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An American National Standard

Standard Specification and Temperature-Electromotive Force (EMF)(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.

Note—Paragraph 1.1, and Tables7, 13, 19, 21, and 46 were editorially corrected and the year date changed on Sept. 23, 2003.

1. Scope

1.1 This specification contains reference tables (Tables 8– to 25) that give temperature-electromotive force (emf) relationships for Types B, E, J, K, N, R, S, T, and C thermocouples.[2] These are the thermocouple types most commonly used in industry.

1.2Also included are lists of standard and special tolerances on initial values of emf versus temperature for thermocouples (Table1), thermocouple extension wires (Table2), and compensating extension wires for thermocouples (Table3).

1.3Tables4–5, included herein, give data on insulation color coding for thermocouple and thermocouple extension wires as customarily used in the United States. 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 givenprovided 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 thatwhich 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 the 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 typeType C are thermocouples have not been established.

1.8 Coefficients for sets of inverse polynomials are given in Table44.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, E608/E608M, E1159, or 1223, as appropriate, for guidance in these areas. E2181/E2181M for guidance in these areas.

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

[1] These tables are under the jurisdiction of ASTM Committee E20 on Temperature Measurement and are the direct responsibility of Subcommittee E20.04 on Thermocouples.

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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).

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. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. 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 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:*[3]

E235 Specification for Thermocouples, Sheathed, Type K and Type N, 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

E~~608~~608/E608M Specification for Mineral-Insulated, Metal-Sheathed Base Metal Thermocouples

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

~~1223Specification for Type N Thermocouple Wire~~ 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~~First edition, 1989~~ 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 ~~26–45,~~ 26 to 45, together with the corresponding equations in Tables 7 and 46 for all ~~of the~~ thermocouple ~~types,~~types except ~~type~~Type C, have been extracted from NIST Monograph 175. Temperature-emf data in ~~Tables24–25~~Tables 24 and 25 and the coefficients for ~~type~~Type C in Tables 7 and 46 have been developed from curves fitted to wire manufacturers~~[2]~~' data.

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

3.3 These tables give emf values to three decimal places (1 µV) at temperature intervals of one degree. ~~Such~~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 ~~the~~ NIST ~~reference noted above~~ Monograph 175 which includes tables giving emf values to four decimal places (0.1 µV) for each type except ~~type~~Type C. Equations which permit easy and unique generation of the temperature-emf relationships ~~will~~can be found in Table 7. For convenience, coefficients of inverse polynomials that may be used to ~~compute~~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).~~ —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, 1½ % silicon (+) versus nickel-4½ % silicon-1⁄10 % magnesium (−).~~ —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 (−).

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[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.

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 ~~of~~in 4.1 identifies a specific temperature-emf relationship ~~(Tables8–23)~~(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). ~~Although tolerances on initial values of emf versus temperature, in most cases, are not established for individual thermoelements with respect to platinum, the~~ 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 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 ~~span.~~range. Most base metal extension wires have the same nominal composition as the thermocouple wires with which they are intended to be used, whereas the *compensating* extension wires for noble metal or refractory metal thermocouple types (S, R, B, or C) are usually of a different, more economical composition whose relative thermoelectric properties as a pair nonetheless closely approximate those of the noble metal or refractory metal thermocouples with which they are to be used over a limited temperature range.

5. Tolerances on Initial Values of ~~EMF~~Emf versus Temperature

5.1 ~~T~~In the United States, thermocouples and matched thermocouple wire pairs are normally supplied conforming to the tolerances on initial values of emf versus temperature ~~listed~~provided in Table 1.

5.1.1 Tolerances on initial values of emf versus temperature for single-leg thermoelements referenced to platinum have been established only for Types KP and KN. These are supplied, by common practice, to a tolerance equivalent to one half the millivolt tolerance of the Type K thermocouple.

5.1.2 For all other thermocouple types, tolerances on initial values of emf versus temperature for single ~~thermoelements, when required,~~ thermoelements should be established by agreement between the ~~consumer~~purchaser and the ~~producer.~~supplier.

5.1.3 In ~~reference~~ Tables 34, 35, 44, and 45, the thermoelements are identified by two thermoelement symbols indicating their applicability to two thermocouple types. This indicates that the temperature-electromotive force relationship of the table is typical of the referenced thermoelements over the temperature range given in Table 1 for the corresponding thermocouple type. It should not be assumed, however, that thermoelements used with one thermocouple type are interchangeable with those of the other, or that they have the same millivolt tolerances for the initial values of emf versus temperature.

5.2 Thermocouple extension wires and compensating extension wires are supplied to conform to the tolerances on initial values of emf versus temperature shown in ~~Tables2–3.~~

~~5.2.1The initial~~ Tables 2 and 3, respectively.

5.2.1 Initial tolerances of extension grade materials and compensating extension materials apply over a more limited ~~span~~range of temperature than the corresponding thermocouple grade materials. Applicable temperature ranges, consistent with typical usage, are given in Tables 2~~–~~ and 3.

6. Color Coding

6.1 Color codes for insulation on thermocouple grade materials, along with corresponding thermocouple and thermoelement letter designations, are given in Table 4.

6.2 Extension wires for thermocouples are distinguished by having an identifying color in the outer jacket as shown in Table 5, where letter designations for the extension thermoelements and pairs are also presented.

~~6.3Information in Tables4–5 is based on customary United States practice.~~

6.3 Information presented in Tables 4 and 5 is based on customary practice in the United States.

NOTE 3—Other insulation color coding conventions may be found in use elsewhere in the world. Refer to Appendix X1 for information.

7. List of Tables

7.1 Following is a list of the tables included in this standard:

7.1.1 *General Tables*:

Table Number	Title
1	Tolerances on Initial Values of Emf versus Temperature for Thermocouples
2	Tolerances on Initial Values of Emf versus Temperature for Extension Wires
3	Tolerances on Initial Values of Emf versus Temperature for Compensating Extension Wires

~~4~~	~~United States Color Codes for Single and Duplex Insulated Thermocouple Wires~~
4	United States Color Codes for Single and Duplex Insulated Thermocouple Wire
~~5~~	~~United States Color Codes for Single and Duplex Insulated Extension Wires~~
5	United States Color Codes for Single and Duplex Insulated Extension Wire
6	Suggested Upper Temperature Limits for Protected Thermocouples
~~7~~	~~Polynomial Coefficients for Generating Thermocouple EMF as a Function of Temperature~~
7	Polynomial Coefficients for Generating Thermocouple Emf as a Function of Temperature

7.1.2 *~~EMF~~Emf versus Temperature Tables for Thermocouples*:

Table Number	Thermocouple Type	Temperature Range[A]
8	B	0 to 1820°C
9	B	32 to 3308°F
10	E	–270 to 1000°C
11	E	–454 to 1832°F
12	J	–210 to 1200°C
13	J	–346 to 2192°F
14	K	–270 to 1372°C
15	K	–454 to 2500°F
16	N	–270 to 1300°C
17	N	–454 to 2372°F
18	R	–50 to 1768°C
19	R	–58 to 3214°F
20	S	–50 to 1768°C
21	S	–58 to 3214°F
22	T	–270 to 400°C
23	T	–454 to 752°F
24	C	0 to 2315°C
25	C	32 to 4200°F

7.1.3 *~~EMF~~Emf versus Temperature Tables for Thermoelements*:

Table Number	Thermocouple Type	Thermoelement Type	Temperature Range[A]
26	B	BP	0 to 1768°C
27	B	BP	32 to 3214°F
28	B	BN	0 to 1768°C
29	B	BN	32 to 3214°F
30	J	JP	–210 to 760°C
31	J	JP	–346 to 1400°F
32	J	JN	–210 to 760°C
33	J	JN	–346 to 1400°F
34	K or E	KP or EP	–270 to 1372°C
35	K or E	KP or EP	–454 to 2500°F
36	K	KN	–270 to 1372°C
37	K	KN	–454 to 2500°F
38	N	NP	–200 to 1300°C
39	N	NP	–328 to 2372°F
40	N	NN	–200 to 1300°C
41	N	NN	–328 to 2372°F
42	T	TP	–270 to 400°C
43	T	TP	–454 to 752°F
44	T or E	TN or EN	–270 to 1000°C
45	T or E	TN or EN	–454 to 1832°F

[A] These temperature ranges represent the ~~range of~~ published temperature versus emf data for the thermocouple and thermoelement types listed. Refer to Table 6 for the recommended ~~maximum~~ upper ~~use~~ temperature limits for a specific thermocouple wire size and type.

