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Reference Tables for Low-Temperature Thermocouples

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Reference Tables for Low-Temperature Thermocouples

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Table of Contents

List of Figures

List of Tables

List of Tables—Continued

Reference Tables for Low-Temperature Thermocouples*

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The experimental program to establish low-temperature reference tables for the commonly used thermocouples has been completed. Details of the experimental system, instrumentation, data analysis, error analysis, and materials tested are given in order to allow the user to better evaluate and apply the results. The results presented here include:

(1) Reference tables for thermocouple types E, K, and T, both as $E=f(T)$ and $T=f(E)$. The shorter $f(E)$ tables have a 0 °C (273.15 K) reference temperature while all other tables have a 0 K reference temperature.
(2) Reference tables for Pt and Ag-28 at % Au vs the materials used in thermocouple types E, K, and T. These data are presented as $E=f(T)$ only.
(3) Orthogonal polynomials and the associated coefficients necessary to generate the data with reduced order approximations.
(4) Power series coefficients for full precision reproduction of the reference data.

The data presented in the $E=f(T)$ tables cover the temperature range from 0 to 280 K. The $T=f(E)$ tables cover the temperature ranges from 273.15 K down to the lowest temperatures allowed by table resolution.

Key words: Cryogenics; homogeneity tests; liquid helium; liquid hydrogen; liquid nitrogen; thermocouples.

1. Introduction

The rapid expansion of cryogenic technology in the last 20 years has created a need for standardized thermocouple calibrations in the cryogenic temperature range. Therefore, an extensive experimental program was initiated at this laboratory to provide the necessary reference data. The overall thermoelectric thermometry program had several objectives: (1) to establish standard thermoelectric reference tables between 4 and 280 K for thermocouple types E, K, and T[1]; (2) to select and test a material for use as a thermoelectric standard below 50 K; (3) to compare materials of the same nominal composition to determine the degree of thermoelectric interchangeability; and (4) to test new thermocouple combinations for possible advantages in specific situations. Results for the first three goals are discussed in this paper; further research must be done on the newer combinations before they can be considered standard materials.

In order to establish thermoelectric values which are representative of thermocouple materials currently being used, we obtained wire from all major thermocouple wire producers in the United States. Most manufacturers submitted two or three spools of wire which were representative of each material requested. Exhaustive preliminary testing was done to determine which of the wires were to be used in the detailed calibration. The final reference values in this report are based on the characteristics of individual wires; they do not represent averages of all the similar wires from the many different companies. Members of the E–20 committee of the American Society for Testing and Materials (ASTM) and the thermocouple wire producers were extremely cooperative throughout the program; the wide selection of representative wires and the chemical analysis of the melts would have been difficult to obtain without their cooperation.

Traditionally, platinum has been used as the thermoelectric reference standard for production control. For temperatures above approximately 50 K, it retains the thermoelectric properties of a good reference material. Below 50 K, however, the thermopower of platinum becomes very dependent upon trace chemical impurities—notably iron. Since trace impurities of iron are difficult to remove from platinum, a thermoelectric reference material which is not as sensitive to trace impurities is needed to replace platinum below 50 K. An alloy of gold in silver has been tested in this laboratory, and it appears to meet the requirements for a low temperature thermoelectric reference material.

* This work was carried out at the National Bureau of Standards under the sponsorship of the National Aeronautics and Space Administration, Space Nuclear Propulsion Office (SNPO–C), Order Number R–45 and W13,300.

[1] The letter designations for thermocouples are explained in Appendix A. Any material manufactured in compliance with an established standard is equally suitable.

The design of our experimental system and of our data acquisition procedure produced a large amount of information on secondary combinations, such as intercomparisons of similar wires from different producers. Knowledge of the comparative thermoelectric behavior of similar wires is of critical importance when adjusting standard reference data to represent a particular thermocouple.

The purpose of this monograph is to present recently acquired data for low temperature thermocouples. Details of the cryostat, measurement scheme, error analysis, analytical representation of the experimental data, etc., are included to allow the individual user to judge the creditability of the data and to further understand the extent and limitations of the experiments.

2. Material Specifications

Materials to be used in the thermocouple calibration program were requested from all major United States producers. Each company was asked to furnish representative samples of the thermocouple materials that they distribute. Multiple spools of each material were requested whenever different melts were available. A list of the wires received for initial testing is given in table 1. The number of participating manufacturers and the total number of spools of each material are also indicated in this table. The complete inventory of wires was tested to determine the degree of thermoelectric homogeneity and interchangability. Results of these preliminary tests are of considerable practical interest and are discussed in detail in the following section. The wires to be included in the detailed calibration from 4 to 280 K were selected after considering the results of the preliminary tests. Whenever possible, one test wire of each type from each company was included—the one most homogeneous and closest to the accepted high-temperature standard values. Only one wire of each type, however, was considered to be the primary wire. The primary wire was used in all appropriate thermoelectric combinations, while the secondary wires were only compared thermoelectrically to the primary wire of the same nominal composition.

TABLE 1. *Total inventory of tested materials for thermocouple types E, K, and T and the reference materials* Ag-28 *at%* Au *and* Pt

ASTM designation or nominal composition	Number of manufacturers represented	Number of spools
EP or KP	3	9
EN or TN	4	10
KN	3	9
TP	2	4
Ag-28 at% Au	3	4
Pt	1	2

The chemical compositions and physical conditions of the calibrated wires are given in tables 2 and 3, respectively. The compositions shown in table 2 are the extremes found in the various spools tested. These data were furnished by the cooperating manufacturers. No attempt will be made here to predict the specific thermoelectric effect of each of the components or impurities in the wires. A method of making such a prediction, in principle at least, is

TABLE 2. *Range of chemical compositions for the tested thermocouple wires*

Letter designation	Chemical composition of test wires (wt%)											
	C	Mn	Si	Cr	Cu	Fe	Co	Al	Mg	Zr	Ca	Ni
EP or KP	0.03 to 0.06	0.03 to 0.06	0.39 to 0.41	9.09 to 9.50	0.0 to 0.01	0.3 to 0.5	0.0 to 0.10	0.0 to 0.01	0.0 to 0.01	0.01 to 0.03	0.0 to 0.01	89.63 to 89.80
EN or TN	0.0 to 0.01	0.86 to 1.88	0.01 to 0.04	0.0 to 0.01	53.66 to 54.73	0.03 to 0.37	0.17 to 0.28					43.73 to 44.21
KN	0.0 to 0.01	1.60 to 2.45	1.03 to 1.70	0.0 to 0.01		0.05 to 0.26	0.50 to 0.62	1.00 to 2.25	0.01 to 0.02	0.0 to 0.05		93.42 to 95.20
Ag-28 at% Au	58.4 wt% Ag, 41.56% Au; 2×10^{-4} wt% Fe and Si; 5×10^{-5} Al, Ca, and Mg; 3×10^{-5} Cu and Pb; 2×10^{-5} Ni.											
Pt	4×10^{-4} wt% O; 1×10^{-4} Au, Mg, Ni and Pb; 7×10^{-5} Fe; 2×10^{-5} Pd and Rh; 1×10^{-5} Ag, Cu and Zr.											

Table 3. *Physical characteristics of some typical thermocouple test wires*

Thermocouple	Wire size AWG	Wire size Diameter (mm)	Insulation coating*	Heat treatment	Average grain intercept diameter	Maximum grain diameter	Grain orientation
EP or KP	32	0.20	glass fiber	as received	7.1 μm	14 μm	no preferred direction
	32	.20	PVF	as received	6.4	13	slight axial preference
	32	.20	PVF	as received	5.0	12	slight axial preference
EN or TN	32	.20	glass fiber	as received	6.3	10	slight axial preference
	32	.20	PVF	as received	6.9	12	no preferred direction
	30	.25	PE	as received	5.6	14	slight axial preference
	30	.25	PTFE	as received	7.4	13	slight axial preference
KN	32	.20	PVF	as received	8.2	16	slight axial preference
	32	.20	PVF	as received	5.7	9	no preferred direction
	32	.20	glass fiber	as received	6.2	15	slight axial preference
TP	32	.20	PTFE	as received	4.8	14	slight axial preference
	30	.25	PE	as received	6.0	15	slight axial preference
Ag-28 at% Au	32	.20	PI(Lab)	1 h/air/400 °C			
Pt	32	.20	PTFE(Lab)	1 h/air/400 °C			

* Abbreviations: PE—polyethylene; PI—polyimid; PTFE—polytetrafluoroethylene; PVF—polyvinyl formal resin; (Lab)—coating was applied in our laboratory, air dried, and baked under infrared lamps.

given by MacDonald [1].[2] The grain size is significant because it is indicative of the heat treatment history of the wires. As shown in table 3, all of the wires except Pt and Ag-28 at% Au were tested in the "as-received" condition.

The platinum and silver-gold alloys are both available as Standard Reference Materials for thermometry from the Office of Standard Reference Materials, National Bureau of Standards, Washington, D.C. 20234.

3. Preliminary Selection and Inhomogeneity Tests

An exhaustive series of preliminary tests were performed on our complete inventory of wires for thermocouple types E, K, and T. These tests were necessary in order to determine the homogeneity characteristics of each type of wire and to determine the most representative wires from each company. The dip test program performed on these materials was designed to provide information on short range, medium range, and long range inhomogeneities and to compare the present materials to existing or proposed standards.

No thermal voltage is developed when a loop of homogeneous wire is subjected to a temperature gradient. Similarly, no voltage is generated when two identical wires are joined and the pair of wires is placed in a temperature gradient. The problem in practical thermometry is, however, that the ideal characteristics "homogeneous" and "identical" are not sufficiently well approximated for real thermocouple materials. Actually, a loop of wire placed in a large temperature gradient will usually produce a resultant voltage, sometimes as large as 10 microvolts (μV) for poor materials. If wire from one spool is connected to wire from a different spool of the same nominal composition, their junction is placed in a cryogenic fluid, and the free ends are held at room temperature, then a significant voltage may result; we have observed readings as large as hundreds of microvolts for poorly controlled alloys. These variable spurious voltages caused by inhomogeneities, physical imperfections, and chemical impurities are usually the main source of imprecision and inaccuracy in thermocouple systems.

For descriptive convenience, we have divided inhomogeneities into four categories based on their distance of separation:

(1) *Short-range inhomogeneities* occur in a single wire and are separated by less than five meters, often being within a few centimeters of each other.

(2) *Medium-range inhomogeneities* occur in wires that are from a single spool but are more than five meters apart.

(3) *Long-range inhomogeneities* are found in wires that are from the same general stock but are from different spools.

(4) *Inter-lot variations* in chemical composition, thermal treatment, and handling occur in materials produced by different manufacturers, or even in wire produced by the same manufacturer at different times.

The latter categories of inhomogeneities lead to much larger spurious voltages in cryogenic systems.

[2] Figures in brackets indicate the literature references at the end of this paper.

Well-prepared thermocouple wire can have short-range inhomogeneity effects as low as 0.1 μV; poorly controlled alloys often have inter-lot variations as large as 100 μV.

Two kinds of probes, shown in figure 1, were used to investigate the various effects of the four categories of inhomogeneities. The first probe configuration, shown in figure 1(a), consisted of a single wire about 4 or 5 meters (m) long, part of it attached to a plastic tube. It did not need to have a large number of coils, even straight lengths of wire would have been satisfactory. This probe was used to test for short-range inhomogeneities. The second probe configuration, shown in figure 1(b), consisted of two wires, each 2 or 3 m long, that were coiled on a plastic tube and joined at the bottom. This probe was used to test for the last three categories of inhomogeneities. The essential difference between the two kinds of probes (besides the junction) was in their manner of thermal tempering; the second kind had tightly wound coils of wire near the junction in order to prevent a thermal gradient across the junction, which often contained dissimilar materials.

For both kinds of probes, the loose ends of the wires were connected to a potentiometer or high-resistance voltmeter; the probes were then dipped into dewars containing cryogenic fluids, usually liquid helium or nitrogen. The first type of probe was dipped in two different manners, one way for static tests, another way for dynamic tests.

For static short-range inhomogeneity tests, the probes were immersed to a given depth in the cryogenic

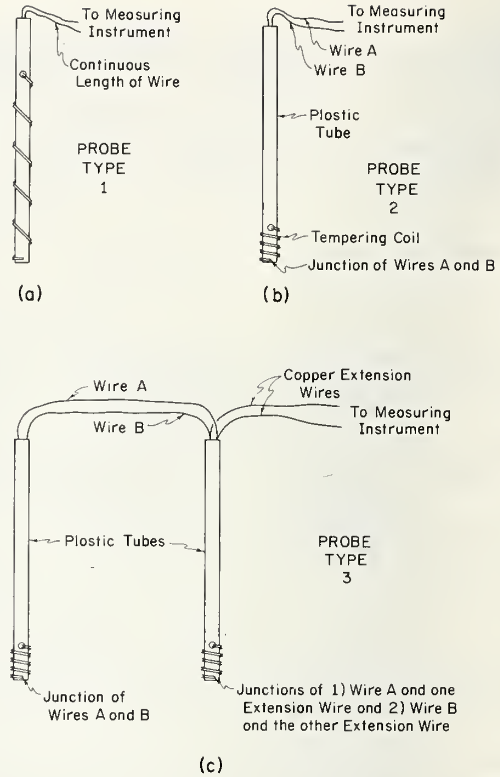

FIGURE 1. *(a) Short-range inhomogeneity probe. (b) Medium-range, long-range, and inter-lot homogeneity probe. (c) Differential thermocouple probe.*

TABLE 4. *Thermocouple wire inhomogeneity data**

Material	Lot code	Short length[1]			Medium length[2]		Different spools[3]	
		Equilibrium		Dynamic	Equilibrium		Equilibrium	
		Liq N_2	Liq He	Liq N_2	Liq N_2	Liq He	Liq N_2	Liq He
EP, KP	A	0.5 μV	0.9 μV	5.5 μV	2.2 μV	2.2 μV	28.0 μV	33.4 μV
	B	1.0	1.2	6.9	1.0	1.0	38.0	39.1
	C	2.6	2.6	8.2	4.5	4.5	4.4	6.1
EN, TN	D	0.9	1.2	1.3	1.6	1.7	6.6	6.6
	E	3.0	3.0	5.1	2.4	2.5	26.0	27.7
	F	2.8	2.8	8.3	10.8	12.5	36.0	44.4
	G	1.6	2.1	6.8	5.8	5.8		
KN	H	0.7	0.7	13.7	3.8	4.9	42.0	45.4
	I	1.9	2.4	14.1	2.2	2.2	1.7	2.8
	J	2.0	2.0	21.4	2.6	2.6	4.6	4.6
TP	K	0.4	0.4	1.0	0.4	0.7	0.5	0.5
	L	0.2	1.4	1.1	1.9	7.6	4.1	37.9
Pt	M	0.3	2.4	3.4				
Ag-28 at% Au	N	0.3	0.3	1.8		0.3		0.3

* Reported data are maximums.
[1] Continuous length of wire—approximately 5 meters.
[2] Compares front and back ends of a single roll—30 to 150 meters.
[3] Widely separated lengths of wires from different spools.

TABLE 5. *Comparison of differential thermocouple dip test data with previously published data and with data from NBS internal reports*

Thermocouple type	Percentage deviations[1]		
	Ice temperature to liquid N_2		Liquid N_2 to liquid He
	NBS Circ. 561[2]	Interim tables[3]	Interim tables[3]
E	+0.38 to +1.29	−0.19 to +0.72	−1.68 to +1.07
K	−0.45 to +0.23	+2.14 to +2.27	−0.54 to +2.3
T	−0.11 to +0.31	+0.89 to +1.31	−2.07 to −1.70

[1] In comparing the present experimental data to past data, a positive percentage indicates that the experimental data were higher in absolute value than the past data. The values used here are the maximums found in testing several thermocouples of each type.
[2] National Bureau of Standards Circular 561, Reference Tables for Thermocouples. Reference 2. The voltages corresponding to the liquid nitrogen temperature had to be extrapolated. No values were available for the He to N_2 range.
[3] Interim values are from low temperature thermocouple tables by R. L. Powell, et al., of the Cryogenics Division, National Bureau of Standards, Boulder, Colorado, distributed Summer, 1965, as an informal report.

fluid and the temperature gradient was allowed to come to equilibrium before readings were taken. In order to obtain more representative values, readings were usually taken at three different levels for each test.

