Designation: E230/E230M – 23

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 thermo-elements 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*

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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

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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.

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 versus Temperature

5.1 In the United States, thermocouples and matched thermocouple wire pairs are normally supplied conforming to the tolerances on initial values of emf versus temperature 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 should be established by agreement between the purchaser and the supplier.

5.1.3 In 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 Tables 2 and 3, respectively.

5.2.1 Initial tolerances of extension grade materials and compensating extension materials apply over a more limited 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.

6.3 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 Wire
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

7.1.2 *Emf versus Temperature Tables for Thermocouples:*

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

7.1.3 *Emf versus Temperature Tables for Thermoelements:*

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

[A] These temperature ranges represent the published temperature versus emf data for the thermocouple and thermoelement types listed. Refer to Table 6 for the recommended upper 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

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8. Keywords

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

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 for base metal and No. 24 AWG for noble and refractory metal thermocouples) 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. 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 usage; 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.

Thermo-couple Type	Temperature Range		Tolerances with Reference Junction 0 °C [32 °F]			
			Standard Tolerances		Special Tolerances	
	°C	°F	°C	°F	°C	°F
T	0 to 370	32 to 700	The greater of ±1.0 °C or ±0.75 %	Note 2	The greater of ±0.5 °C or ±0.4 %	Note 2
J	0 to 760	32 to 1400	The greater of ±2.2 °C or ±0.75 %		The greater of ±1.1 °C or ±0.4 %	
*E	0 to 870	32 to 1600	The greater of ±1.7 °C or ±0.5 %		The greater of ±1.0 °C or ±0.4 %	
K or N	0 to 1260	32 to 2300	The greater of ±2.2 °C or ±0.75 %		The greater of ±1.1 °C or ±0.4 %	
R or S	0 to 1480	32 to 2700	The greater of ±1.5 °C or ±0.25 %		The greater of ±0.6 °C or ±0.1 %	
B	600 to 1700	1100 to 3100	±0.5 %		±0.25 %	
C	0 to 2315	32 to 4200	The greater of ±4.4 °C or 1 %		Not applicable	
T[A]	-200 to 0	-328 to 32	The greater of ±1.0 °C or ±1.5 %	The greater of ±1.8 °F or ±1.5 %	[B]	
*E[A]	-200 to 0	-328 to 32	The greater of ±1.7 °C or ±1 %	The greater of ±3.1 °F or ±1 %	[B]	
K[A]	-200 to 0	-328 to 32	The greater of ±2.2 °C or ±2 %	The greater of ±4.0 °F 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 °C to 870 °C and the greater of ±2.2°C or ±2 % from -200 °C 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 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 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 °C to 0 °C, ±1.0 °C or ±0.5 % (whichever is greater)
Type T, -200 °C 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 thermocouple circuit output that is dependent upon the temperature difference between the extreme ends of the extension wire length.

| Thermocouple Type | Temperature Range | | Tolerances—Reference Junction 0 °C [32 °F] | | | |
| | | | Standard Tolerances | | Special Tolerances | |
	°C	[°F]	°C	[°F]	°C	[°F]
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
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
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 thermocouple circuit output 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] | | |
| | | | Standard Tolerances | | Special Tolerances |
	°C	[°F]	°C	[°F]	
SX	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]
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		

[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 °C to 50 °C [32 °F to 122 °F], where the use of non-compensated (copper/copper) conductors introduces no significant error. For a somewhat larger temperature gradient of 0 °C to 100 °C [32 °F to 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 tolerances given for measurements above 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 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 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 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 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 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 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 may be used at temperatures above the stated limits, but usually at the expense of stability or service life or both. In some instances, it may be necessary to reduce the temperature limits in order to achieve satisfactory performance in service. ASTM MNL-12[A] and other literature sources should be consulted for additional applications information.

	Upper Temperature limit for Various Wire Sizes, °C [°F]					
Thermo-couple Type	No. 8 AWG (3.25 mm [0.128 in.])	No. 14 AWG (1.63 mm [0.064 in.])	No. 20 AWG (0.81 mm [0.032 in.])	No. 24 AWG (0.51 mm [0.020 in.])	No. 28 AWG (0.33 mm [0.013 in.])	No. 30 AWG (0.25 mm [0.010 in.])
T		370 [700]	260 [500]	200 [400]	200 [400]	150 [300]
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]
K and N	1260 [2300]	1090 [2000]	980 [1800]	870 [1600]	870 [1600]	760 [1400]
R and S				1480 [2700][C]		
B				1700 [3100][C]		
C[B]				2315 [4200][C]		

[A] *Manual on the Use of Thermocouples in Temperature Measurement*, ASTM MNL-12, 1993.
[B] Type C thermoelements 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 AWG thermoelements are common for this thermocouple type, but other sizes are available and, with adequate protection, are generally useable over the same temperature range.

