision is required, the reader should refer to NIST Monograph 175 which includes tables giving emf values to four decimal places (0.1 μV) for each type except Type C. Equations which permit easy and unique generation of the temperature-emf relationships can be found in Table 7. For convenience, coefficients of inverse polynomials that may be used to calculate approximate temperature (°C) as a function of thermocouple emf are given in Table 46.

4. Thermocouple Types and Letter Designations

4.1 The letter symbols identifying each reference table are those which are in common use throughout industry and identify the following thermocouple calibrations:

4.1.1 *Type B*—Platinum-30 % rhodium (+) versus platinum-6 % rhodium (−).

4.1.2 *Type E*—Nickel-10 % chromium (+) versus copper-45 % nickel (constantan) (−).

4.1.3 *Type J*—Iron (+) versus copper-45 % nickel (constantan) (−).

4.1.4 *Type K*—Nickel-10 % chromium (+) versus nickel-5 % (aluminum, silicon) (−).

NOTE 2—Silicon, or aluminum and silicon, may be present in combination with other elements.

4.1.5 *Type N*—Nickel-14 % chromium, 1.5 % silicon (+) versus nickel-4.5 % silicon-0.1 % magnesium (−).

4.1.6 *Type R*—Platinum-13 % rhodium (+) versus platinum (−).

4.1.7 *Type S*—Platinum-10 % rhodium (+) versus platinum (−).

4.1.8 *Type T*—Copper (+) versus copper-45 % nickel (constantan) (−).

4.1.9 *Type C*—Tungsten-5 % Rhenium (+) versus Tungsten-26 % Rhenium (−).

4.2 Each letter designation in 4.1 identifies a specific temperature-emf relationship (Tables 8 to 25) and may be applied to any thermocouple conforming thereto within stated tolerances on initial values of emf versus temperature, regardless of its composition.

4.3 The thermoelement identifying symbols in Tables 26 to 45 use the suffix letters P and N to denote, respectively, the positive and negative thermoelement of a given thermocouple type.

4.4 Tables 26 to 45 identify specific temperature-emf relationships of individual thermoelements with respect to platinum (NIST Pt-67). The appropriate letter designation may be applied to any thermoelement which, when combined with its mating thermoelement, will form a thermocouple conforming to the corresponding table within the stated tolerances.

4.5 In Tables 2 and 3, an overall suffix letter "X" (for example KX, TX, EPX, JNX) denotes an "extension grade" material whose thermoelectric properties will match those of the corresponding thermocouple type within the stated extension grade tolerances over a limited temperature range. Most base metal extension wires have the same nominal composition as the thermocouple wires with which they are intended to be

[3] 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.

[4] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899.

[5] Discussed in NIST Technical Note 1263, Guidelines for Implementing the New Representations of the Volt and Ohm Effective January 1, 1990.