For dynamic short-range inhomogeneity tests, the probes were lowered into the fluid at a constant speed. Erratic output voltages were usually observed in these tests because large temperature gradients were developed over different, relatively short lengths of wire as the depth of immersion was changed. The magnitude of the output depended on the type of thermocouple wire, the specific specimen, and, to some extent, the rate of immersion. Since comparable results were desired, a constant immersion rate, 0.5 meter per minute, was used for our tests.

The dynamic, short-range tests were sensitive because large temperature gradients were established over short sections of wire which could contain significant chemical and physical defects. However, when the thermal gradients were allowed to diffuse, as in the static short-range tests, the random thermoelectric voltages tended to cancel one another and the extreme readings became smaller. The static tests were therefore less sensitive indicators of inhomogeneities.

Short-range inhomogeneity tests were useful for selecting homogeneous wire that had a minimum amount of spurious voltages. Results from the tests also gave a good preliminary estimate for the imprecision that could be expected for temperature measurements in the actual cryogenic system. Results from dynamic tests were most appropriate for systems with rapidly fluctuating temperatures or liquid levels; results from static tests were most appropriate for stable cryogenic systems like our laboratory cryostat. Wire that exhibited unusually high spurious thermal voltages (typical values are given later in this section) could be detected and rejected before costly installation in the specialized cryostat.

For tests on medium- or long-range inhomogeneities, or inter-lot variations, the probe configuration shown in figure 1(b) was used. The only differences were in the methods for selection of wires that were assembled in the test rig. The selection criteria were simply those implied in the basic definitions of the three categories of inhomogeneities. The manner of joining the wires was not critical as long as good electrical contact was obtained and the materials were not strained or thermally treated more than a few centimeters away from the junction. The assembled probes were dipped into a cryogenic fluid in the same manner as in static short-range inhomogeneity tests.

Medium- and long-range inhomogeneity tests were useful for determining the variations that occurred in selected lots of thermocouple wire. The deviations in voltage usually became progressively larger as the original positions of the wires became more widely separated. If the material varied beyond acceptable limits, then it was not used in the final calibrations.

The third kind of probe, shown in figure 1(c), was a simple differential thermocouple that was used to determine the thermoelectric voltages at fixed points for the standardized wire types in our inventory. One of the criteria used in selecting wires for the detailed calibrations was that the wire's voltage should be reasonably close to the values given in the former standard tables contained in NBS Circular 561[2].

Table 4 lists typical results for the four kinds of standardized thermocouple wires tested in this program. The values were obtained using Probe Types 1 and 2 at liquid nitrogen and helium temperatures. Table 5 gives the range of deviations that were obtained for Types E, K, and T thermocouples tested at liquid nitrogen and helium temperatures using Type 3 Probes.

A number of samples of each material were given special tests to determine the effect of accidental kinking or straining. The test samples for this case were obtained by deliberately inducing short radius bends (kinks) in the test wire for the "kink" tests and by elongating one leg of the test sample by 2

Table 6. *Kink and strain effects on thermocouple wire*

Material	Lot code	Kink[1]			Strain[2]			Undamaged[3]		
		Equilibrium		Dynamic	Equilibrium		Dynamic	Equilibrium		Dynamic
		Liq He	Liq N_2	Liq N_2	Liq He	Liq N_2	Liq N_2	Liq He	Liq N_2	Liq N_2
EP, KP	A	6.0 μV	6.0 μV	10.5 μV	8.5 μV	7.2 μV	9.0 μV	0.4 μV	0.4 μV	4.2 μV
	B	1.6	1.6	5.8	5.7	4.4	4.3	1.2	1.0	6.9
	C	2.2	2.2	17.1				0.1	0.1	5.5
EN, TN	D	1.3	1.3	5.4	4.7	4.7	6.9	3.0	3.0	4.0
	E	1.4	1.4	5.9				0.4	0.3	0.8
	F	4.8	3.8	8.0				2.1	2.1	6.8
KN	G	1.2	0.8	7.4	4.0	2.8	7.3	1.0	1.0	7.6
	H	1.0	1.0	6.6	1.3	1.3	9.8	0.7	0.7	10.0
	I	3.3	3.3	9.7				1.4	1.4	12.3

[1] Kinks were formed by forming a loop in the wire and applying tension; 6 kinks were made on each wire.
[2] The wires were strained by a 2% elongation.
[3] The "undamaged" results given here are for one particular sample from each company, while the corresponding "short length" tests in table 4 represent the maximum values from several spools from each company.

percent in the "strain" test. Results of these "kink" and "strain" tests are given in table 6, along with similar tests performed before the wire was damaged. These tests were not performed on each wire sample from each manufacturer; however, the general effect of abusing thermocouple wire is evident. The samples used in these tests should represent the outer limit of damage to wires in ordinary assemblies from accidental cold working.

Experimental methods described above allowed us to select materials that were most homogeneous and therefore had the smallest amount of spurious voltages. The tests also provided data necessary for making realistic error analyses.

4. Apparatus

A schematic of the cryostat used to determine the thermal voltage for temperatures between 4 and 280 K is shown in figure 2. The principal parts are labelled UPPER CHAMBER and LOWER CHAMBER. The two chambers are connected by a thermal stand-off tube which serves as a wire duct and allows gas conduction from the lower to the upper chambers. During operation, the lower chamber contains the cryogen. The cryogenic liquid serves as the reference junction for the thermocouples, provides a source of refrigeration for the upper chamber, and serves as a heat sink for all wires that are in the upper chamber. The upper chamber contains a heavy (~10 kg) copper block. The variable junctions of the thermocouples are thermally anchored to this block. A stable temperature gradient is established between the reference junctions and variable junctions by balancing the refrigerator power from the boiling reference cryogen with the power supplied to a heater coil wound on the copper block. A manually controlled heater coil is wrapped on the lower cryostat so that the rate of boiling in the lower chamber may be increased; refrigeration from the liquid to the upper copper block is sufficient without applying external power except for the lowest temperature intervals.

The upper and lower cryostats are completely contained in a vacuum chamber. The vacuum chamber is, in turn, totally immersed in liquid nitrogen.

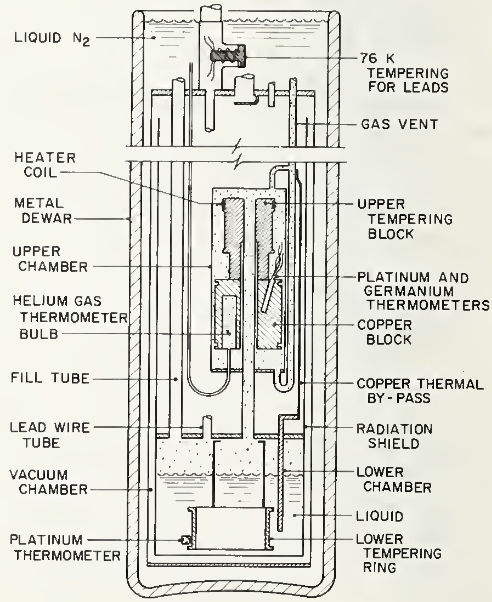

Figure 2. *Schematic of thermocouple calibration cryostat.*

In addition to the vacuum insulation and liquid nitrogen shield, radiation shields have been wrapped on the upper and lower chambers and on the inner surface of the vacuum chamber. The radiation shields consist of layers of aluminum foil separated by balsa wood strips. The insulating vacuum is maintained at approximately 5×10^{-6} torr by a 20 ℓ/s. diffusion pump. All vacuum seals are made using a low melting point solder in the flange and trough arrangement shown in figure 3. The outer vacuum chamber seal is effective at ~76 K, while the seals on the two inner cryostats are used down to 4 K. Seals of this sort require no heavy flange and are made at low enough temperatures that there is little danger of overheating nearby primary thermometers. Care must be taken, however, to center the cup and lip. If either the cup or lip is out of round, differential contraction can cause cracks in the seals at low temperatures.

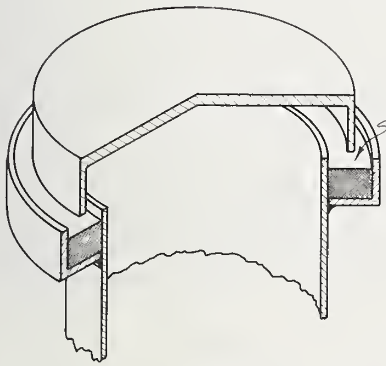

FIGURE 3. *Flange and trough arrangement for using low melting point solder to make cryogenic vacuum seals.*

It is imperative that the upper chamber is isothermal; temperature fluctuations of the variable junction of the thermocouples have to be minimized, since approximately one hour is required to make the necessary measurements at each temperature gradient. Energy flow into the upper chamber is controlled as follows: (1) All wires coming into the system are first brought to 76 K by thermal attachment to the liquid nitrogen shield. They are then thermally anchored in the reference liquid before going into the upper chamber. (2) The gas vent line for the inner chambers is in the proximity of the upper chamber. Since the vent line is in contact with the liquid nitrogen shield, it could be warm relative to the temperature of the upper chamber. A heavy copper thermal bypass was installed to transfer any excess energy to the reference liquid in the lower chamber without coming near the upper chamber. (3) Radiative heat transfer to the copper block is essentially eliminated by placing a concentric thermal shield between the block and the walls of the upper cryostat. The temperature of the shield is regulated by supplying current to a heater coil on the upper chamber walls. The temperature difference between the block and shield was never greater than 0.01 K while taking the data reported in this monograph.

The temperatures of the variable junction block and of the thermal shield surrounding the block are controlled automatically. The controllers used are solid state devices designed specifically for low power (10 watts maximum), high stability applications. For the block heater, either a platinum or germanium resistance thermometer is used as a sensor. A bucking voltage corresponding to the desired thermometer resistance is set on a potentiometer; the controller senses the misbalance between the potentiometer setting and the thermometer voltage and supplies power to the block heater until a null situation is achieved. The temperature drift of the block during a one hour run is nominally between 3 and 5 millikelvin (mK). A separate power supply is used for the shield heater; its control sensor is a four-junction differential thermopile between the block and the shield.

The pressure above the reference cryogen is manostatically controlled [3] when using liquid hydrogen or liquid nitrogen. Pressure control is such that the temperature drift of the reference liquid is less than 3 mK/h, as determined from readings of a calibrated platinum resistance thermometer in the reference liquid. This temperature stability corresponds to less than 0.5 mm pressure drift during the one hour runs. When liquid helium is used as the reference liquid, the system is opened to atmospheric pressure and the temperature is determined by reading the barometric pressure. The maximum pressure variations observed during a single testing period of one hour are usually less than 0.9 mm, which corresponds to a temperature change of 1.4 mK in the liquid helium reference bath [4].

Two types of resistance thermometers are used to determine the temperature of the variable junctions of the thermocouples. Capsule type platinum resistance thermometers are used between 20 and 280 K; germanium resistance thermometers are used below 20 K. Three thermometers of each type are usually inserted in the copper block. The thermal resistance between the thermometers and the block is reduced by wrapping

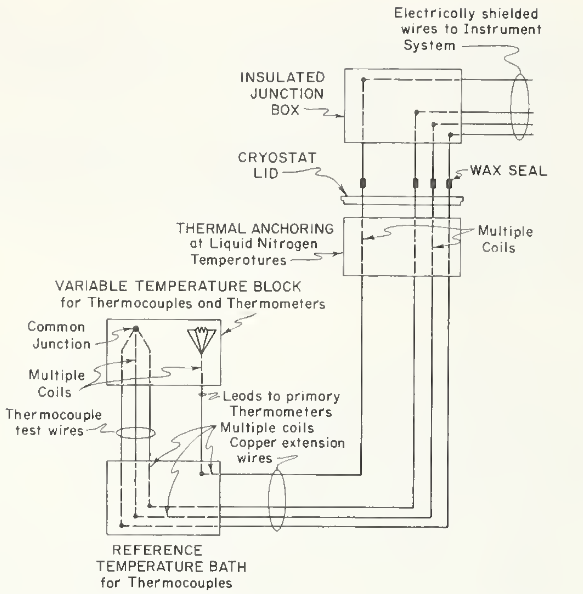

Figure 4. *Schematic of thermal and electrical placement of thermometers in the calibration system.*

each thermometer with 0.025 mm aluminum foil and then removing layers of foil one at a time until a snug fit is obtained between the thermometers and the thermometer wells. For this research, one thermometer of each type was calibrated at NBS-Washington. The ice-point resistance, R_0, for the platinum thermometer was carefully determined by measurement at the triple point of water [5, 6, 7]. The NBS-Washington calibration was then adjusted to account for the precise value of R_0, as measured with our bridge [8]. The two remaining thermometers of each type are used as sensors for the heater control system and as checks on the primary thermometers

The schematic given in figure 4 illustrates the electrical and thermal placement of the thermocouple test wires. The room temperature segments of the copper wires enter the system through a wax seal. The temperature of the wires is subsequently reduced to liquid nitrogen temperature by wrapping on an 11 mm diameter copper rod which is in intimate contact with the liquid nitrogen shield. The wires are then drawn into the reference liquid in the lower chamber. Approximately one meter of each wire is wrapped on the copper cylinder below the reference cryogen level in the lower chamber. This is done to ensure that the wires are at the temperature of the reference liquid before being taken into the upper chamber. The wires are then taken into the upper chamber via the thermal stand-off tube connecting the chambers. Approximately one meter of each wire is wrapped on the upper tempering block. The thermocouple test wires are similarly anchored to the variable temperature block and to a short cylinder in the reference liquid. The thermocouple reference junctions are made by spot welding the copper extension wires to the thermocouple test wires. It is important to note that thermal gradients across the junctions (both variable and reference) are minimized by carefully bringing all wires to the same temperature before the junctions are made.

As mentioned above, a fixed length of one meter of wire was used to thermally anchor the wires at various temperatures. A thermal analysis based on Hust's [9] method indicates that this length is more than should be necessary even under more unfavorable conditions. However, since our thermocouple test wires had various diameters, thermal conductivities, and insulations, we used a conservatively calculated length.

As shown in figure 4, all of the thermocouple test wires come together to form a single junction in the variable temperature chamber. This junction is thermally tied to the copper block, but is electrically insulated from it. The reference junctions in the lower chamber are electrically insulated from one another and are in thermal contact with the reference liquid. There are actually 19 thermocouple test wires in the system during the calibration.

A block diagram of our measurement system is given in figure 5. The output of the various thermometers in the cryostat is fed into a bank of switches labeled THERMOMETER SELECTOR SWITCH in this diagram. The signal from the thermometer or thermometers we wish to monitor is transferred from the thermometer selector switch to another bank of switches labeled INSTRUMENT SELECTOR SWITCH. These switches allow the thermometer signal to be measured on the appropriate instrument. Both the THERMOMETER SELECTOR SWITCHES and the INSTRUMENT SELECTOR SWITCHES are multichanneled, i.e., more than one incoming thermometer signal can be directed to the proper instrument at any

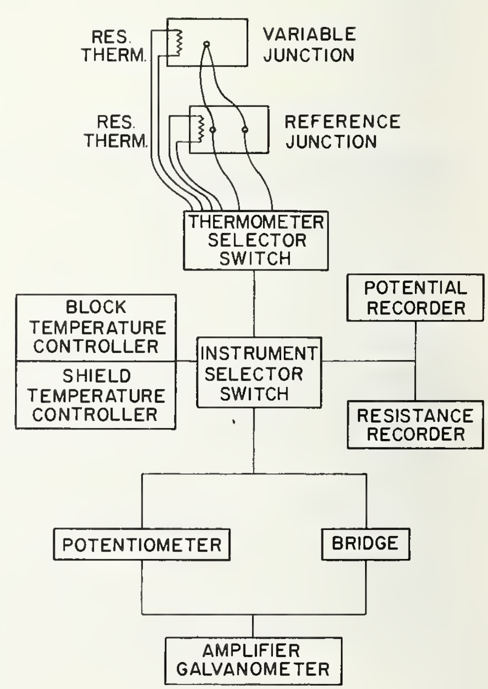

Figure 5. *Block diagram of thermocouple calibration instrumentation.*

one time. The switches used in the sensitive circuits are of the low-thermal, rotary type. All switch banks utilize solder which matches copper thermoelectrically and are shielded by ~0.6 cm thick iron boxes packed with glass fibers. These procedures substantially reduce the spurious thermal voltage effects at the switches.

The instruments indicated in figure 5 are as follows:

(1) The potentiometer is a six dial device with a resolution of 0.01 μV. The limit of error for this instrument is 0.01 percent of reading, plus 0.02 μV. The potentiometer was calibrated at NBS-Boulder prior to the tests. The unsaturated cadmium sulfate standard cell used with this potentiometer was also calibrated in Boulder prior to the tests. The potentiometer is used to measure the thermocouple output, germanium resistance thermometer voltage, and standard resistor voltages.