TABLE 7 Polynomial Coefficients for Generating Thermocouple 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: $E = c_0 + c_1 t + c_2 t^2 + c_3 t^3 \ldots + c_n t^n$. In this expression, E is in millivolts, t is in °C, and c_0, c_1, $c_2 \ldots c_n$ 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}	

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

TABLE 7 *Continued*

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

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

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

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_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 =	$-7.9197332 \times 10^{-18}$	$4.5245112 \times 10^{-20}$

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

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TABLE 7 *Continued*

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	=		$-6.807\ 941\ 157\ 8 \times 10^{-25}$

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	=	$6.322\ 846\ 542\ 6 \times 10^{-7}$	$-8.272\ 625\ 323\ 0 \times 10^{-6}$

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TABLE 7 *Continued*

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	b_0	=	$1.185\ 976 \times 10^{-1}$
See Note 2	b_1	=	$-1.183\ 432 \times 10^{-4}$

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

		−200 °C to 0 °C	0 °C to 1300 °C
Temperature Range			
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

		−200 °C to 0 °C	0 °C to 1300 °C
Temperature Range			
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)

		−270 °C to 0 °C	0 °C to 400 °C
Temperature Range			
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

		−270 °C to 0 °C	0 °C to 1000 °C
Temperature Range			
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	=	$-2.733\ 196\ 978\ 5 \times 10^{-18}$	$-1.474\ 503\ 431\ 3 \times 10^{-24}$

TABLE 7 *Continued*

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

					Type B						
				Temperature in Degrees Celsius (ITS–90)							
											Reference Junctions at 0 °C
°C	0	1	2	3	4	5	6	7	8	9	10
					Thermoelectric Voltage (emf) in Millivolts						
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
500	1.242	1.247	1.252	1.257	1.262	1.267	1.272	1.277	1.282	1.288	1.293
510	1.293	1.298	1.303	1.308	1.313	1.318	1.324	1.329	1.334	1.339	1.344
520	1.344	1.350	1.355	1.360	1.365	1.371	1.376	1.381	1.387	1.392	1.397
530	1.397	1.402	1.408	1.413	1.418	1.424	1.429	1.435	1.440	1.445	1.451
540	1.451	1.456	1.462	1.467	1.472	1.478	1.483	1.489	1.494	1.500	1.505
550	1.505	1.511	1.516	1.522	1.527	1.533	1.539	1.544	1.550	1.555	1.561
560	1.561	1.566	1.572	1.578	1.583	1.589	1.595	1.600	1.506	1.612	1.617
570	1.617	1.623	1.629	1.634	1.640	1.646	1.652	1.657	1.663	1.669	1.675