7.1.4 *Supplementary Table*:

Table Number	Title
~~46~~	~~Coefficients of Inverse Polynomials for Computation of Approximate Temperature as a Function of Thermocouple EMF~~

46	Coefficients of Inverse Polynomials for Computation of Approximate Temperature as a Function of Thermocouple Emf

8. Keywords

8.1 emf computation; compensating extension wire; inverse polynomial; polynomial coefficient; reference tables; thermocouple; thermocouple extension wire; thermoelement; upper temperature limit

APPENDIX

(Nonmandatory Information)

X1. IEC COLOR CODE SYSTEM

X1.1 General

X1.1.1The data presented in Tables4–5 of this specification show the color coding required by this specification. Those colors are well established in the United States and have been in use as the national standard there for many years.

X1.1.2In other parts of the world, there are alternative color code systems, either now in use, or in process of being implemented.

X1.1.3One such color code system is that established by the IEC. The IEC color code system is outlined here for reference. Table X1.1 shows the IEC standard colors for thermocouple cables, extension cables, and compensating cables.

X1.1.1 The data in Tables 4 and 5 show the color coding required by this specification.

X1.1.2 In other parts of the world, there are alternative color code systems in use. An alternative color code system which has been widely accepted outside of the United States is that established by the International Electrotechnical Commission (IEC). For reference, Table X1.1 shows the IEC standard colors for thermocouple cables, extension cables, and compensating cables.

TABLE 1 Tolerances on Initial Values of Emf vs. Temperature for Thermocouples

NOTE 1—Tolerances in this table apply to new essentially homogeneous thermocouple wire, normally in the size range 0.25 to 3 mm in diameter (No. 30 to No. 8 Awg)AWG) and used at temperatures not exceeding the recommended limits of Table 6. If used at higher temperatures these tolerances may not apply.

NOTE 2—At a given temperature that is expressed in °C, the tolerance expressed in °F is 1.8 times larger than the tolerance expressed in °C. Note that wherever applicable, percentage-based tolerances must be computed from temperatures that are expressed in °C. 2—At a given temperature that is expressed in °C, the tolerance expressed in °F is 1.8 times larger than the tolerance expressed in °C. Where tolerances are given in percent, the percentage applies to the temperature being measured when expressed in degrees Celsius. To determine the tolerance in degrees Fahrenheit, multiply the tolerance in degrees Celsius by 9/5.

NOTE 3—**Caution:** Users should be aware that certain characteristics of thermocouple materials, including the emf-versus-temperature relationship may change with time in use; consequently, test results and performance obtained at the time of manufacture may not necessarily apply throughout an extended period of use. Tolerances given in this table apply only to new wire as delivered to the user *and do not allow for changes in characteristics with use*. The magnitude of such changes will depend on such factors as wire size, temperature, time of exposure, and environment. It should be further noted that due to possible changes in homogeneity, attempting to recalibrate *used* thermocouples is likely to yield irrelevant results, and is not recommended. However, it may be appropriate to compare used thermocouples *in-situ* with new or known good ones to ascertain their suitability for further service under the conditions of the comparison.

Thermocouple Type	Temperature Range		Tolerances-Reference Junction 0°C (32°F) [32°F]			
			Standard Tolerances		Special Tolerances	
	°C	°F	°C (whichever is greater)	°F	°C (whichever is greater)	°F
T	0 to 370	32 to 700	±1 or ±0.75 %	Note 2±0.5 or 0.4 %	±0.5 or ±0.4 %	Note 2
T	0 to 370	32 to 700	±1.0 or ±0.75 %	Note 2	±0.5 or ±0.4 %	Note 2
J	0 to 760	32 to 1400	±2.2 or ±0.75 %	±1.1 or 0.4 %	±1.1 or ±0.4 %	
J	0 to 760	32 to 1400	±2.2 or ±0.75 %		±1.1 or ±0.4 %	
E	0 to 870	32 to 1600	±1.7 or ±0.5 %	±1 or ±0.4 %	±.01 or ±0.4 %	
*E	0 to 870	32 to 1600	±1.7 or ±0.5 %		±.01 or ±0.4 %	
K or N	0 to 1260	32 to 2300	±2.2 or ±0.75 %		±1.1 or ±0.4 %	
R or S	0 to 1480	32 to 2700	±1.5 or ±0.25 %		±0.6 or ±0.1 %	
B	870 to 1700	1600 to 3100	±0.5 %		±0.25 %	
C	0 to 2315	32 to 4200	±4.4 or 1 %	Note 2	Not applicable	
T[A]	–200 to 0	–328 to 32	±1 or ±1.5 %		[B]	
T[A]	–200 to 0	–328 to 32	±1.0 or ±1.5 %		[B]	
E[A]	–200 to 0	–328 to 32	±1.7 or ±1 %		[B]	
*E[A]	–200 to 0	–328 to 32	±1.7 or ±1 %		[B]	
K[A]	–200 to 0	–328 to 32	±2.2 or ±2 %		[B]	

*The standard tolerances shown do not apply to Type E mineral-insulated, metal-sheathed (MIMS) thermocouples and thermocouple cables as described in Specifications E608/E608M and E585/E585M. The standard tolerances for MIMS Type E constructions are the greater of ±2.2°C or ±0.75 % from 0 to 870°C and the greater of ±2.2°C or ±2 % from -200 to 0°C.

[A] Thermocouples and thermocouple materials are normally supplied to meet the tolerances specified in the table for temperatures above 0°C. The same materials, however, may not fall within the tolerances ~~given~~ for temperatures below 0°C in the second section of the table. If materials are required to meet the tolerances stated for temperatures below 0°C the purchase order ~~must~~shall so state. Selection of materials usually will be required.

[B] Special tolerances for temperatures below 0°C are difficult to justify due to limited available information. However, the following values for Types E and T thermocouples are suggested as a guide for discussion between the purchaser and supplier:

~~Type E–200 to 0 °C ± 1 °C or ± 0.5% (whichever is greater) Type T–200 to 0 °C ± 0.5 °C or ± 0.8% (whichever is greater)~~ Type E, – 200 to 0°C, ±1.0°C or ±0.5 % (whichever is greater)
Type T, – 200 to 0°C, ±0.5°C or ±0.8 % (whichever is greater)

Initial values of tolerance for Type J thermocouples at temperatures below 0°C and special tolerances for Type K thermocouples below 0°C are not given due to the characteristics of the materials. Data for type N thermocouples below 0°C are not currently available.

TABLE 2 Tolerances on Initial Values of Emf vs. Temperature for Extension Wires

NOTE 1—Tolerances in this table represent the maximum error contribution allowable from new and essentially homogeneous thermocouple extension wire when exposed to the full temperature range given in the table below. Extension grade materials are not intended for use outside the temperature range shown.