(2) The bridge is a type G–2 Mueller bridge. The bridge reads directly to 0.0001 Ω, and interpolation on the galvanometer allows two additional figures in precision. The bridge was calibrated in our laboratory [10] prior to the tests. We found it necessary to provide thermal isolation for the bridge in order to achieve the precision mentioned above. The thermal isolation consists of encasing the entire bridge in a metal box with about 2.5 cm plastic foam completely surrounding the bridge; remote dial manipulations are accomplished by plastic extensions from the bridge dials.

(3) An electronic amplifier galvanometer is used with both the Mueller bridge and with the potentiometer.

(4) The potential and resistance recorders shown are used to monitor the system during cooldown and to roughly indicate when a stable temperature gradient has been established between the upper and lower thermocouple junctions.

5. Experimental Design and Technique

Our method of data acquisition is designed to take advantage of the large amount of partially redundant information available. The common junction allows many different combinations to be measured. Concepts derived by analogy from the connectivity of paths in graph theory are used to determine optimum experimental procedures [11, 12, 13]. As a simple illustration of how graph theory is applied, consider the situation where one is to intercompare some property of two different objects where two other intermediate objects are also available. Graphically this situation can be represented as in figure 6. In this figure, the objects

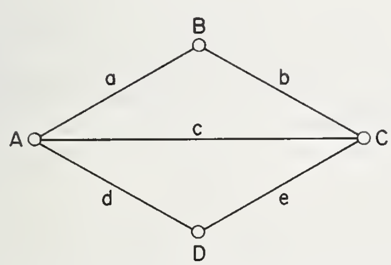

Figure 6. *Four object measurement graph.*

are represented by the vertices and the comparison of some property between objects is represented by the connecting lines. For example, the comparison *a* might represent the difference in weight between objects *A* and *B*. In applying graph theory to thermoelectric measurements, the vertices represent the thermocouple test wires and the connecting lines represent the thermal voltages generated by a given temperature gradient. The thermoelectric voltage between *A* and *C* in figure 6 would be determined by (1) measuring *c*, that is, a direct measurement of the desired voltage, (2) measuring the thermal voltages *a* and *b* and combining these data algebraically, and (3) measuring the thermal voltages *d* and *e* and similarly combining these data. The algebraic combination of $a+b$ and $d+e$ yield two independent determinations of the desired voltage, equivalent to *c*. The final determination of the voltage $(A–C)$ is given by

$$e_{\text{calc}} = (A-C) = [2c + (a+b) + (d+e)]/4. \qquad (1)$$

The measurement *c* is given a weight of 2, since it involves only one experimental determination, whereas the other two measurement paths both require two readings. The estimate of the standard deviation for $(A–C)$ is given by

$$S^2 = \{2(e_{\text{calc}} - c)^2 + [e_{\text{calc}} - (a+b)]^2 + [e_{\text{calc}} - (e+d)]^2\}/3. \qquad (2)$$

The advantages of taking data in this way are that it randomizes potentiometer dial errors, eliminates any subconscious operator prejudice, and randomizes spurious voltages in the lead wires. The magnitudes of *a*, *b*, *c*, *d*, and *e* usually vary considerably; this means that the potentiometer dial settings are also considerably different. Any dial errors which exist are randomized by this method. These random errors would then appear as scatter in the data and would be accounted for in the variance calculated from eq. (2).

Since the potentiometer dial readings vary a great deal and the order of readings may be random, the chance for subconscious operator prejudice is minimized. In order to influence the readings in a systematic way, the operator would have to algebraically combine very different numbers which are not necessarily taken in adjacent readings. This is not done subconsciously, even on the simple four object system being considered here. On the other hand, if multiple readings are taken of the same quantity, there is a strong tendency to produce data which are biased in a systematic way.

Spurious voltages in the extension wires are also randomized by using the graph theory method. Consider a three wire system such as that which would result if the D wire were eliminated from figure 6. Assume the number we actually want is $(B-C)$. This is the thermoelectric voltage generated by the thermocouple made from materials B and C when a thermal gradient, $\Delta T = T_1 - T_2$, exists. The number which is actually measured is b which includes the spurious voltages generated in the extension wires to both B and C. If the spurious voltages δ_{Bi} and δ_{Ci} are zero or are at least known, then the true value of $(B-C)$ may be determined. The voltages δ_{Bi} and δ_{Ci} can be determined by an isothermal test where $T_1 = T_2$. When $T_1 = T_2$, $(B-C) = 0$ and $b = (B-C) + \delta_{Bi} + \delta_{Ci} = \delta_{Bi} + \delta_{Ci}$. However, this determination of the spurious voltages is valid only when the thermal gradients in the system are the same as when the isothermal test was made. In many experimental situations this approach to the spurious voltage problem is not practical. The only other solution is to randomize these voltages so that they appear as scatter in the experimental data and are therefore included in the estimate of the variance, S^2. The graph theory approach does allow these voltages to be randomized. Suppose, for instance, that we wish to determine $(B-C)$ in figure 6. The voltages a, b, and c would then be measured.

$$a = (B-A) + \delta_{A1} + \delta_{B1}$$

$$b = (B-C) + \delta_{B2} + \delta_{C1}$$

$$c = (A-C) + \delta_{A2} + \delta_{C2}$$

$$b_{\mathrm{calc}} = [b + \tfrac{1}{2}(a+c)]/3/2 = \frac{2b+a+c}{3}$$

$$b_{\mathrm{calc}} = \frac{[2(B-C)+(B-A)+(A-C)]}{3} + \frac{\delta_{A1}+\delta_{A2}+\delta_{B1}+2\delta_{B2}+2\delta_{C1}+\delta_{C2}}{3}.$$

If the spurious conditions are stable, i.e., the measurements are made rapidly enough that the system gradients haven't changed,

then $\delta_A = \delta_{A1} = \delta_{A2}$, $\delta_B = \delta_{B1} = \delta_{B2}$, and $\delta_C = \delta_{C1} = \delta_{C2}$

$$\text{and } b_{\mathrm{calc}} = \frac{[2(B-C)+(B-A)+(A-C)]}{3} + \tfrac{2}{3}\delta_A + \delta_B + \delta_C.$$

If the more common procedure of multiple readings of b were used, b would be measured, say, 3 times:

$$b_1 = (B-C)_1 + \delta_B + \delta_C,$$

$$b_2 = (B-C)_2 + \delta_{B1} + \delta_{C1},$$

$$b_3 = (B-C)_3 + \delta_{B2} + \delta_{C2}, \text{ and}$$

$$b_{\mathrm{calc}} = \frac{[(B-C)_1+(B-C)_2+(B-C)_3]}{3} + \frac{\delta_B+\delta_C+\delta_{B1}+\delta_{C1}+\delta_{B2}+\delta_{C2}}{3}.$$

Again, assume stable spurious conditions for the time required to determine b three times. Then $\delta_B = \delta_{B1} = \delta_{B2}$, $\delta_C = \delta_{C1} = \delta_{C2}$, and $b_{\mathrm{calc}} = \overline{(B-C)}_{1,2,3} + \delta_B + \delta_C$. The tendency to randomize dial errors and to eliminate operator prejudice is illustrated by comparing b_{calc} from the graph theory method and from the multiple readings method. More dials are probably changed in determining $(B-C)$, $(B-A)$, and $(A-C)$ than are changed in determining $(B-C)$ three times. The subconscious operator prejudice is reduced by having to combine the two readings $(B-A)$ and $(A-C)$ to get the independent determination of $(B-C)$.

The third and perhaps the most important advantage of the graph theory approach to the measurement of thermocouple outputs is the randomization of spurious voltages in the extension wires. These errors would not be accounted for, i.e., they would be systematic, if the multiple reading approach is utilized. This is shown in the calculation of the estimate of variance for the two methods:

Graph theory:

$$b_{\mathrm{calc}} = \frac{[2(B-C)+(B-A)+(A-C)]}{3} + \frac{\delta_{A1}+\delta_{A2}+\delta_{B1}+2\delta_{B2}+2\delta_{C1}+\delta_{C2}}{3}$$

$$S^2_{b_{\mathrm{calc}}} = \{2(b_{\mathrm{calc}}-b)^2 + [b_{\mathrm{calc}}-(a+c)]^2\}/2;$$

now assume that the only cause of variation is the spurious voltages

$$S^2_{b_{\mathrm{calc}}} = 1/3(\delta_{A'} + \delta_{B'} - \delta_{C'})^2$$

where $\delta_{A'} \equiv \delta_{A1} + \delta_{A2}$,

$\delta_{B'} \equiv \delta_{B1} - \delta_{B2}$, and

$\delta_{C'} \equiv \delta_{C1} - \delta_{C2}$.

If spurious conditions are constant, $\delta_{B'} = 0$, $\delta_{C'} = 0$ and $S^2_{b_{\mathrm{calc}}} = 1/3\,\delta_{A'}^2$.

Multiple measurements:

$$b_{\mathrm{calc}} = \frac{[(B-C)_1+(B-C)_2+(B-C)_3]}{3} + \frac{\delta_B+\delta_C+\delta_{B1}+\delta_{C1}+\delta_{B2}+\delta_{C2}}{3};$$

$$S^2_{b_{\mathrm{calc}}} = \{(b_{\mathrm{calc}}-b_1)^2 + (b_{\mathrm{calc}}-b_2)^2 + (b_{\mathrm{calc}}-b_3)^2\}/2$$

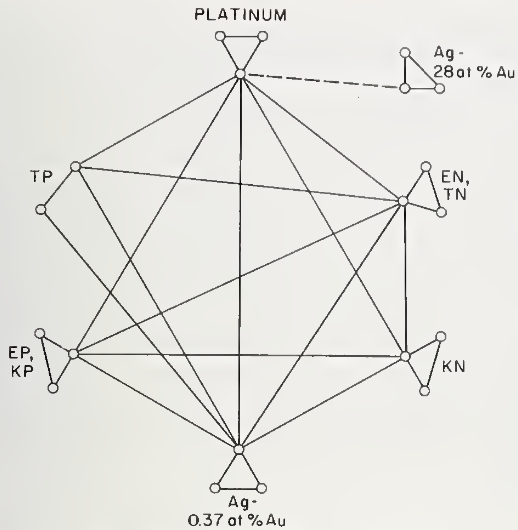

FIGURE 7. *Measurement graph used for calibration of thermocouple materials TP, KP (or EP), KN, TN (or EN), Pt, Ag-0.37 at% Au, and Ag-28 at% Au.*

again assuming all scatter is due to spurious voltages, i.e.,

$$(B-C)_1=(B-C)_2=(B-C)_3, \text{ then}$$

$$18\, S^2_{b_{calc}}=[-2(\delta_B+\delta_C)+\delta_{B1}+\delta_{C1}+\delta_{B2}+\delta_{C2}]^2$$
$$+[-2(\delta_{B1}+\delta_{C1})+\delta_B+\delta_C+\delta_{B2}+\delta_{C2}]^2$$
$$+[-2(\delta_{B2}+\delta_{C2}+\delta_B+\delta_C+\delta_{B1}+\delta_{C1}]^2.$$

Now if the spurious conditions are constant $\delta_B=\delta_{B1}=\delta_{B2}$, $\delta_C=\delta_{C1}=\delta_{C2}$, and $S^2_{b_{calc}}=0$.

The spurious voltages do not appear in the estimate of the standard deviation when the multiple measurement method is used. They are present but unaccounted for until some estimate of systematic error is introduced.

The graph used to represent the measurements made on thermocouple materials TP, TN(EN), KP(EP), KN, Pt, Ag-0.37 at% Au, and Ag-28 at% Au is given in figure 7. The terminology discussed earlier in this section applies to this figure, i.e., materials are represented by the vertices and thermovoltage measurements are represented by lines. The dashed line connecting platinum and Ag-28 at% Au indicates that comparison was made in a separate calibration. This was necessary because the optimum Ag-Au alloy had not been received at the time the original calibration was done. A detailed discussion of how these data were treated is contained in the DATA ANALYSIS section of this report.

Each of the measurements indicated in figure 7 was made at sixty-eight different temperature intervals, 19 in the liquid helium range (4 K to 25 K), 17 in the liquid hydrogen range (19 K to 90 K), and 32 in the liquid nitrogen range (75 K to 290 K). The number of temperature intervals in each range was as above for the Pt versus Ag-28 at% Au combination also, even though the individual intervals were not exactly the same.

During the course of making the measurements, the current of the potentiometer was checked before each set of thermocouple readings, e.g., prior to reading thermocouples 1, 8, 15, etc. This was done to minimize the effect of changing potentiometer standard current due to battery drift. The bridge zero of the Mueller bridge was determined before and after each temperature gradient sequence.

When operating with liquid nitrogen and liquid hydrogen, the temperature of the variable junction was measured three times during each run. These determinations were made at the beginning, near the middle, and at the conclusion of each run. The 3 to 5 mK drift during each run was sufficiently small and linear to allow the true variable temperature of each thermocouple to be approximated. The reference temperature was determined six times during the course of each run. The bath temperature was adjusted to be very near 20 K and 75 K for liquid hydrogen and liquid nitrogen, respectively, by controlling the pressure over the bath liquid. The actual reference temperature for the individual thermocouples was determined by linear interpolation.

The exact time of each of the primary temperature determinations was recorded during each run. Periodically, the time for each step of a run was recorded. After several of these runs, it was clear that the variation of time between a given thermocouple voltage determination and the primary temperature determination was very nearly constant. This information and the chronological data for the primary temperature measurements from all tests allowed the variable and reference temperatures to be determined for each particular thermocouple. The temperatures determined in this way minimized the effect of junction temperature drift.

6. Data Analysis

Two major steps were needed to transform the experimental data from its original form into its final form. The first operation involved making minor adjustments to the data and forming the desired thermocouple combinations using graph theory considerations. The second step consisted of finding the best analytical representation of the adjusted data and calculating statistical quantities such as precision, skewness and elongation.

The first operation on the data was to apply potentiometer dial corrections to all voltage data and to apply Mueller bridge dial corrections to all resistance data. The corrected resistances were used to determine the temperature of the primary platinum thermometer by linear interpolation in the resistance versus temperature tables. The tables used have temperature increments of 1 K from 90 K to 300 K and 0.1 K from 14 K to 90 K. The error introduced by linear interpolation in these tables is less than 0.1 mK above 28 K and less than 0.4 mK below 28 K. The platinum thermometers had been calibrated by members of the Temperature Section, NBS-Washington, using the IPTS-48 and NBS-55 scales; we later updated the calibrations to the IPTS-68 scale [14].

A calibrated germanium resistance thermometer was used to determine variable junction temperatures in the range from 4 K to 20 K. The thermometer current was determined by measuring the voltage across a standard resistor which was in series with the thermometer. Corrected voltages from the thermometer and from the standard resistor were used to determine the resistance of the thermometer. A power series representation of $T=f(R)$ for our thermometer was used to determine the temperature. The germanium thermometer had been calibrated by members of the Cryogenic Physics Section in NBS-Washington, using the NBS P 2–20 (1965) scale [14].

As discussed in the previous section the time sequence of primary temperature determinations and thermocouple readings was known. Using this information, it was possible to determine the variable and reference temperatures which actually existed at the time the thermocouple voltages were measured. However, in order to take advantage of the graph theory approach to data acquisition, it was necessary that all combinations have the same reference temperature and the same variable junction temperature. Linear interpolation in the E_i versus T_i data for each thermocouple combination was used to adjust the variable junction temperature of each thermocouple to the average of the values which are taken for each gradient. An analytic fit of the data near the reference temperature is used to determine the dE_i/dT, necessary to make the small correction which adjusts all reference voltages to the voltage equivalent of 4 K, 20 K, or 75 K reference temperatures.