TABLE 8 *Continued*

					Type B					
					Temperature in Degrees Celsius (ITS–90)					
										Reference Junctions at 0 °C
°C	0	1	2	3	4	5	6	7	8	9	10
					Thermoelectric Voltage (emf) in Millivolts					
580	1.675	1.680	1.686	1.692	1.698	1.704	1.709	1.715	1.721	1.727	1.733
590	1.733	1.739	1.745	1.750	1.756	1.762	1.768	1.774	1.780	1.786	1.792
600	1.792	1.798	1.804	1.810	1.816	1.822	1.828	1.834	1.840	1.846	1.852
610	1.852	1.858	1.864	1.870	1.876	1.882	1.888	1.894	1.901	1.907	1.913
620	1.913	1.919	1.925	1.931	1.937	1.944	1.950	1.956	1.962	1.968	1.975
630	1.975	1.981	1.987	1.993	1.999	2.006	2.012	2.018	2.025	2.031	2.037
640	2.037	2.043	2.050	2.056	2.062	2.069	2.075	2.082	2.088	2.094	2.101
650	2.101	2.107	2.113	2.120	2.126	2.133	2.139	2.146	2.152	2.158	2.165
660	2.165	2.171	2.178	2.184	2.191	2.197	2.204	2.210	2.217	2.224	2.230
670	2.230	2.237	2.243	2.250	2.256	2.263	2.270	2.276	2.283	2.289	2.296
680	2.296	2.303	2.309	2.316	2.323	2.329	2.336	2.343	2.350	2.356	2.363
690	2.363	2.370	2.376	2.383	2.390	2.397	2.403	2.410	2.417	2.424	2.431
700	2.431	2.437	2.444	2.451	2.458	2.465	2.472	2.479	2.485	2.492	2.499
710	2.499	2.506	2.513	2.520	2.527	2.534	2.541	2.548	2.555	2.562	2.569
720	2.569	2.576	2.583	2.590	2.597	2.604	2.611	2.618	2.625	2.632	2.639
730	2.639	2.646	2.653	2.660	2.667	2.674	2.681	2.688	2.696	2.703	2.710
740	2.710	2.717	2.724	2.731	2.738	2.746	2.753	2.760	2.767	2.775	2.782
750	2.782	2.789	2.796	2.803	2.811	2.818	2.825	2.833	2.840	2.847	2.854
760	2.854	2.862	2.869	2.876	2.884	2.891	2.898	2.906	2.913	2.921	2.928
770	2.928	2.935	2.943	2.950	2.958	2.965	2.973	2.980	2.987	2.995	3.002
780	3.002	3.010	3.017	3.025	3.032	3.040	3.047	3.055	3.062	3.070	3.078
790	3.078	3.085	3.093	3.100	3.108	3.116	3.123	3.131	3.138	3.146	3.154
800	3.154	3.161	3.169	3.177	3.184	3.192	3.200	3.207	3.215	3.223	3.230
810	3.230	3.238	3.246	3.254	3.261	3.269	3.277	3.285	3.292	3.300	3.308
820	3.308	3.316	3.324	3.331	3.339	3.347	3.355	3.363	3.371	3.379	3.386
830	3.386	3.394	3.402	3.410	3.418	3.426	3.434	3.442	3.450	3.458	3.466
840	3.466	3.474	3.482	3.490	3.498	3.506	3.514	3.522	3.530	3.538	3.546
850	3.546	3.554	3.562	3.570	3.578	3.586	3.594	3.602	3.610	3.618	3.626
860	3.626	3.634	3.643	3.651	3.659	3.667	3.675	3.683	3.692	3.700	3.708
870	3.708	3.716	3.724	3.732	3.741	3.749	3.757	3.765	3.774	3.782	3.790
880	3.790	3.798	3.807	3.815	3.823	3.832	3.840	3.848	3.857	3.865	3.873
890	3.873	3.882	3.890	3.898	3.907	3.915	3.923	3.932	3.940	3.949	3.957
900	3.957	3.965	3.974	3.982	3.991	3.999	4.008	4.016	4.024	4.033	4.041
910	4.041	4.050	4.058	4.067	4.075	4.084	4.093	4.101	4.110	4.118	4.127
920	4.127	4.135	4.144	4.152	4.161	4.170	4.178	4.187	4.195	4.204	4.213
930	4.213	4.221	4.230	4.239	4.247	4.256	4.265	4.273	4.282	4.291	4.299
940	4.299	4.308	4.317	4.326	4.334	4.343	4.352	4.360	4.369	4.378	4.387
950	4.387	4.396	4.404	4.413	4.422	4.431	4.440	4.448	4.457	4.466	4.475
960	4.475	4.484	4.493	4.501	4.510	4.519	4.528	4.537	4.546	4.555	4.564
970	4.564	4.573	4.582	4.591	4.599	4.608	4.617	4.626	4.635	4.644	4.653
980	4.653	4.662	4.671	4.680	4.689	4.698	4.707	4.716	4.725	4.734	4.743
990	4.743	4.753	4.762	4.771	4.780	4.789	4.798	4.807	4.816	4.825	4.834
1000	4.834	4.843	4.853	4.862	4.871	4.880	4.889	4.898	4.908	4.917	4.926
1010	4.926	4.935	4.944	4.954	4.963	4.972	4.981	4.990	5.000	5.009	5.018
1020	5.018	5.027	5.037	5.046	5.055	5.065	5.074	5.083	5.092	5.102	5.111
1030	5.111	5.120	5.130	5.139	5.148	5.158	5.167	5.176	5.186	5.195	5.205
1040	5.205	5.214	5.223	5.233	5.242	5.252	5.261	5.270	5.280	5.289	5.299
1050	5.299	5.308	5.318	5.327	5.337	5.346	5.356	5.365	5.375	5.384	5.394
1060	5.394	5.403	5.413	5.422	5.432	5.441	5.451	5.460	5.470	5.480	5.489
1070	5.489	5.499	5.508	5.518	5.528	5.537	5.547	5.555	5.566	5.576	5.585
1080	5.585	5.595	5.605	5.614	5.624	5.634	5.643	5.653	5.663	5.672	5.682
1090	5.682	5.692	5.702	5.711	5.721	5.731	5.740	5.750	5.760	5.770	5.780
1100	5.780	5.789	5.799	5.809	5.819	5.828	5.838	5.848	5.858	5.868	5.878
1110	5.878	5.887	5.897	5.907	5.917	5.927	5.937	5.947	5.956	5.966	5.976
1120	5.976	5.986	5.996	6.006	6.016	6.026	6.036	6.046	6.055	6.065	6.075
1130	6.075	6.085	6.095	6.105	6.115	6.125	6.135	6.145	6.155	6.165	6.175
1140	6.175	6.185	6.195	6.205	5.215	6.225	6.235	6.245	6.256	6.266	6.276
1150	6.276	6.286	6.296	6.306	6.316	6.326	6.336	6.346	6.356	6.367	6.377