NOTE 2—Thermocouple extension wire makes a contribution to the total thermoelectric signal that is dependent upon the temperature difference between the extreme ends of the extension wire length. The actual magnitude of any error introduced into a measuring circuit by homogeneous and correctly connected extension wires is equal to the algebraic difference of the deviations at its two end temperatures, as determined for that extension wire pair.

Thermocouple Type	Temperature Range		Tolerances—Reference Junction 0°C ~~(32°F)~~ [32°F]			
			Standard Tolerances		Special Tolerances	
	°C	~~(°F)~~[°F]	°C	~~(°F)~~[°F]	°C	~~(°F)~~ [°F]
~~TX~~	~~–60 to 100~~	~~(–75 to 200)~~	~~±1.0~~	~~(±1.8)~~	~~±0.5~~	~~(±0.9)~~
TX	–60 to 100	[–75 to 200]	±1.0	[±1.8]	±0.5	[±0.9]
~~JX~~	~~0 to 200~~	~~(32 to 400)~~	~~±2.2~~	~~(±4.0)~~	~~±1.1~~	~~(±2.0)~~
JX	0 to 200	[32 to 400]	±2.2	[±4.0]	±1.1	[±2.0]
~~EX~~	~~0 to 200~~	~~(32 to 400)~~	~~±1.7~~	~~(±3.0)~~	~~±1.0~~	~~(±1.8)~~
EX	0 to 200	[32 to 400]	±1.7	[±3.0]	±1.0	[±1.8]
~~KX~~	~~0 to 200~~	~~(32 to 400)~~	~~±2.2~~	~~(±4.0)~~	~~±1.1~~	~~(±2.0)~~
KX	0 to 200	[32 to 400]	±2.2	[±4.0]	±1.1	[±2.0]
~~NX~~	~~0 to 200~~	~~(32 to 400)~~	~~±2.2~~	~~(±4.0)~~	~~±1.1~~	~~(±2.0)~~
NX	0 to 200	[32 to 400]	±2.2	[±4.0]	±1.1	[±2.0]

TABLE 3 Tolerances on Initial Values of Emf vs. Temperature for Compensating Extension Wires

NOTE 1—Tolerances in this table apply to new and essentially homogeneous thermocouple compensating extension wire when used at temperatures within the range given in the table below.

NOTE 2—Thermocouple compensating extension wire makes a contribution to the total thermoelectric signal that is dependent upon the temperature difference between the extreme ends of the compensating extension wire length.

Thermocouple Type	Temperature Range		Tolerances—Reference Junction 0°C ~~(32°F)~~ [32°F]		
			Standard Tolerances		Special Tolerances
	°C	~~(°F)~~[°F]	°C	~~(°F)~~[°F]	
~~SX~~	~~0 to 200~~	~~(32 to 400)~~	~~±5~~	~~(±9)~~	~~A~~
SX	0 to 200	[32 to 400]	±5	[±9]	A
~~RX~~	~~0 to 200~~	~~(32 to 400)~~	~~±5~~	~~(±9)~~	~~A~~
RX	0 to 200	[32 to 400]	±5	[±9]	A
~~BX[B]~~	~~0 to 200~~	~~(32 to 400)~~	~~±4.2~~	~~(±7.6)~~	~~A~~
BX[B]	0 to 200	[32 to 400]	±4.2	[±7.6]	A
~~B[C]~~	~~0 to 100~~	~~(32 to 200)~~	~~±3.7~~	~~(±6.7)~~	~~...~~
B[C]	0 to 100	[32 to 200]	±3.7	[±6.7]	...
~~CX~~	~~0 to 200~~	~~(32 to 400)~~	~~Initial Calibration Tolerance ±0.110 mV~~		
CX	0 to 200	[32 to 400]	Initial Calibration Tolerance ±0.110 mV		

[A] Special tolerance grade compensating extension wires are not available.

[B] Proprietary alloy compensating extension wire is available for use over a wide temperature range.

[C] Special compensating extension wires are not necessary with Type B over the limited temperature range 0 to ~~50 °C (32~~ 50°C [32 to ~~125 °F),~~ 122°F], where the use of non-compensated (copper/copper) conductors introduces no significant error. For a somewhat larger temperature gradient of 0 to ~~100 °C (32~~ 100°C [32 to ~~210 °F)~~ 212°F] across the extension portion of the circuit, the use of non-compensated (copper/copper) extension wires may result in small errors, the magnitude of which will not exceed the ~~tolerance values~~ tolerances given ~~in the table above~~ for measurements above ~~1000 °C (1800 °F).~~ 1000°C [1800°F].

TABLE 4 United States Color Codes for Single and Duplex Insulated Thermocouple Wire

NOTE 1—Data in this table represents customary practice in the United States of America. Different color code conventions may be ~~found~~ in use in other parts of the world.

NOTE 2—For some types of insulations, colors may appear as a stripe or trace strand. High temperature braided ~~insulation is not~~ insulations are normally supplied without color ~~coded.~~coding.

NOTE 3—The noble metal thermocouples are not normally supplied with colored insulations. However, if they were so furnished, the color codes for the corresponding single wire extensions would apply, with a brown overall jacket, where applicable.

Thermocouple Type	Thermoelement Designation	Individual Conductor Color	Overall Jacket Color
T			Brown
	TP (+)	Blue	
	TN (–)	Red	
J			Brown
	JP (+)	White	
	JN (–)	Red	
E			Brown
	EP (+)	Purple	
	EN (–)	Red	
K			Brown
	KP (+)	Yellow	
	KN (–)	Red	
N			Brown
	NP (+)	Orange	
	NN (–)	Red	

TABLE 5 United States Color Codes for Single and Duplex Insulated Extension Wire

NOTE 1—Data in this table represents customary practice in the United States of America. Different color code conventions may be ~~found~~ in use in other parts of the world.

NOTE 2—For some types of insulations, colors may appear as a stripe or trace strand. High temperature braided insulations are normally supplied without color ~~code.~~ coding.

Thermocouple Type	Thermoelement Designation	Individual Conductor Color	Overall Jacket Color
TX			Blue
	TPX (+)	Blue	
	TNX (–)	Red, or Red/Blue Trace	
JX			Black
	JPX (+)	White	
	JNX (–)	Red, or Red/Black Trace	
EX			Purple
	EPX (+)	Purple	
	ENX (–)	Red, or Red/Purple Trace	
KX			Yellow
	KPX (+)	Yellow	
	KNX (–)	Red, or Red/Yellow Trace	
NX			Orange
	NPX (+)	Orange	
	NNX (–)	Red, or Red/Orange Trace	
RX or SX[A]			Green
	RPX/SPX (+)	Black	
	RNX/SNX (–)	Red, or Red/Black Trace	
BX[B]			Gray
	BPX (+)	Gray	
	BNX (–)	Red, or Red/Gray Trace	
CX			Red
	CPX (+)	Green	
	CNX (–)	Red	

[A] Type R and S thermocouples utilize the same extension alloys.

[B] Color code shown is applicable to constructions incorporating proprietary Type B compensating extension alloy wires. When uncompensated (copper/copper) extension materials are used with Type B thermocouples, the extension wire insulation is not normally color coded.

TABLE 6 Suggested Upper Temperature Limits for Protected Thermocouples

NOTE 1—This table ~~gives~~provides the recommended upper temperature limits for the various thermocouple types and wire sizes. These limits apply to protected thermocouples, that is, thermocouples in conventional closed-end protecting tubes. They do not apply to ~~sheathed thermocouples having compacted mineral oxide insulation.~~ compacted, mineral-insulated, metal-sheathed thermocouples.