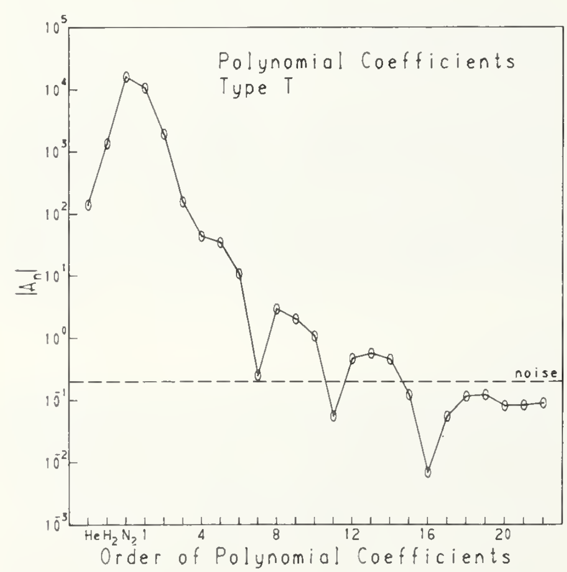

FIGURE 8. *Graph of | A_n | versus number of coefficients for thermocouple Type T.*

After these corrections and adjustments have been made, the data represent the thermoelectric voltages of the desired thermocouple combinations with identical reference temperatures and identical variable temperatures. Graph theory manipulations were then performed with these data to obtain multiple indirect determinations of a given thermal voltage. The general procedure for calculation of thermal voltages is similar to that given in the previous discussion of graph theory.

The next major step in the data analysis is to fit the experimental data in order to provide a continuous $E=f(T)$ relationship for each thermocouple combination. The method used to represent the data is a modified Gram-Schmidt approximation [15, 16]. The calculated values for the voltages of each thermocouple combination were approximated by a series of orthonormal polynomials in the L_2 norm (least squares), that is,

$$E(T)=\sum_{n=1}^{L} A_n F_n(T)$$

where

$E(T)$ = thermocouple potential in microvolts;

T = temperature in degrees Kelvin;

L = the highest order fit—an order high enough to represent the data with no loss of precision, but not so high as to introduce mathematical oscillations;

A_n = constants to be determined by the fitting approximations; and

$F_n(T)$ = orthonormal polynomials, orthonormal on the data points over the range of variation of the independent variable, T.

The orthonormal polynomials are taken to be the truncated power series

$$F_n(T)=\sum_{j=1}^{n} C_{n\,j} T^j$$

where the $C_{n\,j}$ are determined from the orthonormality conditions at the measured temperatures. It should be stressed that the F_n are determined by the values of the independent variable T only. The $F_n(T)$ are therefore the same for all thermocouple combinations which are based on the same set of temperatures. All of the data for the solid line measurements in figure 7 are based on the same set of temperatures. The dashed line measurement, being from a second set of calibrations, is based on another set of temperatures. Rather than provide two sets of orthonormal polynomials, interpolations in the second set of data were done to provide the E_i, T_i data for Pt versus Ag-28 at% Au at the temperatures used in the first calibration. Third and fourth order interpolations were sufficient to convert the second calibration data to the temperatures of the first calibration within the precision of the data.

There is, therefore, a single set of orthonormal polynomials for all of the data being reported here. The coefficients A_n are determined by minimizing the sum of the squared deviations in E and are different for each thermocouple combination. The highest order, L, also differs from combination to combination.

A common problem in the numerical analysis of data fitting by polynomials is selection of the proper order—an order high enough to represent the data with no loss of precision, but not so high as to introduce mathematical oscillations. This problem is well solved by the method of fitting with orthonormal polynomials. The absolute values of the coefficients A_n decrease with increasing n as long as they are larger than the noise level. However, when the noise level is reached the coefficients are random valued. An inspection of a graph of $|A_n|$ versus number of terms (n) shows the noise level and the probable maximum value of n that is significant. In figure 8, $|A_n|$ versus n is shown for thermocouple Type T. The coefficient for order 11 is accidentally below the noise level of 2×10^{-1}. The first three points in the figure are called the range shift constants. As mentioned previously, our data are taken using three different reference temperatures; the range shift constants plotted in figure 8 are used to adjust these reference temperatures to a common value. Figure 9 shows a least squares approximation to the experimental data for thermocouple Type T before the range shift constants are applied. The necessary shifts are determined by using the principle of successive temperatures [17]. This principle may be illustrated by considering two dissimilar homogeneous metals which produce a thermal voltage of E_1 when the junctions are at temperatures T_1 and T_2 and a thermal voltage of E_2 when the junctions are at temperatures T_2 and T_3. The thermal voltage generated when the junctions are at temperatures T_1 and T_3 will be E_1+E_2.

Another advantage of the orthonormal polynomial representation is that the function may be simplified by lowering the order of the fit without having to determine new A_n. A quantitative discussion of errors associated with reduced order fits and with reduced number of significant figures is given in the STANDARD TABLES AND FUNCTIONS section.

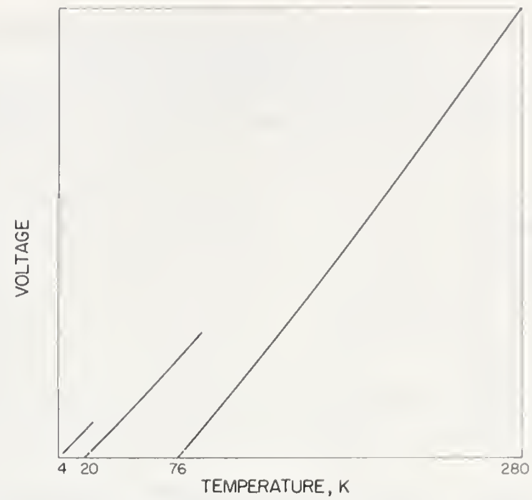

Figure 9. *Least squares approximations to typical data before the range shift constants are applied.*

As a convenience to users who wish to use the highest order, and therefore highest precision, fit for a particular thermocouple combination, the orthonormal polynomials and coefficients have been combined to give simple power series coefficients. The power series method of generating the standard data is more straight forward to program for a computer, since it involves only one summation. Using the power series coefficients, the $E=f(T)$ relationships are given by

$$E=\sum_{j=0}^{L} B_j T^j$$

It should be stressed that the full array of coefficients must be used in the power series method, whereas in the orthogonal representation each order is independent.

7. Error Analysis

The estimate of variance used in the first stage of our data analysis was arrived at by using the direct measurement and the various indirect measurements:

$$S^2=\frac{\alpha(E_{\text{calc}}-E_{\text{direct}})^2+(E_{\text{calc}}-E_{\text{indirect(1)}})^2+(E_{\text{calc}}-E_{\text{indirect(2)}})^2}{(n-1)}$$

where α is a weighting factor. The direct and indirect measurements were weighted to account for the actual number of experimental determinations used to make up each indirect voltage.

In the curve fitting part of the analysis, the precision of the analytical approximation of the data was needed. Again, precision is determined by the estimate of the variance. The coefficients, A_n, and the standard devia-

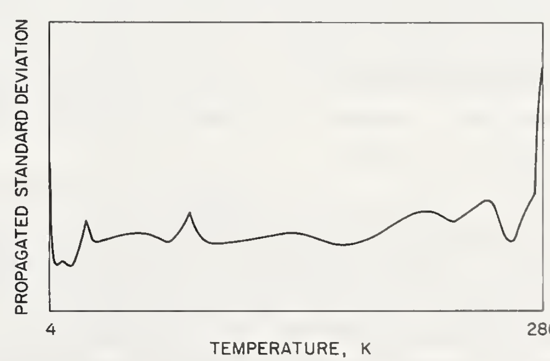

Figure 10. *Characteristic propagated standard deviation (σ_E) in voltage for the thermocouple calibrations.*

TABLE 7. *Average values of the standard deviations for the main thermocouple combinations*

Thermocouple material	$\sigma_E(\mu V)$
Type E	0.12
Type K	0.08
Type T	0.06
Pt versus Ag-28 at% Au	0.06
Pt versus TN	0.12
Ag-28 at% Au versus TN	0.13

tions, σ_{An}, are available from the orthonormal fit $E(T)=f(A_n, F_n(T))$. The estimate of the standard deviation of a predicted point [18, 19] is then given by

$$\sigma_E=\left[\sum_{i=1}^{n}\left(\frac{\partial f}{\partial_{Ai}}\sigma_{Ai}\right)^2\right]^{1/2},$$

where n = number of coefficients.

The σ_E obtained in this way is an indication of both the scatter in the experimental data for a particular thermocouple pair and of the closeness of the fitting approximation to the experimental data. A typical example of a σ_E versus temperature curve is shown in figure 10. It should be noted that the propagated standard deviation increases radically at both ends of the graph. This is partially because our input data are less precise near 4 and 280 K. However, the upturns are caused primarily by the lack of constraints near the extremes, a typical characteristic encountered in curve fitting to data.

The standard deviation for each of the main thermocouple combinations is given in tables 7 and 8. The tabular values represent averages for the entire curves; values near the extremes will usually be about twice as large.

Thermoelectric data for the thermocouple combinations listed in table 8 were obtained by the addition of shift adjustment constants to the analytical representation of the experimental data. Therefore, their total imprecision must include the imprecision of the adjustment. The total standard deviation for these combinations is calculated from

$$\sigma_{E,\text{total}}=[\sigma_E{}^2+\sigma_{\text{adj.}}{}^2]^{1/2}.$$

TABLE 8. *Average values of the standard deviation of the thermocouple combinations, average values for the standard deviation of the adjustment constant, and the overall standard deviation resulting from the combined effect of these uncertainties*

Thermocouple material	$\sigma_E(\mu V)$	$\sigma_{\text{adj}}(\mu V)$	$\sigma_{E,\ \text{total}}(\mu V)$
KP versus Pt	0.10	0.06	0.12
Pt versus TP	0.10	0.07	0.12
Pt versus KN	0.10	0.08	0.13
KP versus Ag-28 at% Au	0.12	0.06	0.13
TP versus Ag-28 at% Au	0.11	0.07	0.13
Ag-28 at% Au versus KN	0.12	0.08	0.14

TABLE 9. *Estimates of systematic errors in temperature measurements*

Source of error	Estimated bias (in millikelvin) for each temperature range (Kelvin)					
	4 to 20 K		20 to 75 K		75 to 280 K	
	Reference block	Variable block	Reference block	Variable block	Reference block	Variable block
Nonlinear temperature drift	0.6	2.0	1.0	1.1	0.5	0.6
Nonuniform time intervals	0.1	0.1	0.1	0.1	0.1	0.1
Mueller bridge uncertainty			1.3	0.4	0.4	0.9
Potentiometer uncertainty		0.8				
Helium vapor pressure manometer correction	0.2					
Thermal gradients in variable block		0.1		0.2		0.5
Germanium R. T. uncertainty		2.0				
Platinum R. T. uncertainty			2.0	2.0	2.0	3.0
Estimate of total uncertainty in temperature difference		3.0		3.5		3.9

TABLE 10. *Estimated systematic errors in thermocouple voltage readings*

Thermocouple material	Estimated systematic error (μV)		
	4–20 K	20–75 K	75–280 K
Type E	0.03	0.13	1.04
Type K	0.02	0.08	0.70
Type T	0.03	0.09	0.67
Pt versus KN	0.02	0.07	0.30
KP versus Pt	0.02	0.04	0.42
Pt versus TN	0.03	0.11	0.64
Pt versus TP	0.02	0.04	0.04
Pt versus Ag-28 at% Au	0.02	0.05	0.06
Ag-28 at% Au versus KN	0.02	0.03	0.28
KP versus Ag-28 at% Au	0.02	0.07	0.44
Ag-28 at% Au versus TN	0.03	0.04	0.62
TP versus Ag-28 at% Au	0.03	0.03	0.07

TABLE 11. *Total uncertainties in thermocouple calibrations*

These data include all random and systematic uncertainties.

Thermocouple material	Total uncertainty		
	4–20 K	20–75 K	75–280 K
Type E	29.9 mK	10.8 mK	25.1 mK
Type K	38.1	12.0	25.9
Type T	25.4	10.5	24.7
Pt versus KN	112.3	21.7	27.7
KP versus Pt	132.9	40.2	28.1
Pt versus TN	40.1	12.3	24.8
Pt versus TP	529.6	39.8	141.2
Pt versus Ag-28 at% Au	153.2	18.3	57.3
Ag-28 at% Au versus KN	267.0	58.7	29.9
KP versus Ag-28 at% Au	89.1	19.9	27.2
Ag-28 at% Au versus TN	52.5	16.2	25.4
TP versus Ag-28 at% Au	597.9	112.7	61.2

Values for the initial (σ_E), adjustment ($\sigma_{adj.}$), and total ($\sigma_{E,total}$) standard deviations for these combinations are given in table 8.

The systematic errors, unlike the random errors or imprecision, can only be estimated from a knowledge of the system. The main possible sources of systematic error in the determination of the independent variable, T, are as follows: (1) deviation from linear temperature drift during the course of a single run, (2) nonuniform time intervals between thermocouple voltage readings, (3) Mueller bridge bias that remains or occurs after the calibration, (4) similar potentiometer errors, (5) platinum resistance thermometer calibration errors, (6) similar germanium resistance thermometer errors, and (7) thermal gradients in the variable temperature block. Our estimates of these errors are given in table 9. The quoted uncertainties do not include the systematic errors caused by disagreement between the International Practical Temperature Scale and the true thermodynamic scale. These errors are estimated to be about 2 mK.

There are three main sources of systematic error in our measurement of thermocouple voltages: (1) potentiometer uncertainty, (2) uncertainty in the standard reference cells used with the potentiometer, and (3) adjustment of the actual reference temperatures to a fixed value at 4.0, 20.0, and 75.0 K, using calculated values of dE/dT for each of the thermocouple combinations. Estimates of these systematic errors are given in table 10.

The total uncertainties in the thermoelectric voltages expressed in millikelvin, are given in table 11. The values in the table are obtained by taking the square root of the sum of the squares of the corresponding values in tables 7, 8, 9 and 10. The voltage uncertainties are converted to temperature uncertainties by dividing them by the Seebeck coefficient, dE/dT, appropriate for each thermocouple combination in each temperature range.

8. Standard Tables and Functions

Units for the thermocouple tables and functions are based on the "NBS as-maintained volt" [20]; the International Practical Temperature Scale, IPTS-68 [21, 22, 23] for temperature above 20 K; and the NBS acoustical scale, P 2-20 (1965) [24, 25] for temperatures between 4 and 20 K. The tabular values of thermovoltages for Types E, K, and T are slightly different from those reported informally by us earlier [26, 27]. The earlier values were based on a preliminary IPTS-68 scale; the preliminary and final IPTS-68 scales differed slightly.

The thermovoltages for the other thermocouple combinations (Pt and Ag-28 at% Au versus KP, KN, TP, TN) are also different from those reported earlier; they have been adjusted in two ways. The temperature scale modification discussed above was required to

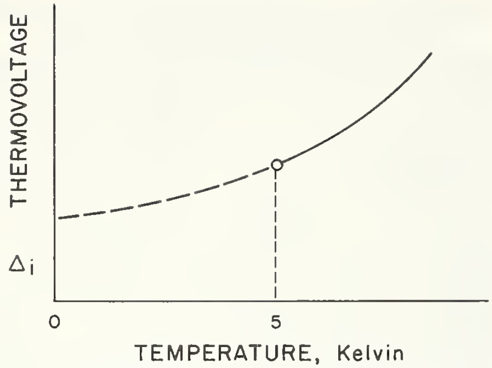

FIGURE 11. *Illustration of the nonzero thermoelectric voltage at* T = 0 K *which results when experimental data are extrapolated from 5 K to 0 K.*

base these values on the final IPTS-68 and the NBS P 2-20 (1965) scales. The second modification was required to establish internal consistency between the tables referenced to platinum and Ag-28 at% Au and those tables based on the E, K, and T combinations. For example,

$$\text{Type } E = EP - EN = (EP - \text{Pt}) + (\text{Pt} - EN).$$

The algebraic combination of the values for (EP−Pt) and (Pt−EN) must yield (EP−EN). The reason for the earlier inconsistency in the absolute numbers (there was no inconsistency if temperature differences were used) was that our data were extrapolated to 0 K from about 5 K. Each resulting table was then shifted by a constant Δ_i (see figure 11) so that $E = 0$ μV at $T = 0$ K. Since each table was shifted by a constant, Δ_i, the sensitivity or slope was not affected. The difference in thermal voltage between any two temperatures has not been changed. It must be emphasized that the adjustments made for these reasons do not devalue the data significantly; the need for the shifts was created by requiring that $E = 0$ μV at $T = 0$ K when the extrapolation from the lowest data point would not otherwise pass through $E = 0$ μV at $T = 0$ K.

The method used to insure additive consistency among all of the tables was to solve three simultaneous equations for the materials referenced to platinum. Equations for those materials are as follows:

(1) $\text{Type } E = (EP - \text{Pt} + \Delta_{EP}) + (\text{Pt} - \text{EN} + \Delta_{EN})$,

(2) $\text{Type } K = (KP - \text{Pt} + \Delta_{KP}) + (\text{Pt} - KN + \Delta_{KN})$,

and

(3) $\text{Type } T = (\text{Pt} - TN + \Delta_{TN}) - (\text{Pt} - TP + \Delta_{TP})$.