TABLE 8 *Continued*

Type B

Temperature in Degrees Celsius (ITS–90)

										Reference Junctions at 0 °C	
°C	0	1	2	3	4	5	6	7	8	9	10
					Thermoelectric Voltage (emf) in Millivolts						
1160	6.377	6.387	6.397	6.407	5.417	6.427	6.438	6.448	6.458	6.468	6.478
1170	6.478	6.488	6.499	6.509	6.519	6.529	6.539	6.550	6.560	6.570	6.580
1180	6.580	6.591	6.601	6.611	6.621	6.632	6.642	6.652	6.663	6.673	6.683
1190	6.683	6.693	6.704	6.714	6.724	6.735	6.745	6.755	6.766	6.776	6.786
1200	6.786	6.797	6.807	6.818	6.828	6.838	6.849	6.859	6.869	5.880	6.890
1210	6.890	6.901	6.911	6.922	6.932	6.942	6.953	6.963	6.974	6.984	6.995
1220	6.995	7.005	7.016	7.026	7.037	7.047	7.058	7.068	7.079	7.089	7.100
1230	7.100	7.110	7.121	7.131	7.142	7.152	7.163	7.173	7.184	7.194	7.205
1240	7.205	7.216	7.226	7.237	7.247	7.258	7.269	7.279	7.290	7.300	7.311
1250	7.311	7.322	7.332	7.343	7.353	7.364	7.375	7.385	7.396	7.407	7.417
1260	7.417	7.428	7.439	7.449	7.460	7.471	7.482	7.492	7.503	7.514	7.524
1270	7.524	7.535	7.546	7.557	7.567	7.578	7.589	7.600	7.610	7.621	7.632
1280	7.632	7.643	7.653	7.664	7.675	7.686	7.697	7.707	7.718	7.729	7.740
1290	7.740	7.751	7.761	7.772	7.783	7.794	7.805	7.816	7.827	7.837	7.848
1300	7.848	7.859	7.870	7.881	7.892	7.903	7.914	7.924	7.935	7.946	7.957
1310	7.957	7.968	7.979	7.990	8.001	8.012	8.023	8.034	8.045	8.056	8.066
1320	8.066	8.077	8.088	8.099	8.110	8.121	8.132	8.143	8.154	8.165	8.176
1330	8.176	8.187	8.198	8.209	8.220	8.231	8.242	8.253	8.264	8.275	8.286
1340	8.286	8.298	8.309	8.320	8.331	8.342	8.353	8.364	8.375	8.386	8.397
1350	8.397	8.408	8.419	8.430	8.441	8.453	8.464	8.475	8.486	8.497	8.508
1360	8.508	8.519	8.530	8.542	8.553	8.564	8.575	8.586	8.597	8.508	8.620
1370	8.620	8.631	8.642	8.653	8.664	8.675	8.687	8.698	8.709	8.720	8.731
1380	8.731	8.743	8.754	8.765	8.776	8.787	8.799	8.810	8.821	8.832	8.844
1390	8.844	8.855	8.866	8.877	8.889	8.900	8.911	8.922	8.934	8.945	8.956
1400	8.956	8.967	8.979	8.990	9.001	9.013	9.024	9.035	9.047	9.058	9.069
1410	9.069	9.080	9.092	9.103	9.114	9.126	9.137	9.148	9.160	9.171	9.182
1420	9.182	9.194	9.205	9.216	9.228	9.239	9.251	9.262	9.273	9.285	9.296
1430	9.296	9.307	9.319	9.330	9.342	9.353	9.364	9.376	9.387	9.398	9.410
1440	9.410	9.421	9.433	9.444	9.456	9.467	9.478	9.490	9.501	9.513	9.524
1450	9.524	9.536	9.547	9.558	9.570	9.581	9.593	9.604	9.616	9.627	9.639