NOTE 2—The temperature limits given here are intended only as a guide to the user and they should not be taken as absolute values nor as guarantees of satisfactory service life or performance. These types and sizes ~~are sometimes~~may be used at temperatures above the ~~given~~stated limits, but usually at the expense of stability or service life or both. In ~~other~~some instances, it may be necessary to reduce the ~~above~~temperature limits in order to achieve ~~adequate~~satisfactory performance in service. ASTM MNL-12[A] and other literature sources should be consulted for additional applications information.

Thermocouple Type	Upper Temperature limit for Various Wire ~~Sizes (Awg),~~ Sizes, °C ~~(°F)~~ [°F]					
	~~No. 8 Gage~~ No. 8 AWG (3.25 mm [0.128 in.])	~~No. 14 Gage~~ No. 14 AWG (1.63 mm [0.064 in.])	~~No. 20 Gage~~ No. 20 AWG (0.81 mm [0.032 in.])	~~No. 24 Gage~~ No. 24 AWG (0.51 mm [0.020 in.])	~~No. 28 Gage~~ No. 28 AWG (0.33 mm [0.013 in.])	~~No. 30 Gage~~ No. 30 AWG (0.25 mm [0.010 in.])
~~T~~		~~370 (700)~~	~~260 (500)~~	~~200 (400)~~	~~200 (400)~~	~~150 (300)~~
T		370 [700]	260 [500]	200 [400]	200 [400]	150 [300]
~~J~~	~~760 (1400)~~	~~590 (1100)~~	~~480 (900)~~	~~370 (700)~~	~~370 (700)~~	~~320 (600)~~
J	760 [1400]	590 [1100]	480 [900]	370 [700]	370 [700]	320 [600]
~~E~~	~~870 (1600)~~	~~650 (1200)~~	~~540 (1000)~~	~~430 (800)~~	~~430 (800)~~	~~370 (700)~~
E	870 [1600]	650 [1200]	540 [1000]	430 [800]	430 [800]	370 [700]
~~K and N~~	~~1260 (2300)~~	~~1090 (2000)~~	~~980 (1800)~~	~~870 (1600)~~	~~870 (1600)~~	~~760 (1400)~~
K and N	1260 [2300]	1090 [2000]	980 [1800]	870 [1600]	870 [1600]	760 [1400]
~~R and S~~				~~1480 (2700)~~		
R and S				1480 [2700]		
~~B~~				~~1700 (3100)~~		
B				1700 [3100]		
~~C[B]~~				~~2315 (4200)[C]~~		
C[B]				2315 [4200][C]		

[A] *Manual on the Use of Thermocouples in Temperature Measurement*, ASTM MNL-12, 1993.

[B] Type C thermoelements ~~cannot operate~~ are not suitable for use in the presence of oxygen; therefore, protection for these thermocouples must provide an inert or non-oxidizing environment.

[C] No. 24 ~~Gage~~AWG thermoelements are common for this thermocouple type, but other sizes are ~~possible~~available and, with adequate protection, are generally useable over the same temperature range.

TABLE 7 Polynomial Coefficients for Generating Thermocouple ~~EMF~~Emf as a Function of Temperature

NOTE 1—The following table contains sets of polynomial coefficients used to compute emfs for the various types of thermocouples and for their individual thermoelements paired with Pt–67, when reference junctions are at 0°C.

NOTE 2—The coefficients given are for an expression of the form: $E = c_0 + c_1 t + c_2 t^2 + c_3 t^3 ... + c_n t^n$. In this expression, E is in millivolts, t is in °C, and c_0, c_1, c_2... c_n are the coefficients given in the following table. For the Type K thermocouple and the Type KN thermoelement, coefficients b_0 and b_1 for an exponential term containing *e*, the natural logarithm base, also appear in the table. This term is of the form: $b_0 e^{b_1 (t - 126.9686)^2}$ and, where given, it is to be evaluated and added to the polynomial result.

NOTE 3—If emf values on another temperature scale are desired, first convert the desired temperature to its equivalent in °C, then evaluate the appropriate polynomial from the table below using the °C equivalent temperature.

TYPE B Thermocouple

Temperature Range	0 °C to 630.615 °C	630.615 °C to 1820 °C
c_0 =	0.0	–3.893 816 862 1 ....
c_1 =	–2.465 081 834 6 × 10^{-4}	2.857 174 747 0 × 10^{-2}
c_2 =	5.904 042 117 1 × 10^{-6}	–8.488 510 478 5 × 10^{-5}
c_3 =	–1.325 793 163 6 × 10^{-9}	1.578 528 016 4 × 10^{-7}
c_4 =	1.566 829 190 1 × 10^{-12}	–1.683 534 486 4 × 10^{-10}
c_5 =	–1.694 452 924 0 × 10^{-15}	1.110 979 401 3 × 10^{-13}
c_6 =	6.299 034 709 4 × 10^{-19}	–4.451 543 103 3 × 10^{-17}
c_7 =	....	9.897 564 082 1 × 10^{-21}
c_8 =	....	–9.379 133 028 9 × 10^{-25}

TYPE E Thermocouple

Temperature Range	–270 °C to 0 °C	0 °C to 1000 °C
c_0 =	0.0	0.0
c_1 =	5.866 550 870 8 × 10^{-2}	5.866 550 871 0 × 10^{-2}
c_2 =	4.541 097 712 4 × 10^{-5}	4.503 227 558 2 × 10^{-5}
c_3 =	–7.799 804 868 6 × 10^{-7}	2.890 840 721 2 × 10^{-8}
c_4 =	–2.580 016 084 3 × 10^{-8}	–3.305 689 665 2 × 10^{-10}
c_5 =	–5.945 258 305 7 × 10^{-10}	6.502 440 327 0 × 10^{-13}
c_6 =	–9.321 405 866 7 × 10^{-12}	–1.919 749 550 4 × 10^{-16}
c_7 =	–1.028 760 553 4 × 10^{-13}	–1.253 660 049 7 × 10^{-18}
c_8 =	–8.037 012 362 1 × 10^{-16}	2.148 921 756 9 × 10^{-21}
c_9 =	–4.397 949 739 1 × 10^{-18}	–1.438 804 178 2 × 10^{-24}
c_{10} =	–1.641 477 635 5 × 10^{-20}	3.596 089 948 1 × 10^{-28}
c_{11} =	–3.967 361 951 6 × 10^{-23}	....
c_{12} =	–5.582 732 872 1 × 10^{-26}	....
c_{13} =	–3.465 784 201 3 × 10^{-29}	....

TYPE J Thermocouple

Temperature Range	–210 °C to 760 °C	760 °C to 1200 °C
c_0 =	0.0	2.964 562 568 1 × 10^{2}
c_1 =	5.038 118 781 5 × 10^{-2}	–1.497 612 778 6 ....
c_2 =	3.047 583 693 0 × 10^{-5}	3.178 710 392 4 × 10^{-3}
c_3 =	–8.568 106 572 0 × 10^{-8}	–3.184 768 670 1 × 10^{-6}
c_4 =	1.322 819 529 5 × 10^{-10}	1.572 081 900 4 × 10^{-9}
c_5 =	–1.705 295 833 7 × 10^{-13}	–3.069 136 905 6 × 10^{-13}
c_6 =	2.094 809 069 7 × 10^{-16}	....
c_7 =	–1.253 839 533 6 × 10^{-19}	....
c_8 =	1.563 172 569 7 × 10^{-23}	....