Note that $EP = KP$ and that $TN = EN$ so that $\Delta_{EP} = \Delta_{KP}$ and $\Delta_{TN} = \Delta_{EN}$. Let $\Delta_{EN} = 0$ arbitrarily, then

(1) $\text{Type } E = (EP - \text{Pt} + \Delta_{EP}) + (\text{Pt} - EN)$,

(2) $\text{Type } K = (EP - \text{Pt} + \Delta_{EP}) + (\text{Pt} - KN + \Delta_{KN})$,

and

(3) $\text{Type } T = (\text{Pt} - EN) - (\text{Pt} - TP + \Delta_{TP})$.

The required shifts are then determined by eqs. (4), (5), and (6) below.

(4) $\Delta_{EP} = \text{Type } E - (EP - \text{Pt}) - (\text{Pt} - EN)$,

(5) $\Delta_{KN} = \text{Type } K - \text{Type } E - (\text{Pt} - KN) + (\text{Pt} - EN)$,

and

(6) $\Delta_{TP} = (\text{Pt} - EN) - (\text{Pt} - TP) - \text{Type } T$.

The tables referenced to Ag-28 at% Au are calculated by eqs. (7) through (10).

(7) $EP -$ Ag-28 at% Au

= (Pt − Ag-28 at% Au) + (EP − Pt),

(8) Ag-28 at% Au − KN

= (Pt − KN) − (Pt − Ag-28 at% Au),

(9) Ag-28 at% Au − TN

= (Pt − TN) − (Pt − Ag-28 at% Au),

and

(10) $TP -$ Ag-28 at% Au

= (Pt − Ag-28 at% Au) − (Pt − TP).

The platinum-referenced tables used in these equations include the adjustments discussed previously.

Tabular data for thermocouple types E, K, and T are presented in three different forms. The first form, given in tables 12, 13, and 14, is the full-precision representations of $E(T)$, $S(T)$, and $dS(T)$. The second and third forms of the same data are reduced precision tables for both $E(T)$ (tables 15, 16, and 17) and $T(E)$ (tables 18, 19, and 20). Tables 12 through 17 are referenced to 0 K while tables 18 through 20 are referenced to 0° C (273.15 K). The reduced precision formats are especially useful for field applications.

The remaining thermocouple combinations consist of platinum and Ag-28 at% Au versus the materials in thermocouple types E, K, and T. These tabular data are presented in tables 21 through 29 as $E(T)$, $S(T)$, and $dS(T)$ in full precision. Other tabular formats for these data are not given.

Graphic representation of E, $dE/dT \equiv S$ and $d^2E/dT^2 \equiv dS/dT$ versus T are given in figures 12 through 14 for thermocouple types E, K, and T. Graphs of E and S versus T are given in figures 15 through 18 for the remaining thermocouple combinations.

Modern methods of data analysis require that functional representations of thermocouple data also be available. As mentioned previously, the full precision tables presented in this report were generated with orthonormal polynomials and coefficients. Our primary reason for using this approach, rather than the more common power series, was that we could select the optimum order for the fit and then examine lower and higher orders without having to redetermine new coefficients. In the final analysis, this functional approach presents the user with an often needed alternative not available when power series alone are used.

Since each fit in the orthonormal polynomial scheme represents a best fit for that order, the user can determine his own accuracy requirements and choose the lowest order fit that fills these particular needs. Computer economy benefits greatly from this freedom. In situations where all of the precision inherent in the experimental data is required, a power series using the highest order of fit may be used, using the recombined coefficients from the orthogonal expansion.

The thermal voltages given in tables 12 through 14 and 21 through 29 are given by

$$E(T) = A_o + \sum_{n=1}^{L} A_n F_n(T)$$

where the orthogonal polynomials $F_n(T)$ are given by

$$F_n(T) = \sum_{j=1}^{n} C_{n\,j} T^{j}.$$

The $F_n(T)$ (up to $n=14$) for our data are given in table 30 to 12 significant figures. For computer economy and round-off considerations, the table is given in the product-factored form. The orthogonal polynomial coefficients, A_n, for each of the thermocouple combinations are given in tables 31 and 32. The numbers are given with a sufficient number of significant digits so that no precision is lost in the final calculation. Since many computers cannot handle 12 significant figures in single precision, double precision constants and software are usually required if the computed values are to retain all of the precision inherent in the experimental data. If the full array of functions and constants $(L_{MAX})_i$ are used with a double precision program, the resultant precision of the data fits are those given in tables 7 and 8.

The thermocouple calibration data given in tables 12 through 14 and 21 through 29 were computed using 26 digits (84 binary bits) and the highest order fit (L_i) for each thermocouple combination, as given in tables 31 and 32.

However, the functional representation can be simplified at the cost of increasing the standard deviation of the fit. One simplifying step is to reduce the order of the fit. This may be done without having to redetermine the constants due to the orthogonal representation, i.e., the lower order function uses the same A_n and represents the best fit for that order. The standard deviation of the fit increases as the order is reduced, as is shown in tables 33 and 34. A second method of simplifying the computation is to reduce the number of digits carried in the calculations. Table 35 shows the limits of error to be expected when using decreasing numbers of digits. When reducing either the number of coefficients used or the number of digits carried, one must consider both the errors found in tables 33 and 34 and table 35. For example, if one wishes to generate the data for Type T with a precision of 1 μV, table 33 shows that $L=6$. Table 35 shows that to achieve this precision 10 decimal digits (32 binary bits) should be carried.

The full precision data may be generated using the more common power series formulation:

$$E(T) = B_o + \sum_{n=1}^{L} B_n T^n$$

for each of the thermocouple combinations being reported. Tables 36 and 37 contain the B_n needed; again, the B_n are given with a sufficient number of digits so that no significant precision is lost. The resultant precision is the same as for the highest order orthogonal fit.

Table 12. *Type E—thermoelectric voltage,* E(T), *Seebeck coefficient ,* S(T), *and derivative of the Seebeck coefficient,* dS(T)

T K	E µV	S µV/K	dS/dT nV/K^2	T K	E µV	S µV/K	dS/dT nV/K^2	T K	E µV	S µV/K	dS/dT nV/K^2
0	0.00	-0.203	604.4	60	704.83	21.637	280.0	120	2445.13	35.611	199.7
1	0.09	0.384	571.8	61	726.61	21.915	277.7	121	2480.84	35.811	198.8
2	0.76	0.941	543.0	62	748.66	22.192	275.4	122	2516.75	36.009	198.0
3	1.97	1.472	517.7	63	770.99	22.466	273.1	123	2552.86	36.207	197.1
4	3.69	1.978	495.6	64	793.59	22.738	270.9	124	2589.17	36.403	196.2
5	5.92	2.464	476.2	65	816.47	23.008	268.8	125	2625.67	36.599	195.4
6	8.61	2.931	459.4	66	839.61	23.276	266.7	126	2662.36	36.794	194.5
7	11.77	3.383	444.7	67	863.02	23.541	264.6	127	2699.25	36.988	193.7
8	15.38	3.821	432.1	68	886.69	23.805	262.6	128	2736.34	37.181	192.9
9	19.41	4.248	421.1	69	910.63	24.067	260.7	129	2773.62	37.374	192.0
10	23.87	4.664	411.7	70	934.82	24.326	258.8	130	2811.09	37.565	191.2
11	28.74	5.072	403.6	71	959.28	24.584	256.9	131	2848.75	37.756	190.4
12	34.01	5.472	396.7	72	983.99	24.840	255.1	132	2886.60	37.946	189.6
13	39.68	5.865	390.8	73	1008.96	25.094	253.4	133	2924.64	38.136	188.9
14	45.74	6.254	385.8	74	1034.18	25.347	251.7	134	2962.87	38.324	188.1
15	52.18	6.637	381.5	75	1059.65	25.598	250.0	135	3001.29	38.512	187.3
16	59.01	7.017	377.8	76	1085.37	25.847	248.4	136	3039.89	38.699	186.6
17	66.22	7.393	374.6	77	1111.35	26.095	246.9	137	3078.69	38.885	185.9
18	73.80	7.766	371.9	78	1137.56	26.341	245.4	138	3117.66	39.070	185.1
19	81.75	8.137	369.5	79	1164.03	26.585	243.9	139	3156.83	39.255	184.4
20	90.07	8.505	367.4	80	1190.73	26.829	242.4	140	3196.17	39.439	183.7
21	98.76	8.872	365.6	81	1217.68	27.070	241.0	141	3235.70	39.623	183.0
22	107.81	9.237	363.9	82	1244.87	27.311	239.7	142	3275.42	39.805	182.3
23	117.23	9.600	362.3	83	1272.30	27.550	238.3	143	3315.31	39.987	181.6
24	127.01	9.961	360.8	84	1299.97	27.787	237.0	144	3355.39	40.169	180.9
25	137.15	10.321	359.3	85	1327.88	28.024	235.7	145	3395.65	40.349	180.3
26	147.65	10.680	357.9	86	1356.02	28.259	234.5	146	3436.09	40.529	179.6
27	158.51	11.037	356.4	87	1384.40	28.493	233.2	147	3476.71	40.708	179.0
28	169.73	11.393	354.9	88	1413.01	28.725	232.0	148	3517.51	40.887	178.3
29	181.30	11.747	353.4	89	1441.85	28.957	230.9	149	3558.48	41.065	177.7
30	193.22	12.099	351.8	90	1470.92	29.187	229.7	150	3599.64	41.242	177.0
31	205.50	12.450	350.1	91	1500.22	29.416	228.6	151	3640.97	41.419	176.4
32	218.12	12.800	348.4	92	1529.75	29.644	227.4	152	3682.47	41.595	175.8
33	231.09	13.147	346.5	93	1559.51	29.871	226.3	153	3724.16	41.771	175.2
34	244.41	13.493	344.6	94	1589.49	30.097	225.2	154	3766.02	41.946	174.6
35	258.08	13.836	342.7	95	1619.70	30.321	224.1	155	3808.05	42.120	173.9
36	272.09	14.178	340.6	96	1650.13	30.545	223.1	156	3850.26	42.293	173.3
37	286.43	14.517	338.4	97	1680.79	30.768	222.0	157	3892.64	42.466	172.7
38	301.12	14.855	336.2	98	1711.67	30.989	221.0	158	3935.19	42.639	172.1
39	316.14	15.190	333.9	99	1742.77	31.210	219.9	159	3977.91	42.811	171.5
40	331.50	15.523	331.5	100	1774.09	31.429	218.9	160	4020.81	42.982	170.9
41	347.19	15.853	329.1	101	1805.63	31.647	217.9	161	4063.88	43.153	170.3
42	363.20	16.181	326.6	102	1837.38	31.865	216.9	162	4107.11	43.323	169.7
43	379.55	16.506	324.1	103	1869.36	32.081	215.9	163	4150.52	43.492	169.1
44	396.21	16.829	321.5	104	1901.54	32.297	214.9	164	4194.10	43.661	168.5
45	413.20	17.149	318.9	105	1933.95	32.511	213.9	165	4237.84	43.829	167.9
46	430.51	17.467	316.3	106	1966.57	32.724	212.9	166	4281.76	43.997	167.3
47	448.14	17.782	313.6	107	1999.40	32.937	211.9	167	4325.84	44.164	166.7
48	466.07	18.094	311.0	108	2032.44	33.148	210.9	168	4370.08	44.330	166.1
49	484.32	18.404	308.3	109	2065.69	33.359	210.0	169	4414.50	44.496	165.5
50	502.88	18.711	305.6	110	2099.16	33.568	209.0	170	4459.07	44.661	164.9
51	521.74	19.015	303.0	111	2132.83	33.777	208.1	171	4503.82	44.826	164.3
52	540.91	19.317	300.3	112	2166.71	33.984	207.1	172	4548.73	44.990	163.7
53	560.38	19.616	297.7	113	2200.80	34.191	206.2	173	4593.80	45.153	163.1
54	580.14	19.912	295.1	114	2235.09	34.397	205.2	174	4639.03	45.316	162.5
55	600.20	20.206	292.5	115	2269.59	34.601	204.3	175	4684.43	45.478	161.8
56	620.55	20.497	289.9	116	2304.29	34.805	203.4	176	4729.99	45.640	161.2
57	641.19	20.786	287.4	117	2339.20	35.008	202.4	177	4775.71	45.800	160.6
58	662.12	21.072	284.9	118	2374.31	35.210	201.5	178	4821.59	45.961	160.0
59	683.33	21.355	282.5	119	2409.62	35.411	200.6	179	4867.63	46.120	159.4
60	704.83	21.637	280.0	120	2445.13	35.611	199.7	180	4913.83	46.279	158.7

Table 12. *Type E—thermoelectric voltage,* E(T), *Seebeck coefficient* , S(T), *and derivative of the Seebeck coefficient,* dS(T)—Continued

T K	E µV	S µV/K	dS/dT nV/K²
180	4913.83	46.279	158.7
181	4960.19	46.438	158.1
182	5006.70	46.596	157.5
183	5053.38	46.753	156.9
184	5100.21	46.909	156.2
185	5147.20	47.065	155.6
186	5194.34	47.221	155.0
187	5241.64	47.375	154.4
188	5289.09	47.529	153.7
189	5336.70	47.683	153.1
190	5384.46	47.835	152.5
191	5432.37	47.988	151.9
192	5480.43	48.139	151.2
193	5528.65	48.290	150.6
194	5577.01	48.440	150.0
195	5625.53	48.590	149.4
196	5674.19	48.739	148.8
197	5723.00	48.888	148.2
198	5771.97	49.036	147.6
199	5821.08	49.183	147.0
200	5870.33	49.330	146.4
201	5919.74	49.476	145.9
202	5969.28	49.622	145.3
203	6018.98	49.767	144.7
204	6068.82	49.911	144.1
205	6118.80	50.055	143.6
206	6168.93	50.198	143.0
207	6219.20	50.341	142.5
208	6269.61	50.483	141.9
209	6320.16	50.625	141.4
210	6370.86	50.766	140.9
211	6421.69	50.907	140.3
212	6472.67	51.047	139.8
213	6523.79	51.186	139.3
214	6575.04	51.325	138.8
215	6626.44	51.464	138.3
216	6677.97	51.602	137.8
217	6729.64	51.739	137.3
218	6781.45	51.876	136.8
219	6833.39	52.013	136.3
220	6885.47	52.149	135.8
221	6937.69	52.284	135.3
222	6990.04	52.419	134.8
223	7042.53	52.554	134.3
224	7095.15	52.688	133.8
225	7147.90	52.821	133.3
226	7200.79	52.955	132.8
227	7253.81	53.087	132.3
228	7306.97	53.219	131.9
229	7360.25	53.351	131.4
230	7413.67	53.482	130.9
231	7467.22	53.613	130.4
232	7520.89	53.743	129.9
233	7574.70	53.872	129.4
234	7628.64	54.002	129.0
235	7682.70	54.130	128.5
236	7736.90	54.259	128.0
237	7791.22	54.386	127.5
238	7845.67	54.514	127.1
239	7900.25	54.641	126.6
240	7954.95	54.767	126.1
240	7954.95	54.767	126.1
241	8009.78	54.893	125.7
242	8064.74	55.018	125.2
243	8119.82	55.143	124.8
244	8175.02	55.268	124.3
245	8230.35	55.392	123.9
246	8285.81	55.516	123.5
247	8341.38	55.639	123.1
248	8397.09	55.762	122.7
249	8452.91	55.884	122.3
250	8508.85	56.006	121.9
251	8564.92	56.128	121.5
252	8621.11	56.250	121.2
253	8677.42	56.371	120.8
254	8733.85	56.491	120.5
255	8790.40	56.611	120.1
256	8847.07	56.731	119.8
257	8903.86	56.851	119.4
258	8960.78	56.970	119.1
259	9017.81	57.089	118.7
260	9074.95	57.208	118.3
261	9132.22	57.326	117.9
262	9189.61	57.444	117.4
263	9247.11	57.561	116.9
264	9304.73	57.677	116.3
265	9362.46	57.793	115.6
266	9420.31	57.908	114.8
267	9478.28	58.023	113.9
268	9536.36	58.136	112.8
269	9594.55	58.248	111.5
270	9652.85	58.359	110.0
271	9711.27	58.468	108.2
272	9769.79	58.575	106.2
273	9828.42	58.680	103.7
274	9887.15	58.783	100.9
275	9945.98	58.882	97.6
276	10004.91	58.978	93.8
277	10063.94	59.069	89.3
278	10123.05	59.156	84.2
279	10182.25	59.237	78.2
280	10241.52	59.312	71.4