1460	9.639	9.650	9.662	9.673	9.684	9.696	9.707	9.719	9.730	9.742	9.753
1470	9.753	9.765	9.776	9.788	9.799	9.811	9.822	9.834	9.845	9.857	9.868
1480	9.868	9.880	9.891	9.903	9.914	9.926	9.937	9.949	9.961	9.972	9.984
1490	9.984	9.995	10.007	10.018	10.030	10.041	10.053	10.064	10.076	10.088	10.099
1500	10.099	10.111	10.122	10.134	10.145	10.157	10.168	10.180	10.192	10.203	10.215
1510	10.215	10.226	10.238	10.249	10.261	10.273	10.284	10.296	10.307	10.319	10.331
1520	10.331	10.342	10.354	10.365	10.377	10.389	10.400	10.412	10.423	10.435	10.447
1530	10.447	10.458	10.470	10.482	10.493	10.505	10.516	10.528	10.540	10.551	10.563
1540	10.563	10.575	10.586	10.598	10.609	10.621	10.633	10.644	10.656	10.668	10.679
1550	10.679	10.691	10.703	10.714	10.726	10.738	10.749	10.761	10.773	10.784	10.796
1560	10.796	10.808	10.819	10.831	10.843	10.854	10.866	10.877	10.889	10.901	10.913
1570	10.913	10.924	10.936	10.948	10.959	10.971	10.983	10.994	11.006	11.018	11.029
1580	11.029	11.041	11.053	11.064	11.076	11.088	11.099	11.111	11.123	11.134	11.146
1590	11.146	11.158	11.169	11.181	11.193	11.205	11.216	11.228	11.240	11.251	11.263
1600	11.263	11.275	11.286	11.298	11.310	11.321	11.333	11.345	11.357	11.368	11.380
1610	11.380	11.392	11.403	11.415	11.427	11.438	11.450	11.462	11.474	11.485	11.497
1620	11.497	11.509	11.520	11.532	11.544	11.555	11.567	11.579	11.591	11.602	11.614
1630	11.614	11.626	11.637	11.649	11.661	11.673	11.684	11.696	11.708	11.719	11.731
1640	11.731	11.743	11.754	11.766	11.778	11.790	11.801	11.813	11.825	11.836	11.848
1650	11.848	11.860	11.871	11.883	11.895	11.907	11.918	11.930	11.942	11.953	11.965
1660	11.965	11.977	11.988	12.000	12.012	12.024	12.035	12.047	12.059	12.070	12.082
1670	12.082	12.094	12.105	12.117	12.129	12.141	12.152	12.164	12.176	12.187	12.199
1680	12.199	12.211	12.222	12.234	12.246	12.257	12.269	12.281	12.292	12.304	12.316
1690	12.316	12.327	12.339	12.351	12.363	12.374	12.386	12.398	12.409	12.421	12.433
1700	12.433	12.444	12.456	12.468	12.479	12.491	12.503	12.514	12.526	12.538	12.549
1710	12.549	12.561	12.572	12.584	12.596	12.607	12.619	12.631	12.642	12.554	12.666
1720	12.666	12.677	12.689	12.701	12.712	12.724	12.736	12.747	12.759	12.770	12.782
1730	12.782	12.794	12.805	12.817	12.829	12.840	12.852	12.863	12.875	12.887	12.898
1740	12.898	12.910	12.921	12.933	12.945	12.956	12.968	12.980	12.991	13.003	13.014