TABLE 7 Polynomial Coefficients for Generating Thermocouple ~~EMF~~Emf as a Function of Temperature *Continued*

TYPE K Thermocouple

Temperature Range			–270 °C to 0 °C	0 °C to 1372 °C
	c_0	=	0.0	–1.760 041 368 6 × 10^{-2}
	c_1	=	3.945 012 802 5 × 10^{-2}	3.892 120 497 5 × 10^{-2}
	c_2	=	2.362 237 359 8 × 10^{-5}	1.855 877 003 2 × 10^{-5}
	c_3	=	–3.285 890 678 4 × 10^{-7}	–9.945 759 287 4 × 10^{-8}
	c_4	=	–4.990 482 877 7 × 10^{-9}	3.184 094 571 9 × 10^{-10}
	c_5	=	–6.750 905 917 3 × 10^{-11}	–5.607 284 488 9 × 10^{-13}
	c_6	=	–5.741 032 742 8 × 10^{-13}	5.607 505 905 9 × 10^{-16}
	c_7	=	–3.108 887 289 4 × 10^{-15}	–3.202 072 000 3 × 10^{-19}
	c_8	=	–1.045 160 936 5 × 10^{-17}	9.715 114 715 2 × 10^{-23}
	c_9	=	–1.988 926 687 8 × 10^{-20}	–1.210 472 127 5 × 10^{-26}
	c_{10}	=	–1.632 269 748 6 × 10^{-23}	....
Exponential Coefficients See Note 2	b_0	=	....	1.185 976 × 10^{-1}
	b_1	=	....	–1.183 432 × 10^{-4}

TYPE N Thermocouple

Temperature Range			–270 °C to 0 °C	0 °C to 1300 °C
	c_0	=	0.0	0.0
	c_1	=	2.615 910 596 2 × 10^{-2}	2.592 939 460 1 × 10^{-2}
	c_2	=	1.095 748 422 8 × 10^{-5}	1.571 014 188 0 × 10^{-5}
	c_3	=	–9.384 111 155 4 × 10^{-8}	4.382 562 723 7 × 10^{-8}
	c_4	=	–4.641 203 975 9 × 10^{-11}	–2.526 116 979 4 × 10^{-10}
	c_5	=	–2.630 335 771 6 × 10^{-12}	6.431 181 933 9 × 10^{-13}
	c_6	=	–2.265 343 800 3 × 10^{-14}	–1.006 347 151 9 × 10^{-15}
	c_7	=	–7.608 930 079 1 × 10^{-17}	9.974 533 899 2 × 10^{-19}
	c_8	=	–9.341 966 783 5 × 10^{-20}	–6.086 324 560 7 × 10^{-22}
	c_9	=	....	2.084 922 933 9 × 10^{-25}
	c_{10}	=	....	–3.068 219 615 1 × 10^{-29}

TYPE R Thermocouple

Temperature Range			–50 °C to 1064.18 °C	1064.18 °C to 1664.5 °C	1664.5 °C to 1768.1 °C
	c_0	=	0.0	2.951 579 253 16	1.522 321 182 09 × 10^{2}
	c_1	=	5.289 617 297 65 × 10^{-3}	–2.520 612 513 32 × 10^{-3}	–2.688 198 885 45 × 10^{-1}
	c_2	=	1.391 665 897 82 × 10^{-5}	1.595 645 018 65 × 10^{-5}	1.712 802 804 71 × 10^{-4}
	c_3	=	–2.388 556 930 17 × 10^{-8}	–7.640 859 475 76 × 10^{-9}	–3.458 957 064 53 × 10^{-8}
	c_4	=	3.569 160 010 63 × 10^{-11}	2.053 052 910 24 × 10^{-12}	–9.346 339 710 46 × 10^{-15}
	c_5	=	–4.623 476 662 98 × 10^{-14}	–2.933 596 681 73 × 10^{-16}	....
	c_6	=	5.007 774 410 34 × 10^{-17}	....	....
	c_7	=	–3.731 058 861 91 × 10^{-20}	....	....
	c_8	=	1.577 164 823 67 × 10^{-23}	....	....
	c_9	=	–2.810 386 252 51 × 10^{-27}	....	....

TYPE S Thermocouple

Temperature Range			–50 °C to 1064.18 °C	1064.18 °C to 1664.5 °C	1664.5 °C to 1768.1 °C
	c_0	=	0.0	1.329 004 440 85	1.466 282 326 36 × 10^{2}
	c_1	=	5.403 133 086 31 × 10^{-3}	3.345 093 113 44 × 10^{-3}	–2.584 305 167 52 × 10^{-1}
	c_2	=	1.259 342 897 40 × 10^{-5}	6.548 051 928 18 × 10^{-6}	1.636 935 746 41 × 10^{-4}
	c_3	=	–2.324 779 686 89 × 10^{-8}	–1.648 562 592 09 × 10^{-9}	–3.304 390 469 87 × 10^{-8}
	c_4	=	3.220 288 230 36 × 10^{-11}	1.299 896 051 74 × 10^{-14}	–9.432 236 906 12 × 10^{-15}
	c_5	=	–3.314 651 963 89 × 10^{-14}	....	....
	c_6	=	2.557 442 517 86 × 10^{-17}	....	....
	c_7	=	–1.250 688 713 93 × 10^{-20}	....	....
	c_8	=	2.714 431 761 45 × 10^{-24}	....	....

TABLE 7 Polynomial Coefficients for Generating Thermocouple ~~EMF~~Emf as a Function of Temperature *Continued*

TYPE T Thermocouple

Temperature Range		–270 °C to 0 °C	0 °C to 400 °C
c_0	=	0.0	0.0
c_1	=	$3.874\ 810\ 636\ 4 \times 10^{-2}$	$3.874\ 810\ 636\ 4 \times 10^{-2}$
c_2	=	$4.419\ 443\ 434\ 7 \times 10^{-5}$	$3.329\ 222\ 788\ 0 \times 10^{-5}$
c_3	=	$1.184\ 432\ 310\ 5 \times 10^{-7}$	$2.061\ 824\ 340\ 4 \times 10^{-7}$
c_4	=	$2.003\ 297\ 355\ 4 \times 10^{-8}$	$-2.188\ 225\ 684\ 6 \times 10^{-9}$
c_5	=	$9.013\ 801\ 955\ 9 \times 10^{-10}$	$1.099\ 688\ 092\ 8 \times 10^{-11}$
c_6	=	$2.265\ 115\ 659\ 3 \times 10^{-11}$	$-3.081\ 575\ 877\ 2 \times 10^{-14}$
c_7	=	$3.607\ 115\ 420\ 5 \times 10^{-13}$	$4.547\ 913\ 529\ 0 \times 10^{-17}$
c_8	=	$3.849\ 393\ 988\ 3 \times 10^{-15}$	$-2.751\ 290\ 167\ 3 \times 10^{-20}$
c_9	=	$2.821\ 352\ 192\ 5 \times 10^{-17}$	....
c_{10}	=	$1.425\ 159\ 477\ 9 \times 10^{-19}$	....
c_{11}	=	$4.876\ 866\ 228\ 6 \times 10^{-22}$	....
c_{12}	=	$1.079\ 553\ 927\ 0 \times 10^{-24}$	....
c_{13}	=	$1.394\ 502\ 706\ 2 \times 10^{-27}$	....
c_{14}	=	$7.979\ 515\ 392\ 7 \times 10^{-31}$	....