Table 13. *Type K—thermoelectric voltage,* E(T), *Seebeck coefficient,* S(T), *and derivative of the Seebeck coefficient,* dS(T)

T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²
0	0.00	0.241	146.9	60	383.56	12.757	197.0	120	1473.20	23.144	153.9
1	0.32	0.391	154.3	61	396.41	12.954	196.0	121	1496.42	23.297	153.4
2	0.78	0.549	161.3	62	409.47	13.149	195.0	122	1519.80	23.451	152.8
3	1.42	0.714	167.7	63	422.71	13.344	194.0	123	1543.32	23.603	152.2
4	2.21	0.884	173.7	64	436.15	13.537	193.0	124	1567.00	23.755	151.6
5	3.19	1.061	179.2	65	449.79	13.730	192.1	125	1590.83	23.906	151.1
6	4.34	1.243	184.3	66	463.61	13.922	191.1	126	1614.81	24.057	150.5
7	5.67	1.429	189.0	67	477.63	14.112	190.2	127	1638.95	24.207	149.9
8	7.20	1.621	193.4	68	491.84	14.302	189.2	128	1663.23	24.357	149.3
9	8.92	1.816	197.3	69	506.23	14.491	188.3	129	1687.66	24.506	148.8
10	10.83	2.015	200.9	70	520.82	14.678	187.4	130	1712.24	24.654	148.2
11	12.95	2.218	204.2	71	535.59	14.865	186.5	131	1736.97	24.802	147.6
12	15.27	2.424	207.2	72	550.55	15.051	185.6	132	1761.84	24.950	147.0
13	17.80	2.632	209.9	73	565.69	15.237	184.8	133	1786.87	25.096	146.4
14	20.53	2.843	212.3	74	581.02	15.421	183.9	134	1812.04	25.243	145.9
15	23.48	3.057	214.5	75	596.53	15.604	183.1	135	1837.35	25.388	145.3
16	26.65	3.272	216.4	76	612.23	15.787	182.2	136	1862.81	25.533	144.7
17	30.03	3.489	218.1	77	628.11	15.969	181.4	137	1888.42	25.678	144.1
18	33.63	3.708	219.5	78	644.17	16.150	180.6	138	1914.17	25.821	143.5
19	37.45	3.928	220.8	79	660.41	16.330	179.8	139	1940.06	25.965	142.9
20	41.48	4.150	221.9	80	676.83	16.510	179.1	140	1966.10	26.107	142.3
21	45.75	4.372	222.8	81	693.43	16.688	178.3	141	1992.28	26.249	141.7
22	50.23	4.595	223.5	82	710.20	16.866	177.5	142	2018.60	26.391	141.1
23	54.94	4.819	224.0	83	727.16	17.043	176.8	143	2045.06	26.532	140.6
24	59.87	5.043	224.4	84	744.29	17.220	176.1	144	2071.66	26.672	140.0
25	65.02	5.268	224.7	85	761.60	17.396	175.3	145	2098.40	26.811	139.4
26	70.40	5.493	224.9	86	779.08	17.571	174.6	146	2125.28	26.950	138.8
27	76.01	5.718	224.9	87	796.74	17.745	173.9	147	2152.30	27.089	138.2
28	81.84	5.942	224.8	88	814.57	17.918	173.2	148	2179.46	27.227	137.6
29	87.89	6.167	224.6	89	832.58	18.091	172.6	149	2206.75	27.364	137.0
30	94.17	6.392	224.3	90	850.75	18.264	171.9	150	2234.19	27.501	136.4
31	100.68	6.616	224.0	91	869.10	18.435	171.2	151	2261.76	27.637	135.7
32	107.40	6.840	223.5	92	887.62	18.606	170.6	152	2289.46	27.772	135.1
33	114.36	7.063	223.0	93	906.31	18.776	169.9	153	2317.30	27.907	134.5
34	121.53	7.285	222.4	94	925.18	18.946	169.3	154	2345.27	28.041	133.9
35	128.93	7.508	221.7	95	944.21	19.115	168.6	155	2373.38	28.175	133.3
36	136.54	7.729	221.0	96	963.40	19.283	168.0	156	2401.62	28.308	132.7
37	14[illegible].38	7.950	220.3	97	982.77	19.451	167.4	157	2430.00	28.440	132.1
38	152.44	8.169	219.4	98	1002.31	19.618	166.8	158	2458.50	28.572	131.5
39	160.72	8.388	218.6	99	1022.01	19.784	166.2	159	2487.14	28.703	130.9
40	169.22	8.607	217.7	100	1041.87	19.950	165.5	160	2515.91	28.834	130.3
41	177.94	8.824	216.8	101	1061.91	20.115	164.9	161	2544.81	28.964	129.7
42	186.87	9.040	215.8	102	1082.11	20.280	164.3	162	2573.84	29.093	129.0
43	196.02	9.256	214.9	103	1102.47	20.444	163.7	163	2603.00	29.222	128.4
44	205.38	9.470	213.9	104	1122.99	20.608	163.2	164	2632.28	29.350	127.8
45	214.95	9.683	212.9	105	1143.68	20.770	162.6	165	2661.70	29.478	127.2
46	224.74	9.896	211.8	106	1164.53	20.933	162.0	166	2691.24	29.604	126.6
47	234.75	10.107	210.8	107	1185.55	21.094	161.4	167	2720.90	29.731	126.0
48	244.96	10.317	209.7	108	1206.72	21.255	160.8	168	2750.70	29.856	125.3
49	255.38	10.526	208.7	109	1228.06	21.416	160.2	169	2780.62	29.981	124.7
50	266.01	10.735	207.6	110	1249.55	21.576	159.7	170	2810.66	30.106	124.1
51	276.85	10.942	206.5	111	1271.21	21.735	159.1	171	2840.83	30.230	123.5
52	287.89	11.148	205.5	112	1293.02	21.894	158.5	172	2871.12	30.353	122.9
53	299.14	11.353	204.4	113	1315.00	22.052	157.9	173	2901.53	30.475	122.2
54	310.60	11.556	203.3	114	1337.13	22.210	157.4	174	2932.07	30.597	121.6
55	322.26	11.759	202.3	115	1359.42	22.367	156.8	175	2962.73	30.718	121.0
56	334.12	11.961	201.2	116	1381.86	22.524	156.2	176	2993.51	30.839	120.4
57	346.18	12.162	200.1	117	1404.46	22.679	155.6	177	3024.41	30.959	119.7
58	358.44	12.361	199.1	118	1427.22	22.835	155.1	178	3055.42	31.079	119.1
59	370.90	12.560	198.1	119	1450.13	22.990	154.5	179	3086.56	31.197	118.5
60	383.56	12.757	197.0	120	1473.20	23.144	153.9	180	3117.82	31.316	117.9

Table 13. *Type K—thermoelectric voltage,* E(T), *Seebeck coefficient,* S(T), *and derivative of the Seebeck coefficient,* dS(T) —Continued

T K	E μV	S μV/K	dS/dT nV/K²
180	3117.82	31.316	117.9
181	3149.19	31.433	117.2
182	3180.68	31.550	116.6
183	3212.29	31.666	116.0
184	3244.02	31.782	115.3
185	3275.86	31.897	114.7
186	3307.81	32.011	114.1
187	3339.88	32.125	113.4
188	3372.06	32.238	112.8
189	3404.36	32.351	112.2
190	3436.76	32.463	111.5
191	3469.28	32.574	110.9
192	3501.91	32.684	110.3
193	3534.65	32.794	109.6
194	3567.50	32.904	109.0
195	3600.46	33.012	108.3
196	3633.52	33.120	107.7
197	3666.70	33.228	107.1
198	3699.98	33.334	106.4
199	3733.36	33.440	105.8
200	3766.86	33.546	105.1
201	3800.46	33.651	104.5
202	3834.16	33.755	103.8
203	3867.96	33.858	103.2
204	3901.87	33.961	102.5
205	3935.89	34.063	101.9
206	3970.00	34.165	101.2
207	4004.22	34.266	100.6
208	4038.53	34.366	99.9
209	4072.95	34.466	99.3
210	4107.46	34.565	98.6
211	4142.08	34.663	98.0
212	4176.79	34.761	97.3
213	4211.60	34.857	96.7
214	4246.50	34.954	96.0
215	4281.51	35.049	95.3
216	4316.60	35.144	94.7
217	4351.79	35.239	94.0
218	4387.08	35.333	93.4
219	4422.46	35.426	92.7
220	4457.93	35.518	92.1
221	4493.49	35.610	91.4
222	4529.15	35.701	90.7
223	4564.90	35.791	90.1
224	4600.73	35.881	89.4
225	4636.66	35.970	88.8
226	4672.67	36.059	88.1
227	4708.77	36.146	87.5
228	4744.96	36.233	86.8
229	4781.24	36.320	86.2
230	4817.60	36.406	85.5
231	4854.05	36.491	84.8
232	4890.59	36.575	84.2
233	4927.20	36.659	83.5
234	4963.90	36.743	82.9
235	5000.69	36.825	82.2
236	5037.55	36.907	81.6
237	5074.50	36.988	80.9
238	5111.53	37.069	80.3
239	5148.64	37.149	79.6
240	5185.83	37.228	79.0
240	5185.83	37.228	79.0
241	5223.10	37.307	78.4
242	5260.44	37.385	77.7
243	5297.87	37.462	77.1
244	5335.37	37.539	76.4
245	5372.94	37.615	75.8
246	5410.60	37.691	75.1
247	5448.32	37.765	74.5
248	5486.13	37.840	73.8
249	5524.00	37.913	73.2
250	5561.95	37.986	72.5
251	5599.98	38.058	71.9
252	5638.07	38.130	71.2
253	5676.23	38.201	70.6
254	5714.47	38.271	69.9
255	5752.78	38.340	69.2
256	5791.15	38.409	68.5
257	5829.59	38.477	67.9
258	5868.10	38.545	67.2
259	5906.68	38.612	66.5
260	5945.33	38.678	65.8
261	5984.04	38.743	65.1
262	6022.81	38.808	64.3
263	6061.65	38.872	63.6
264	6100.56	38.935	62.8
265	6139.52	38.998	62.1
266	6178.55	39.059	61.3
267	6217.64	39.120	60.5
268	6256.79	39.180	59.6
269	6296.00	39.239	58.8
270	6335.27	39.298	57.9
271	6374.60	39.355	57.0
272	6413.98	39.412	56.1
273	6453.42	39.467	55.1
274	6492.91	39.522	54.1
275	6532.46	39.575	53.0
276	6572.06	39.628	51.9
277	6611.72	39.679	50.8
278	6651.42	39.729	49.6
279	6691.18	39.778	48.4
280	6730.98	39.826	47.1

TABLE 14. *Type T—thermoelectric voltage,* E(T), *Seebeck coefficient,* S(T), *and derivative of the Seebeck coefficient,* dS(T)

T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²
0	0.00	-0.400	526.6	60	461.11	13.826	154.6	120	1540.74	21.931	126.0
1	-0.15	0.099	473.2	61	475.01	13.980	152.9	121	1562.73	22.057	125.8
2	0.18	0.549	428.0	62	489.07	14.132	151.3	122	1584.85	22.182	125.6
3	0.94	0.958	390.1	63	503.28	14.283	149.8	123	1607.10	22.308	125.4
4	2.09	1.332	358.4	64	517.64	14.432	148.4	124	1629.47	22.433	125.3
5	3.59	1.677	332.3	65	532.14	14.580	147.1	125	1651.96	22.558	125.1
6	5.43	1.998	310.9	66	546.79	14.726	146.0	126	1674.58	22.683	125.0
7	7.58	2.300	293.5	67	561.59	14.872	144.9	127	1697.33	22.808	124.8
8	10.03	2.586	279.7	68	576.54	15.016	143.9	128	1720.20	22.933	124.7
9	12.75	2.860	268.8	69	591.62	15.159	142.9	129	1743.20	23.058	124.5
10	15.74	3.124	260.3	70	606.86	15.302	142.1	130	1766.31	23.182	124.4
11	19.00	3.381	254.0	71	622.23	15.444	141.3	131	1789.56	23.306	124.3
12	22.50	3.633	249.3	72	637.74	15.584	140.6	132	1812.93	23.431	124.2
13	26.26	3.880	246.0	73	653.40	15.725	139.9	133	1836.42	23.555	124.0
14	30.26	4.125	243.8	74	669.19	15.864	139.3	134	1860.04	23.679	123.9
15	34.51	4.368	242.5	75	685.13	16.003	138.8	135	1883.78	23.803	123.8
16	39.00	4.610	241.8	76	701.20	16.142	138.3	136	1907.64	23.926	123.7
17	43.73	4.852	241.5	77	717.41	16.280	137.8	137	1931.63	24.050	123.5
18	48.70	5.094	241.6	78	733.76	16.417	137.4	138	1955.74	24.173	123.4
19	53.92	5.335	241.8	79	750.24	16.555	137.0	139	1979.98	24.297	123.3
20	59.37	5.577	242.2	80	766.87	16.691	136.6	140	2004.33	24.420	123.2
21	65.07	5.820	242.5	81	783.63	16.828	136.2	141	2028.82	24.543	123.0
22	71.01	6.062	242.7	82	800.52	16.964	135.9	142	2053.42	24.666	122.9
23	77.20	6.305	242.7	83	817.55	17.100	135.6	143	2078.15	24.789	122.7
24	83.62	6.548	242.6	84	834.72	17.235	135.3	144	2103.00	24.911	122.6
25	90.29	6.790	242.2	85	852.02	17.370	135.0	145	2127.97	25.034	122.4
26	97.20	7.032	241.6	86	869.46	17.505	134.7	146	2153.07	25.156	122.3
27	104.36	7.273	240.8	87	887.03	17.640	134.5	147	2178.28	25.279	122.1
28	111.75	7.513	239.7	88	904.74	17.774	134.2	148	2203.62	25.401	121.9
29	119.38	7.752	238.3	89	922.58	17.908	133.9	149	2229.08	25.522	121.8
30	127.25	7.990	236.7	90	940.56	18.042	133.7	150	2254.67	25.644	121.6
31	135.36	8.226	234.8	91	958.66	18.175	133.4	151	2280.37	25.766	121.4
32	143.70	8.459	232.7	92	976.91	18.309	133.1	152	2306.20	25.887	121.2
33	152.28	8.691	230.4	93	995.28	18.442	132.9	153	2332.15	26.008	121.0
34	161.08	8.920	227.9	94	1013.79	18.574	132.6	154	2358.21	26.129	120.7
35	170.12	9.147	225.2	95	1032.43	18.707	132.3	155	2384.40	26.249	120.5
36	179.38	9.371	222.4	96	1051.20	18.839	132.1	156	2410.71	26.370	120.3
37	188.86	9.592	219.4	97	1070.11	18.971	131.8	157	2437.14	26.490	120.1
38	198.56	9.809	216.4	98	1089.14	19.102	131.5	158	2463.69	26.610	119.8
39	208.48	10.024	213.2	99	1108.31	19.234	131.2	159	2490.36	26.730	119.6
40	218.61	10.236	210.0	100	1127.61	19.365	131.0	160	2517.15	26.849	119.3
41	228.95	10.444	206.7	101	1147.04	19.496	130.7	161	2544.06	26.968	119.0
42	239.49	10.649	203.4	102	1166.60	19.626	130.4	162	2571.09	27.087	118.8
43	250.24	10.851	200.1	103	1186.29	19.757	130.1	163	2598.24	27.206	118.5
44	261.19	11.049	196.8	104	1206.12	19.886	129.8	164	2625.50	27.324	118.2
45	272.34	11.245	193.5	105	1226.07	20.016	129.6	165	2652.88	27.442	118.0
46	283.68	11.437	190.3	106	1246.15	20.146	129.3	166	2680.39	27.560	117.7
47	295.21	11.625	187.1	107	1266.36	20.275	129.0	167	2708.00	27.678	117.4
48	306.93	11.811	184.0	108	1286.70	20.404	128.7	168	2735.74	27.795	117.1
49	318.83	11.993	181.0	109	1307.17	20.532	128.5	169	2763.59	27.912	116.8
50	330.92	12.173	178.0	110	1327.76	20.661	128.2	170	2791.56	28.029	116.6
51	343.18	12.349	175.2	111	1348.49	20.789	128.0	171	2819.65	28.145	116.3
52	355.62	12.523	172.5	112	1369.34	20.916	127.7	172	2847.85	28.261	116.0
53	368.23	12.694	169.8	113	1390.32	21.044	127.5	173	2876.17	28.377	115.7
54	381.00	12.863	167.3	114	1411.43	21.171	127.2	174	2904.61	28.493	115.5
55	393.95	13.029	164.9	115	1432.66	21.298	127.0	175	2933.16	28.608	115.2
56	407.06	13.193	162.6	116	1454.02	21.425	126.8	176	2961.82	28.723	114.9
57	420.33	13.354	160.4	117	1475.51	21.552	126.6	177	2990.60	28.838	114.7
58	433.77	13.514	158.4	118	1497.13	21.678	126.3	178	3019.50	28.952	114.4
59	447.36	13.671	156.4	119	1518.87	21.805	126.1	179	3048.51	29.067	114.2
60	461.11	13.826	154.6	120	1540.74	21.931	126.0	180	3077.63	29.181	113.9