TYPE C Coefficients

t = 0 °C to 2315 °C

		0 °C to 630.615 °C	630.615 °C to 2315 °C
c_0	=	0.0000000	4.0528823×10^{-1}
c_1	=	1.3406032×10^{-2}	1.1509355×10^{-2}
c_2	=	1.1924992×10^{-5}	1.5696453×10^{-5}
~~c_3~~	~~=~~	~~$-7.9806354 \times 10^{-9}$~~	~~$-1.3704412 \times 10^{-8}$~~
c_3	=	$-7.9806354 \times 10^{-9}$	$-1.3704412 \times 10^{-8}$
~~c_4~~	~~=~~	~~$-5.0787515 \times 10^{-12}$~~	~~$5.2290873 \times 10^{-12}$~~
c_4	=	$-5.0787515 \times 10^{-12}$	$5.2290873 \times 10^{-12}$
c_5	=	$1.3164197 \times 10^{-14}$	$-9.2082758 \times 10^{-16}$
~~c_6~~	~~=~~	~~$-7.9197332 \times 10^{-18}$~~	~~$4.5245112 \times 10^{-20}$~~
c_6	=	$-7.9197332 \times 10^{-18}$	$4.5245112 \times 10^{-20}$

TYPE BP Thermoelement vs. Platinum (NIST Pt–67)

Temperature Range		0 °C to 630.615 °C	630.615 °C to 1768.1 °C
c_0	=	0.0	–7.968 043 228 2 ....
c_1	=	$4.822\ 787\ 568\ 7 \times 10^{-3}$	$6.394\ 111\ 021\ 3 \times 10^{-2}$
c_2	=	$1.565\ 116\ 570\ 9 \times 10^{-5}$	$-1.710\ 242\ 141\ 0 \times 10^{-4}$
c_3	=	$-2.223\ 379\ 788\ 2 \times 10^{-8}$	$3.055\ 578\ 252\ 7 \times 10^{-7}$
c_4	=	$2.833\ 324\ 407\ 4 \times 10^{-11}$	$-3.210\ 574\ 449\ 2 \times 10^{-10}$
c_5	=	$-2.025\ 894\ 044\ 7 \times 10^{-14}$	$2.090\ 910\ 279\ 4 \times 10^{-13}$
c_6	=	$6.148\ 870\ 509\ 6 \times 10^{-18}$	$-8.233\ 582\ 542\ 6 \times 10^{-17}$
c_7	=	....	$1.782\ 284\ 151\ 5 \times 10^{-20}$
c_8	=	....	$-1.618\ 707\ 418\ 7 \times 10^{-24}$

TYPE BN Thermoelement vs. Platinum (NIST Pt–67)

Temperature Range		0 °C to 630.615 °C	630.615 °C to 1768.1 °C
c_0	=	0.0	–4.074 226 366 2 ....
c_1	=	$5.069\ 295\ 752\ 2 \times 10^{-3}$	$3.536\ 936\ 274\ 3 \times 10^{-2}$
c_2	=	$9.747\ 123\ 592\ 0 \times 10^{-6}$	$-8.613\ 910\ 931\ 5 \times 10^{-5}$
c_3	=	$-2.090\ 800\ 471\ 8 \times 10^{-8}$	$1.477\ 050\ 236\ 2 \times 10^{-7}$
c_4	=	$2.676\ 641\ 488\ 3 \times 10^{-11}$	$-1.527\ 039\ 962\ 9 \times 10^{-10}$
c_5	=	$-1.856\ 448\ 752\ 3 \times 10^{-14}$	$9.799\ 308\ 780\ 5 \times 10^{-14}$
c_6	=	$5.518\ 967\ 038\ 6 \times 10^{-18}$	$-3.782\ 039\ 439\ 3 \times 10^{-17}$
c_7	=	....	$7.925\ 277\ 432\ 8 \times 10^{-21}$
c_8	=	....	$-6.807\ 941\ 157\ 8 \times 10^{-25}$

TABLE 7 Polynomial Coefficients for Generating Thermocouple ~~EMF~~Emf as a Function of Temperature *Continued*

TYPE JP Thermoelement vs. Platinum (NIST Pt–67)

Temperature Range			–210 °C to 760 °C
	c_0	=	0.0
	c_1	=	$1.791\ 354\ 855\ 9 \times 10^{-2}$
	c_2	=	$4.677\ 466\ 335\ 8 \times 10^{-6}$
	c_3	=	$-7.122\ 599\ 299\ 1 \times 10^{-8}$
	c_4	=	$1.335\ 212\ 501\ 6 \times 10^{-10}$
	c_5	=	$-1.500\ 896\ 263\ 9 \times 10^{-13}$
	c_6	=	$1.551\ 431\ 962\ 5 \times 10^{-16}$
	c_7	=	$-7.950\ 357\ 212\ 5 \times 10^{-20}$
	c_8	=	$2.429\ 790\ 391\ 0 \times 10^{-24}$

Platinum (NIST Pt–67) vs. **TYPE JN** Thermoelement

Temperature Range			–210 °C to 760 °C
	c_0	=	0.0
	c_1	=	$3.246\ 763\ 925\ 6 \times 10^{-2}$
	c_2	=	$2.579\ 837\ 059\ 4 \times 10^{-5}$
	c_3	=	$-1.445\ 507\ 273\ 0 \times 10^{-8}$
	c_4	=	$-1.239\ 297\ 209\ 3 \times 10^{-12}$
	c_5	=	$-2.043\ 995\ 698\ 0 \times 10^{-14}$
	c_6	=	$5.433\ 771\ 071\ 8 \times 10^{-17}$
	c_7	=	$-4.588\ 038\ 123\ 5 \times 10^{-20}$
	c_8	=	$1.320\ 193\ 530\ 6 \times 10^{-23}$

TYPE KP or EP Thermoelement vs. Platinum (NIST Pt–67)

Temperature Range			–270 °C to 0 °C	0 °C to 1372 °C
	c_0	=	0.0	0.0
	c_1	=	$2.581\ 195\ 057\ 4 \times 10^{-2}$	$2.581\ 195\ 057\ 3 \times 10^{-2}$
	c_2	=	$2.299\ 008\ 894\ 3 \times 10^{-5}$	$2.683\ 139\ 535\ 5 \times 10^{-5}$
	c_3	=	$-6.157\ 475\ 446\ 0 \times 10^{-7}$	$-3.867\ 519\ 441\ 2 \times 10^{-8}$
	c_4	=	$-2.327\ 184\ 376\ 5 \times 10^{-8}$	$3.030\ 555\ 323\ 4 \times 10^{-11}$
	c_5	=	$-5.457\ 033\ 359\ 6 \times 10^{-10}$	$-1.028\ 040\ 353\ 3 \times 10^{-14}$
	c_6	=	$-7.845\ 394\ 226\ 4 \times 10^{-12}$	$-3.448\ 171\ 733\ 0 \times 10^{-17}$
	c_7	=	$-7.251\ 284\ 060\ 8 \times 10^{-14}$	$8.251\ 289\ 448\ 0 \times 10^{-20}$
	c_8	=	$-4.356\ 917\ 479\ 1 \times 10^{-16}$	$-7.889\ 338\ 217\ 7 \times 10^{-23}$
	c_9	=	$-1.664\ 752\ 760\ 6 \times 10^{-18}$	$3.569\ 925\ 312\ 6 \times 10^{-26}$
	c_{10}	=	$-3.737\ 720\ 750\ 1 \times 10^{-21}$	$-6.331\ 536\ 065\ 9 \times 10^{-30}$
	c_{11}	=	$-3.774\ 144\ 269\ 5 \times 10^{-24}$	....
	c_{12}	=	$1.002\ 535\ 559\ 0 \times 10^{-27}$	....
	c_{13}	=	$3.893\ 531\ 072\ 5 \times 10^{-30}$	....