Table 14. *Type T—thermoelectric voltage,* E(T)*, Seebeck coefficient,* S(T)*, and derivative of the Seebeck coefficient,* dS(T)—Continued

T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²
180	3077.63	29.181	113.9	240	5025.40	35.591	99.3				
181	3106.87	29.294	113.7	241	5061.04	35.690	99.2				
182	3136.22	29.408	113.4	242	5096.78	35.789	99.1				
183	3165.68	29.521	113.2	243	5132.62	35.888	99.0				
184	3195.26	29.634	113.0	244	5168.56	35.987	98.9				
185	3224.95	29.747	112.8	245	5204.60	36.086	98.8				
186	3254.76	29.860	112.5	246	5240.73	36.185	98.8				
187	3284.67	29.972	112.3	247	5276.97	36.284	98.7				
188	3314.70	30.085	112.1	248	5313.30	36.382	98.6				
189	3344.84	30.197	111.9	249	5349.73	36.481	98.5				
190	3375.09	30.308	111.7	250	5386.26	36.579	98.4				
191	3405.46	30.420	111.5	251	5422.89	36.678	98.3				
192	3435.93	30.531	111.3	252	5459.62	36.776	98.1				
193	3466.52	30.643	111.1	253	5496.44	36.874	97.9				
194	3497.22	30.754	111.0	254	5533.37	36.972	97.6				
195	3528.03	30.865	110.8	255	5570.39	37.069	97.3				
196	3558.95	30.975	110.6	256	5607.50	37.166	97.0				
197	3589.98	31.086	110.4	257	5644.72	37.263	96.6				
198	3621.12	31.196	110.2	258	5682.03	37.359	96.1				
199	3652.37	31.306	110.0	259	5719.44	37.455	95.6				
200	3683.73	31.416	109.8	260	5756.94	37.551	95.0				
201	3715.20	31.526	109.6	261	5794.54	37.645	94.3				
202	3746.78	31.635	109.4	262	5832.23	37.739	93.6				
203	3778.47	31.744	109.2	263	5870.02	37.833	92.9				
204	3810.27	31.853	108.9	264	5907.90	37.925	92.1				
205	3842.18	31.962	108.7	265	5945.87	38.017	91.3				
206	3874.20	32.071	108.5	266	5983.93	38.108	90.5				
207	3906.32	32.179	108.2	267	6022.08	38.198	89.8				
208	3938.55	32.287	108.0	268	6060.32	38.287	89.0				
209	3970.90	32.395	107.7	269	6098.66	38.376	88.4				
210	4003.34	32.503	107.4	270	6137.08	38.464	88.0				
211	4035.90	32.610	107.2	271	6175.58	38.552	87.7				
212	4068.56	32.717	106.9	272	6214.18	38.640	87.8				
213	4101.34	32.824	106.6	273	6252.86	38.728	88.2				
214	4134.21	32.930	106.3	274	6291.64	38.816	89.0				
215	4167.20	33.036	106.0	275	6330.50	38.906	90.5				
216	4200.29	33.142	105.7	276	6369.45	38.997	92.6				
217	4233.48	33.248	105.4	277	6408.49	39.091	95.6				
218	4266.78	33.353	105.0	278	6447.63	39.189	99.7				
219	4300.19	33.458	104.7	279	6486.87	39.291	105.0				
220	4333.70	33.562	104.4	280	6526.22	39.399	111.8				
221	4367.31	33.667	104.0								
222	4401.03	33.770	103.7								
223	4434.85	33.874	103.4								
224	4468.78	33.977	103.1								
225	4502.81	34.080	102.7								
226	4536.94	34.183	102.4								
227	4571.17	34.285	102.1								
228	4605.51	34.387	101.8								
229	4639.94	34.488	101.5								
230	4674.48	34.590	101.2								
231	4709.12	34.691	101.0								
232	4743.87	34.792	100.7								
233	4778.71	34.892	100.5								
234	4813.65	34.993	100.2								
235	4848.69	35.093	100.0								
236	4883.84	35.193	99.9								
237	4919.08	35.293	99.7								
238	4954.42	35.392	99.5								
239	4989.86	35.492	99.4								
240	5025.40	35.591	99.3								

Table 15. *Type E—reduced precision tables,* E(T)

THERMOELECTRIC VOLTAGE IN ABSOLUTE μV

K	0	1	2	3	4	5	6	7	8	9	10	K
0	0.0	0.1	0.8	2.0	3.7	5.9	8.6	11.8	15.4	19.4	23.9	0
10	23.9	28.7	34.0	39.7	45.7	52.2	59.0	66.2	73.8	81.7	90.1	10
20	90.1	98.8	107.8	117.2	127.0	137.2	147.7	158.5	169.7	181.3	193.2	20
30	193.2	205.5	218.1	231.1	244.4	258.1	272.1	286.4	301.1	316.1	331.5	30
40	331.5	347.2	363.2	379.5	396.2	413.2	430.5	448.1	466.1	484.3	502.9	40
50	502.9	521.7	540.9	560.4	580.1	600.2	620.6	641.2	662.1	683.3	704.8	50
60	704.8	726.6	748.7	771.0	793.6	816.5	839.6	863.0	886.7	910.6	934.8	60
70	934.8	959.3	984.0	1009.0	1034.2	1059.7	1085.4	1111.3	1137.6	1164.0	1190.7	70
80	1190.7	1217.7	1244.9	1272.3	1300.0	1327.9	1356.0	1384.4	1413.0	1441.8	1470.9	80
90	1470.9	1500.2	1529.8	1559.5	1589.5	1619.7	1650.1	1680.8	1711.7	1742.8	1774.1	90
100	1774.1	1805.6	1837.4	1869.4	1901.5	1933.9	1966.6	1999.4	2032.4	2065.7	2099.2	100
110	2099.2	2132.8	2166.7	2200.8	2235.1	2269.6	2304.3	2339.2	2374.3	2409.6	2445.1	110
120	2445.1	2480.8	2516.8	2552.9	2589.2	2625.7	2662.4	2699.3	2736.3	2773.6	2811.1	120
130	2811.1	2848.7	2886.6	2924.6	2962.9	3001.3	3039.9	3078.7	3117.7	3156.8	3196.2	130
140	3196.2	3235.7	3275.4	3315.3	3355.4	3395.7	3436.1	3476.7	3517.5	3558.5	3599.6	140
150	3599.6	3641.0	3682.5	3724.2	3766.0	3808.0	3850.3	3892.6	3935.2	3977.9	4020.8	150
160	4020.8	4063.9	4107.1	4150.5	4194.1	4237.8	4281.8	4325.8	4370.1	4414.5	4459.1	160
170	4459.1	4503.8	4548.7	4593.8	4639.0	4684.4	4730.0	4775.7	4821.6	4867.6	4913.8	170
180	4913.8	4960.2	5006.7	5053.4	5100.2	5147.2	5194.3	5241.6	5289.1	5336.7	5384.5	180
190	5384.5	5432.4	5480.4	5528.6	5577.0	5625.5	5674.2	5723.0	5772.0	5821.1	5870.3	190
200	5870.3	5919.7	5969.3	6019.0	6068.8	6118.8	6168.9	6219.2	6269.6	6320.2	6370.9	200
210	6370.9	6421.7	6472.7	6523.8	6575.0	6626.4	6678.0	6729.6	6781.4	6833.4	6885.5	210
220	6885.5	6937.7	6990.0	7042.5	7095.1	7147.9	7200.8	7253.8	7307.0	7360.3	7413.7	220
230	7413.7	7467.2	7520.9	7574.7	7628.6	7682.7	7736.9	7791.2	7845.7	7900.2	7955.0	230
240	7955.0	8009.8	8064.7	8119.8	8175.0	8230.4	8285.8	8341.4	8397.1	8452.9	8508.9	240
250	8508.9	8564.9	8621.1	8677.4	8733.9	8790.4	8847.1	8903.9	8960.8	9017.8	9075.0	250
260	9075.0	9132.2	9189.6	9247.1	9304.7	9362.5	9420.3	9478.3	9536.4	9594.6	9652.9	260
270	9652.9	9711.3	9769.8	9828.4	9887.1	9946.0	10004.9	10063.9	10123.0	10182.2	10241.5	270
280	10241.5											280
K	0	1	2	3	4	5	6	7	8	9	10	K

Table 16. *Type K—reduced precision tables,* E(T)

THERMOELECTRIC VOLTAGE IN ABSOLUTE μV

K	0	1	2	3	4	5	6	7	8	9	10	K
0	0.0	0.3	0.8	1.4	2.2	3.2	4.3	5.7	7.2	8.9	10.8	0
10	10.8	12.9	15.3	17.8	20.5	23.5	26.6	30.0	33.6	37.4	41.5	10
20	41.5	45.7	50.2	54.9	59.9	65.0	70.4	76.0	81.8	87.9	94.2	20
30	94.2	100.7	107.4	114.4	121.5	128.9	136.5	144.4	152.4	160.7	169.2	30
40	169.2	177.9	186.9	196.0	205.4	215.0	224.7	234.7	245.0	255.4	266.0	40
50	266.0	276.8	287.9	299.1	310.6	322.3	334.1	346.2	358.4	370.9	383.6	50
60	383.6	396.4	409.5	422.7	436.2	449.8	463.6	477.6	491.8	506.2	520.8	60
70	520.8	535.6	550.5	565.7	581.0	596.5	612.2	628.1	644.2	660.4	676.8	70
80	676.8	693.4	710.2	727.2	744.3	761.6	779.1	796.7	814.6	832.6	850.8	80
90	850.8	869.1	887.6	906.3	925.2	944.2	963.4	982.8	1002.3	1022.0	1041.9	90
100	1041.9	1061.9	1082.1	1102.5	1123.0	1143.7	1164.5	1185.5	1206.7	1228.1	1249.6	100
110	1249.6	1271.2	1293.0	1315.0	1337.1	1359.4	1381.9	1404.5	1427.2	1450.1	1473.2	110
120	1473.2	1496.4	1519.8	1543.3	1567.0	1590.8	1614.8	1638.9	1663.2	1687.7	1712.2	120
130	1712.2	1737.0	1761.8	1786.9	1812.0	1837.4	1862.8	1888.4	1914.2	1940.1	1966.1	130
140	1966.1	1992.3	2018.6	2045.1	2071.7	2098.4	2125.3	2152.3	2179.5	2206.8	2234.2	140
150	2234.2	2261.8	2289.5	2317.3	2345.3	2373.4	2401.6	2430.0	2458.5	2487.1	2515.9	150
160	2515.9	2544.8	2573.8	2603.0	2632.3	2661.7	2691.2	2720.9	2750.7	2780.6	2810.7	160
170	2810.7	2840.8	2871.1	2901.5	2932.1	2962.7	2993.5	3024.4	3055.4	3086.6	3117.8	170
180	3117.8	3149.2	3180.7	3212.3	3244.0	3275.9	3307.8	3339.9	3372.1	3404.4	3436.8	180
190	3436.8	3469.3	3501.9	3534.6	3567.5	3600.5	3633.5	3666.7	3700.0	3733.4	3766.9	190
200	3766.9	3800.5	3834.2	3868.0	3901.9	3935.9	3970.0	4004.2	4038.5	4072.9	4107.5	200
210	4107.5	4142.1	4176.8	4211.6	4246.5	4281.5	4316.6	4351.8	4387.1	4422.5	4457.9	210
220	4457.9	4493.5	4529.2	4564.9	4600.7	4636.7	4672.7	4708.8	4745.0	4781.2	4817.6	220
230	4817.6	4854.1	4890.6	4927.2	4963.9	5000.7	5037.6	5074.5	5111.5	5148.6	5185.8	230
240	5185.8	5223.1	5260.4	5297.9	5335.4	5372.9	5410.6	5448.3	5486.1	5524.0	5562.0	240
250	5562.0	5600.0	5638.1	5676.2	5714.5	5752.8	5791.2	5829.6	5868.1	5906.7	5945.3	250
260	5945.3	5984.0	6022.8	6061.7	6100.6	6139.5	6178.6	6217.6	6256.8	6296.0	6335.3	260
270	6335.3	6374.6	6414.0	6453.4	6492.9	6532.5	6572.1	6611.7	6651.4	6691.2	6731.0	270
280	6731.0											280
K	0	1	2	3	4	5	6	7	8	9	10	K

Table 17. *Type T—reduced precision tables,* E(T)

K	0	1	2	3	4	5	6	7	8	9	10	K
					THERMOELECTRIC VOLTAGE IN ABSOLUTE μV							
0	0.0	-0.1	0.2	0.9	2.1	3.6	5.4	7.6	10.0	12.7	15.7	0
10	15.7	19.0	22.5	26.3	30.3	34.5	39.0	43.7	48.7	53.9	59.4	10
20	59.4	65.1	71.0	77.2	83.6	90.3	97.2	104.4	111.7	119.4	127.3	20
30	127.3	135.4	143.7	152.3	161.1	170.1	179.4	188.9	198.6	208.5	218.6	30
40	218.6	228.9	239.5	250.2	261.2	272.3	283.7	295.2	306.9	318.8	330.9	40
50	330.9	343.2	355.6	368.2	381.0	394.0	407.1	420.3	433.8	447.4	461.1	50
60	461.1	475.0	489.1	503.3	517.6	532.1	546.8	561.6	576.5	591.6	606.9	60
70	606.9	622.2	637.7	653.4	669.2	685.1	701.2	717.4	733.8	750.2	766.9	70
80	766.9	783.6	800.5	817.6	834.7	852.0	869.5	887.0	904.7	922.6	940.6	80
90	940.6	958.7	976.9	995.3	1013.8	1032.4	1051.2	1070.1	1089.1	1108.3	1127.6	90
100	1127.6	1147.0	1166.6	1186.3	1206.1	1226.1	1246.1	1266.4	1286.7	1307.2	1327.8	100
110	1327.8	1348.5	1369.3	1390.3	1411.4	1432.7	1454.0	1475.5	1497.1	1518.9	1540.7	110
120	1540.7	1562.7	1584.9	1607.1	1629.5	1652.0	1674.6	1697.3	1720.2	1743.2	1766.3	120
130	1766.3	1789.6	1812.9	1836.4	1860.0	1883.8	1907.6	1931.6	1955.7	1980.0	2004.3	130
140	2004.3	2028.8	2053.4	2078.1	2103.0	2128.0	2153.1	2178.3	2203.6	2229.1	2254.7	140
150	2254.7	2280.4	2306.2	2332.1	2358.2	2384.4	2410.7	2437.1	2463.7	2490.4	2517.2	150
160	2517.2	2544.1	2571.1	2598.2	2625.5	2652.9	2680.4	2708.0	2735.7	2763.6	2791.6	160
170	2791.6	2819.7	2847.9	2876.2	2904.6	2933.2	2961.8	2990.6	3019.5	3048.5	3077.6	170
180	3077.6	3106.9	3136.2	3165.7	3195.3	3225.0	3254.8	3284.7	3314.7	3344.8	3375.1	180
190	3375.1	3405.5	3435.9	3466.5	3497.2	3528.0	3558.9	3590.0	3621.1	3652.4	3683.7	190
200	3683.7	3715.2	3746.8	3778.5	3810.3	3842.2	3874.2	3906.3	3938.6	3970.9	4003.3	200
210	4003.3	4035.9	4068.6	4101.3	4134.2	4167.2	4200.3	4233.5	4266.8	4300.2	4333.7	210
220	4333.7	4367.3	4401.0	4434.9	4468.8	4502.8	4536.9	4571.2	4605.5	4639.9	4674.5	220
230	4674.5	4709.1	4743.9	4778.7	4813.7	4848.7	4883.8	4919.1	4954.4	4989.9	5025.4	230
240	5025.4	5061.0	5096.8	5132.6	5168.6	5204.6	5240.7	5277.0	5313.3	5349.7	5386.3	240
250	5386.3	5422.9	5459.6	5496.4	5533.4	5570.4	5607.5	5644.7	5682.0	5719.4	5756.9	250
260	5756.9	5794.5	5832.2	5870.0	5907.9	5945.9	5983.9	6022.1	6060.3	6098.7	6137.1	260
270	6137.1	6175.6	6214.2	6252.9	6291.6	6330.5	6369.4	6408.5	6447.6	6486.9	6526.2	270
280	6526.2											280
K	0	1	2	3	4	5	6	7	8	9	10	K