Platinum (NIST Pt–67) vs. **TYPE KN** Thermoelement

Temperature Range			–270 °C to 0 °C	0 °C to 1372 °C
	c_0	=	0.0	$-1.760\ 041\ 368\ 6 \times 10^{-2}$
	c_1	=	$1.363\ 817\ 745\ 2 \times 10^{-2}$	$1.310\ 925\ 440\ 3 \times 10^{-2}$
	c_2	=	$6.322\ 846\ 542\ 6 \times 10^{-7}$	$-8.272\ 625\ 323\ 0 \times 10^{-6}$
	c_3	=	$2.871\ 584\ 767\ 6 \times 10^{-7}$	$-6.078\ 239\ 846\ 2 \times 10^{-8}$
	c_4	=	$1.828\ 136\ 088\ 7 \times 10^{-8}$	$2.881\ 039\ 039\ 6 \times 10^{-10}$
	c_5	=	$4.781\ 942\ 767\ 9 \times 10^{-10}$	$-5.504\ 480\ 453\ 6 \times 10^{-13}$
	c_6	=	$7.271\ 290\ 952\ 1 \times 10^{-12}$	$5.952\ 323\ 079\ 2 \times 10^{-16}$
	c_7	=	$6.940\ 395\ 331\ 9 \times 10^{-14}$	$-4.027\ 200\ 945\ 1 \times 10^{-19}$
	c_8	=	$4.252\ 401\ 385\ 5 \times 10^{-16}$	$1.760\ 445\ 293\ 3 \times 10^{-22}$
	c_9	=	$1.644\ 863\ 493\ 8 \times 10^{-18}$	$-4.780\ 397\ 440\ 1 \times 10^{-26}$
	c_{10}	=	$3.721\ 398\ 052\ 6 \times 10^{-21}$	$6.331\ 536\ 065\ 9 \times 10^{-30}$
	c_{11}	=	$3.774\ 144\ 269\ 5 \times 10^{-24}$	....
	c_{12}	=	$-1.002\ 535\ 559\ 0 \times 10^{-27}$	....
	c_{13}	=	$-3.893\ 531\ 072\ 5 \times 10^{-30}$	....
Exponential Coefficients See Note 2	b_0	=	....	$1.185\ 976 \times 10^{-1}$
	b_1	=	....	$-1.183\ 432 \times 10^{-4}$

TABLE 7 Polynomial Coefficients for Generating Thermocouple ~~EMF~~Emf as a Function of Temperature *Continued*

TYPE NP Thermoelement vs. Platinum (NIST Pt–67)

Temperature Range		–200 °C to 0 °C	0 °C to 1300 °C
	c_0 =	0.0	0.0
	c_1 =	$1.541\ 798\ 843\ 0 \times 10^{-2}$	$1.544\ 538\ 594\ 7 \times 10^{-2}$
	c_2 =	$2.570\ 738\ 245\ 7 \times 10^{-5}$	$2.672\ 234\ 128\ 9 \times 10^{-5}$
	c_3 =	$-9.018\ 782\ 577\ 1 \times 10^{-8}$	$-2.559\ 531\ 305\ 2 \times 10^{-8}$
	c_4 =	$-5.365\ 479\ 300\ 5 \times 10^{-10}$	$-3.302\ 809\ 741\ 4 \times 10^{-11}$
	c_5 =	$-3.352\ 621\ 597\ 6 \times 10^{-12}$	$2.007\ 532\ 297\ 1 \times 10^{-13}$
	c_6 =	$-7.272\ 344\ 767\ 0 \times 10^{-15}$	$-4.270\ 815\ 423\ 0 \times 10^{-16}$
	c_7 =	....	$5.181\ 347\ 352\ 2 \times 10^{-19}$
	c_8 =	....	$-3.688\ 712\ 493\ 1 \times 10^{-22}$
	c_9 =	....	$1.426\ 873\ 470\ 8 \times 10^{-25}$
	c_{10} =	....	$-2.312\ 130\ 215\ 4 \times 10^{-29}$

Platinum (NIST Pt–67) vs. **TYPE NN** Thermoelement

Temperature Range		–200 °C to 0 °C	0 °C to 1300 °C
	c_0 =	0.0	0.0
	c_1 =	$1.074\ 111\ 753\ 2 \times 10^{-2}$	$1.048\ 400\ 865\ 5 \times 10^{-2}$
	c_2 =	$-1.474\ 989\ 822\ 9 \times 10^{-5}$	$-1.101\ 219\ 940\ 9 \times 10^{-5}$
	c_3 =	$-3.653\ 285\ 783\ 2 \times 10^{-9}$	$6.942\ 094\ 028\ 9 \times 10^{-8}$
	c_4 =	$4.901\ 358\ 902\ 9 \times 10^{-10}$	$-2.195\ 836\ 005\ 3 \times 10^{-10}$
	c_5 =	$7.222\ 858\ 260\ 4 \times 10^{-13}$	$4.423\ 649\ 636\ 8 \times 10^{-13}$
	c_6 =	$-1.538\ 109\ 323\ 6 \times 10^{-14}$	$-5.792\ 656\ 096\ 4 \times 10^{-16}$
	c_7 =	$-7.608\ 930\ 079\ 1 \times 10^{-17}$	$4.793\ 186\ 547\ 0 \times 10^{-19}$
	c_8 =	$-9.341\ 966\ 783\ 5 \times 10^{-20}$	$-2.397\ 612\ 067\ 6 \times 10^{-22}$
	c_9 =	....	$6.580\ 494\ 631\ 8 \times 10^{-26}$
	c_{10} =	....	$-7.560\ 893\ 996\ 5 \times 10^{-30}$

TYPE TP Thermoelement vs. Platinum (NIST Pt–67)

Temperature Range		–270 °C to 0 °C	0 °C to 400 °C
	c_0 =	0.0	0.0
	c_1 =	$5.894\ 548\ 229\ 7 \times 10^{-3}$	$5.894\ 548\ 226\ 5 \times 10^{-3}$
	c_2 =	$2.177\ 354\ 616\ 7 \times 10^{-5}$	$1.509\ 134\ 765\ 2 \times 10^{-5}$
	c_3 =	$2.826\ 761\ 733\ 1 \times 10^{-7}$	$1.385\ 988\ 324\ 2 \times 10^{-7}$
	c_4 =	$2.256\ 129\ 063\ 2 \times 10^{-8}$	$-1.827\ 351\ 164\ 9 \times 10^{-9}$
	c_5 =	$9.502\ 026\ 902\ 0 \times 10^{-10}$	$1.033\ 635\ 649\ 1 \times 10^{-11}$
	c_6 =	$2.412\ 716\ 823\ 3 \times 10^{-11}$	$-3.065\ 826\ 553\ 4 \times 10^{-14}$
	c_7 =	$3.910\ 747\ 567\ 8 \times 10^{-13}$	$4.681\ 530\ 823\ 5 \times 10^{-17}$
	c_8 =	$4.217\ 403\ 476\ 6 \times 10^{-15}$	$-2.974\ 071\ 681\ 2 \times 10^{-20}$
	c_9 =	$3.094\ 671\ 890\ 4 \times 10^{-17}$	$1.474\ 503\ 431\ 3 \times 10^{-24}$
	c_{10} =	$1.551\ 930\ 033\ 9 \times 10^{-19}$	$-3.659\ 405\ 308\ 7 \times 10^{-28}$
	c_{11} =	$5.235\ 860\ 981\ 1 \times 10^{-22}$	....
	c_{12} =	$1.136\ 383\ 791\ 3 \times 10^{-24}$	....
	c_{13} =	$1.433\ 054\ 079\ 2 \times 10^{-27}$	....
	c_{14} =	$7.979\ 515\ 392\ 7 \times 10^{-31}$	....

Platinum (NIST Pt–67) vs. **TYPE TN or EN** Thermoelement

Temperature Range		–270 °C to 0 °C	0 °C to 1000 °C
	c_0 =	0.0	0.0
	c_1 =	$3.285\ 355\ 813\ 4 \times 10^{-2}$	$3.285\ 355\ 813\ 8 \times 10^{-2}$
	c_2 =	$2.242\ 088\ 818\ 1 \times 10^{-5}$	$1.820\ 088\ 022\ 7 \times 10^{-5}$
	c_3 =	$-1.642\ 329\ 422\ 6 \times 10^{-7}$	$6.758\ 360\ 162\ 4 \times 10^{-8}$
	c_4 =	$-2.528\ 317\ 078\ 0 \times 10^{-9}$	$-3.608\ 745\ 197\ 5 \times 10^{-10}$
	c_5 =	$-4.882\ 249\ 460\ 9 \times 10^{-11}$	$6.605\ 244\ 362\ 3 \times 10^{-13}$
	c_6 =	$-1.476\ 011\ 640\ 4 \times 10^{-12}$	$-1.574\ 932\ 377\ 1 \times 10^{-16}$
	c_7 =	$-3.036\ 321\ 473\ 1 \times 10^{-14}$	$-1.336\ 172\ 944\ 2 \times 10^{-18}$
	c_8 =	$-3.680\ 094\ 883\ 0 \times 10^{-16}$	$2.227\ 815\ 139\ 1 \times 10^{-21}$
	c_9 =	$-2.733\ 196\ 978\ 5 \times 10^{-18}$	$-1.474\ 503\ 431\ 3 \times 10^{-24}$
	c_{10} =	$-1.267\ 705\ 560\ 5 \times 10^{-20}$	$3.659\ 405\ 308\ 7 \times 10^{-28}$
	c_{11} =	$-3.589\ 947\ 524\ 7 \times 10^{-23}$	....
	c_{12} =	$-5.682\ 986\ 428\ 0 \times 10^{-26}$	....
	c_{13} =	$-3.855\ 137\ 308\ 5 \times 10^{-29}$	....

TABLE 8 Type B Thermocouple

Temperature in Degrees Celsius (ITS–90)

~~EMF in Millivolts~~ ~~Reference Junctions at 0°C~~

Reference Junctions at 0°C

~~THERMOELECTRIC VOLTAGE IN MILLIVOLTS~~

Thermoelectric Voltage (emf) in Millivolts

°C	0	1	2	3	4	5	6	7	8	9	10
0	0.000	–0.000	–0.000	–0.001	–0.001	–0.001	–0.001	–0.001	–0.002	–0.002	–0.002
10	–0.002	–0.002	–0.002	–0.002	–0.002	–0.002	–0.002	–0.002	–0.003	–0.003	–0.003
20	–0.003	–0.003	–0.003	–0.003	–0.003	–0.002	–0.002	–0.002	–0.002	–0.002	–0.002
30	–0.002	–0.002	–0.002	–0.002	–0.002	–0.001	–0.001	–0.001	0.001	–0.001	–0.000
40	–0.000	–0.000	–0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.002
50	0.002	0.003	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.006	0.006
60	0.006	0.007	0.007	0.008	0.008	0.009	0.009	0.010	0.010	0.011	0.011
70	0.011	0.012	0.012	0.013	0.014	0.014	0.015	0.015	0.016	0.017	0.017
80	0.017	0.018	0.019	0.020	0.020	0.021	0.022	0.022	0.023	0.024	0.025
90	0.025	0.026	0.026	0.027	0.028	0.029	0.030	0.031	0.031	0.032	0.033
100	0.033	0.034	0.035	0.036	0.037	0.038	0.039	0.040	0.041	0.042	0.043
110	0.043	0.044	0.045	0.046	0.047	0.048	0.049	0.050	0.051	0.052	0.053
120	0.053	0.055	0.056	0.057	0.058	0.059	0.060	0.062	0.063	0.064	0.065
130	0.065	0.066	0.068	0.069	0.070	0.072	0.073	0.074	0.075	0.077	0.078
140	0.078	0.079	0.081	0.082	0.084	0.085	0.086	0.088	0.089	0.091	0.092
150	0.092	0.094	0.095	0.096	0.098	0.099	0.101	0.102	0.104	0.106	0.107
160	0.107	0.109	0.110	0.112	0.113	0.115	0.117	0.118	0.120	0.122	0.123
170	0.123	0.125	0.127	0.128	0.130	0.132	0.134	0.135	0.137	0.139	0.141
180	0.141	0.142	0.144	0.146	0.148	0.150	0.151	0.153	0.155	0.157	0.159
190	0.159	0.161	0.163	0.165	0.166	0.168	0.170	0.172	0.174	0.176	0.178
200	0.178	0.180	0.182	0.184	0.186	0.188	0.190	0.192	0.195	0.197	0.199
210	0.199	0.201	0.203	0.205	0.207	0.209	0.212	0.214	0.216	0.218	0.220
220	0.220	0.222	0.225	0.227	0.229	0.231	0.234	0.236	0.238	0.241	0.243
230	0.243	0.245	0.248	0.250	0.252	0.255	0.257	0.259	0.262	0.264	0.267
240	0.267	0.269	0.271	0.274	0.276	0.279	0.281	0.284	0.286	0.289	0.291
250	0.291	0.294	0.296	0.299	0.301	0.304	0.307	0.309	0.312	0.314	0.317
260	0.317	0.320	0.322	0.325	0.328	0.330	0.333	0.336	0.338	0.341	0.344
270	0.344	0.347	0.349	0.352	0.355	0.358	0.360	0.363	0.366	0.369	0.372
280	0.372	0.375	0.377	0.380	0.383	0.386	0.389	0.392	0.395	0.398	0.401
290	0.401	0.404	0.407	0.410	0.413	0.416	0.419	0.422	0.425	0.428	0.431
300	0.431	0.434	0.437	0.440	0.443	0.446	0.449	0.452	0.455	0.458	0.462
310	0.462	0.465	0.468	0.471	0.474	0.478	0.481	0.484	0.487	0.490	0.494
320	0.494	0.497	0.500	0.503	0.507	0.510	0.513	0.517	0.520	0.523	0.527
330	0.527	0.530	0.533	0.537	0.540	0.544	0.547	0.550	0.554	0.557	0.561
340	0.561	0.564	0.568	0.571	0.575	0.578	0.582	0.585	0.589	0.592	0.596
350	0.596	0.599	0.603	0.607	0.610	0.614	0.617	0.621	0.625	0.628	0.632
360	0.632	0.636	0.639	0.643	0.647	0.650	0.654	0.658	0.662	0.665	0.669
370	0.669	0.673	0.677	0.680	0.684	0.688	0.692	0.696	0.700	0.703	0.707
380	0.707	0.711	0.715	0.719	0.723	0.727	0.731	0.735	0.738	0.742	0.746
390	0.746	0.750	0.754	0.758	0.762	0.766	0.770	0.774	0.778	0.782	0.787
400	0.787	0.791	0.795	0.799	0.803	0.807	0.811	0.815	0.819	0.824	0.828
410	0.828	0.832	0.836	0.840	0.844	0.849	0.853	0.857	0.861	0.866	0.870
420	0.870	0.874	0.878	0.883	0.887	0.891	0.896	0.900	0.904	0.909	0.913
430	0.913	0.917	0.922	0.926	0.930	0.935	0.939	0.944	0.948	0.953	0.957
440	0.957	0.961	0.966	0.970	0.975	0.979	0.984	0.988	0.993	0.997	1.002
450	1.002	1.007	1.011	1.016	1.020	1.025	1.030	1.034	1.039	1.043	1.048
460	1.048	1.053	1.057	1.062	1.067	1.071	1.076	1.081	1.086	1.090	1.095
470	1.095	1.100	1.105	1.109	1.114	1.119	1.124	1.129	1.133	1.138	1.143
480	1.143	1.148	1.153	1.158	1.163	1.167	1.172	1.177	1.182	1.187	1.192
490	1.192	1.197	1.202	1.207	1.212	1.217	1.222	1.227	1.232	1.237	1.242