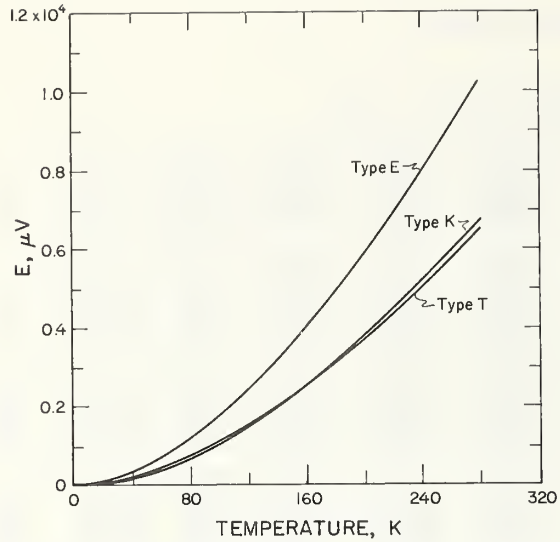

FIGURE 12. *Thermoelectric voltage for primary thermocouple types, E, K, and T.*

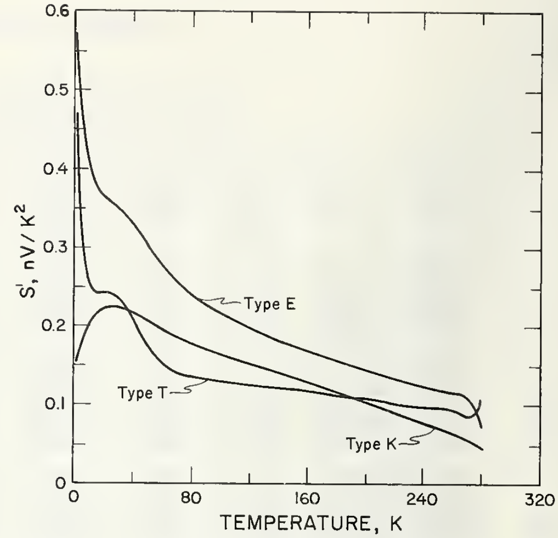

FIGURE 14. *Derivative of the Seebeck coefficient for primary thermocouple types E, K, and T.*

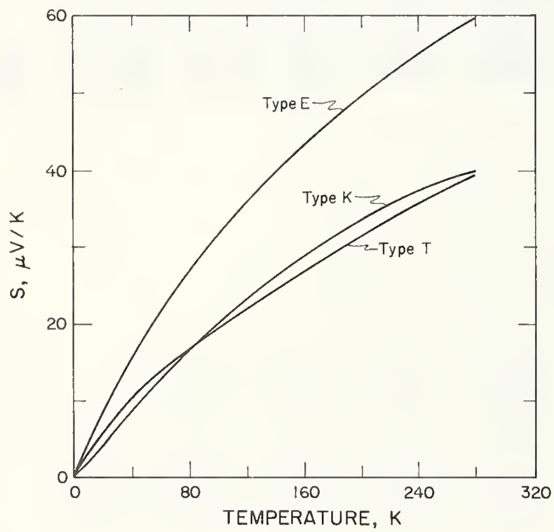

FIGURE 13. *Seebeck coefficient for primary thermocouple types E, K, and T.*

mV	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	mV
						TEMPERATURES IN K						
-9.80	12.58	10.70	8.47	5.51								-9.80
-9.70	25.01	24.02	23.00	21.94	20.83	19.66	18.44	17.14	15.74	14.24	12.58	-9.70
-9.60	33.46	32.70	31.93	31.14	30.33	29.50	28.65	27.78	26.88	25.96	25.01	-9.60
-9.50	40.37	39.72	39.07	38.41	37.74	37.05	36.36	35.66	34.94	34.21	33.46	-9.50
-9.40	46.38	45.81	45.23	44.65	44.06	43.46	42.86	42.25	41.63	41.00	40.37	-9.40
-9.30	51.81	51.29	50.76	50.23	49.70	49.16	48.61	48.06	47.51	46.95	46.38	-9.30
-9.20	56.81	56.32	55.84	55.35	54.85	54.35	53.85	53.35	52.84	52.33	51.81	-9.20
-9.10	61.48	61.03	60.57	60.11	59.65	59.18	58.71	58.24	57.77	57.29	56.81	-9.10
-9.00	65.90	65.47	65.03	64.60	64.16	63.72	63.28	62.83	62.38	61.94	61.48	-9.00
-8.90	70.10	69.69	69.27	68.86	68.44	68.02	67.60	67.18	66.75	66.33	65.90	-8.90
-8.80	74.12	73.73	73.33	72.93	72.53	72.13	71.73	71.32	70.92	70.51	70.10	-8.80
-8.70	77.99	77.61	77.22	76.84	76.46	76.07	75.68	75.30	74.90	74.51	74.12	-8.70
-8.60	81.72	81.35	80.98	80.61	80.24	79.87	79.50	79.12	78.74	78.37	77.99	-8.60
-8.50	85.33	84.98	84.62	84.26	83.90	83.54	83.18	82.82	82.45	82.09	81.72	-8.50
-8.40	88.84	88.49	88.15	87.80	87.45	87.10	86.75	86.40	86.04	85.69	85.33	-8.40
-8.30	92.25	91.91	91.58	91.24	90.90	90.56	90.22	89.87	89.53	89.19	88.84	-8.30
-8.20	95.58	95.25	94.92	94.59	94.26	93.92	93.59	93.26	92.92	92.59	92.25	-8.20
-8.10	98.82	98.50	98.18	97.86	97.53	97.21	96.88	96.56	96.23	95.90	95.58	-8.10
-8.00	101.99	101.68	101.37	101.05	100.73	100.42	100.10	99.78	99.46	99.14	98.82	-8.00
-7.90	105.10	104.79	104.48	104.18	103.87	103.56	103.24	102.93	102.62	102.31	101.99	-7.90
-7.80	108.14	107.84	107.54	107.24	106.93	106.63	106.33	106.02	105.71	105.41	105.10	-7.80
-7.70	111.13	110.83	110.54	110.24	109.94	109.64	109.35	109.05	108.75	108.45	108.14	-7.70
-7.60	114.06	113.77	113.48	113.19	112.90	112.60	112.31	112.02	111.72	111.43	111.13	-7.60
-7.50	116.94	116.66	116.37	116.08	115.80	115.51	115.22	114.93	114.64	114.35	114.06	-7.50
-7.40	119.78	119.50	119.21	118.93	118.65	118.37	118.08	117.80	117.51	117.23	116.94	-7.40
-7.30	122.57	122.29	122.01	121.74	121.46	121.18	120.90	120.62	120.34	120.06	119.78	-7.30
-7.20	125.32	125.04	124.77	124.50	124.22	123.95	123.67	123.40	123.12	122.84	122.57	-7.20
-7.10	128.02	127.75	127.49	127.22	126.95	126.67	126.40	126.13	125.86	125.59	125.32	-7.10
-7.00	130.69	130.43	130.16	129.90	129.63	129.36	129.10	128.83	128.56	128.29	128.02	-7.00
-6.90	133.33	133.07	132.81	132.54	132.28	132.02	131.75	131.49	131.22	130.96	130.69	-6.90
-6.80	135.93	135.67	135.41	135.15	134.89	134.63	134.37	134.11	133.85	133.59	133.33	-6.80
-6.70	138.50	138.24	137.99	137.73	137.48	137.22	136.96	136.70	136.45	136.19	135.93	-6.70
-6.60	141.04	140.79	140.53	140.28	140.03	139.77	139.52	139.26	139.01	138.76	138.50	-6.60
-6.50	143.55	143.30	143.05	142.80	142.55	142.30	142.05	141.79	141.54	141.29	141.04	-6.50
-6.40	146.03	145.78	145.53	145.29	145.04	144.79	144.54	144.29	144.05	143.80	143.55	-6.40
-6.30	148.48	148.24	147.99	147.75	147.50	147.26	147.01	146.77	146.52	146.27	146.03	-6.30
-6.20	150.91	150.67	150.43	150.18	149.94	149.70	149.46	149.21	148.97	148.73	148.48	-6.20
-6.10	153.31	153.07	152.83	152.59	152.35	152.11	151.87	151.63	151.39	151.15	150.91	-6.10
-6.00	155.69	155.45	155.22	154.98	154.74	154.51	154.27	154.03	153.79	153.55	153.31	-6.00
mV	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	mV

TEMPERATURES IN K

mV	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	mV
-6.00	155.69	155.45	155.22	154.98	154.74	154.51	154.27	154.03	153.79	153.55	153.31	-6.00
-5.90	158.05	157.81	157.58	157.34	157.11	156.87	156.64	156.40	156.16	155.93	155.69	-5.90
-5.80	160.38	160.15	159.92	159.68	159.45	159.22	158.98	158.75	158.52	158.28	158.05	-5.80
-5.70	162.69	162.46	162.23	162.00	161.77	161.54	161.31	161.08	160.85	160.61	160.38	-5.70
-5.60	164.99	164.76	164.53	164.30	164.07	163.84	163.61	163.38	163.15	162.92	162.69	-5.60
-5.50	167.26	167.03	166.80	166.58	166.35	166.12	165.90	165.67	165.44	165.21	164.99	-5.50
-5.40	169.51	169.29	169.06	168.84	168.61	168.39	168.16	167.94	167.71	167.48	167.26	-5.40
-5.30	171.74	171.52	171.30	171.08	170.85	170.63	170.41	170.18	169.96	169.73	169.51	-5.30
-5.20	173.96	173.74	173.52	173.30	173.08	172.85	172.63	172.41	172.19	171.97	171.74	-5.20
-5.10	176.16	175.94	175.72	175.50	175.28	175.06	174.84	174.62	174.40	174.18	173.96	-5.10
-5.00	178.34	178.12	177.90	177.69	177.47	177.25	177.03	176.81	176.60	176.38	176.16	-5.00
-4.90	180.51	180.29	180.07	179.86	179.64	179.42	179.21	178.99	178.77	178.56	178.34	-4.90
-4.80	182.65	182.44	182.23	182.01	181.80	181.58	181.37	181.15	180.94	180.72	180.51	-4.80
-4.70	184.79	184.58	184.36	184.15	183.94	183.72	183.51	183.30	183.08	182.87	182.65	-4.70
-4.60	186.91	186.70	186.48	186.27	186.06	185.85	185.64	185.43	185.21	185.00	184.79	-4.60
-4.50	189.01	188.80	188.59	188.38	188.17	187.96	187.75	187.54	187.33	187.12	186.91	-4.50
-4.40	191.10	190.89	190.68	190.48	190.27	190.06	189.85	189.64	189.43	189.22	189.01	-4.40
-4.30	193.18	192.97	192.76	192.56	192.35	192.14	191.93	191.73	191.52	191.31	191.10	-4.30
-4.20	195.24	195.03	194.83	194.62	194.42	194.21	194.00	193.80	193.59	193.38	193.18	-4.20
-4.10	197.29	197.09	196.88	196.68	196.47	196.27	196.06	195.86	195.65	195.45	195.24	-4.10
-4.00	199.33	199.12	198.92	198.72	198.51	198.31	198.11	197.90	197.70	197.49	197.29	-4.00
-3.90	201.35	201.15	200.95	200.75	200.54	200.34	200.14	199.94	199.73	199.53	199.33	-3.90
-3.80	203.37	203.17	202.96	202.76	202.56	202.36	202.16	201.96	201.76	201.56	201.35	-3.80
-3.70	205.37	205.17	204.97	204.77	204.57	204.37	204.17	203.97	203.77	203.57	203.37	-3.70
-3.60	207.36	207.16	206.96	206.76	206.56	206.36	206.17	205.97	205.77	205.57	205.37	-3.60
-3.50	209.34	209.14	208.94	208.74	208.55	208.35	208.15	207.95	207.75	207.56	207.36	-3.50
-3.40	211.30	211.11	210.91	210.72	210.52	210.32	210.13	209.93	209.73	209.53	209.34	-3.40
-3.30	213.26	213.07	212.87	212.68	212.48	212.28	212.09	211.89	211.70	211.50	211.30	-3.30
-3.20	215.21	215.02	214.82	214.63	214.43	214.24	214.04	213.85	213.65	213.46	213.26	-3.20
-3.10	217.15	216.95	216.76	216.57	216.37	216.18	215.99	215.79	215.60	215.40	215.21	-3.10
-3.00	219.07	218.88	218.69	218.50	218.30	218.11	217.92	217.73	217.53	217.34	217.15	-3.00
-2.90	220.99	220.80	220.61	220.42	220.23	220.03	219.84	219.65	219.46	219.27	219.07	-2.90
-2.80	222.90	222.71	222.52	222.33	222.14	221.95	221.76	221.56	221.37	221.18	220.99	-2.80
-2.70	224.80	224.61	224.42	224.23	224.04	223.85	223.66	223.47	223.28	223.09	222.90	-2.70
-2.60	226.69	226.50	226.31	226.12	225.93	225.74	225.55	225.37	225.18	224.99	224.80	-2.60
-2.50	228.57	228.38	228.19	228.00	227.82	227.63	227.44	227.25	227.06	226.88	226.69	-2.50
-2.40	230.44	230.25	230.07	229.88	229.69	229.51	229.32	229.13	228.94	228.76	228.57	-2.40
-2.30	232.30	232.12	231.93	231.75	231.56	231.37	231.19	231.00	230.81	230.63	230.44	-2.30
-2.20	234.16	233.97	233.79	233.60	233.42	233.23	233.05	232.86	232.68	232.49	232.30	-2.20
-2.10	236.01	235.82	235.64	235.45	235.27	235.08	234.90	234.71	234.53	234.34	234.16	-2.10
-2.00	237.84	237.66	237.48	237.29	237.11	236.93	236.74	236.56	236.37	236.19	236.01	-2.00
-1.90	239.68	239.49	239.31	239.13	238.94	238.76	238.58	238.40	238.21	238.03	237.84	-1.90
-1.80	241.50	241.32	241.14	240.95	240.77	240.59	240.41	240.22	240.04	239.86	239.68	-1.80
-1.70	243.32	243.13	242.95	242.77	242.59	242.41	242.23	242.05	241.86	241.68	241.50	-1.70
-1.60	245.12	244.94	244.76	244.58	244.40	244.22	244.04	243.86	243.68	243.50	243.32	-1.60
-1.50	246.93	246.75	246.57	246.39	246.21	246.03	245.85	245.67	245.48	245.30	245.12	-1.50
-1.40	248.72	248.54	248.36	248.18	248.00	247.82	247.64	247.46	247.28	247.10	246.93	-1.40
-1.30	250.51	250.33	250.15	249.97	249.79	249.61	249.43	249.26	249.08	248.90	248.72	-1.30
-1.20	252.29	252.11	251.93	251.75	251.58	251.40	251.22	251.04	250.86	250.68	250.51	-1.20
-1.10	254.06	253.88	253.71	253.53	253.35	253.17	253.00	252.82	252.64	252.46	252.29	-1.10
-1.00	255.83	255.65	255.47	255.30	255.12	254.94	254.77	254.59	254.41	254.24	254.06	-1.00
-0.90	257.59	257.41	257.23	257.06	256.88	256.71	256.53	256.36	256.18	256.00	255.83	-0.90
-0.80	259.34	259.16	258.99	258.81	258.64	258.46	258.29	258.11	257.94	257.76	257.59	-0.80
-0.70	261.09	260.91	260.74	260.56	260.39	260.21	260.04	259.86	259.69	259.51	259.34	-0.70
-0.60	262.83	262.65	262.48	262.31	262.13	261.96	261.78	261.61	261.44	261.26	261.09	-0.60
-0.50	264.56	264.39	264.22	264.04	263.87	263.70	263.52	263.35	263.18	263.00	262.83	-0.50
-0.40	266.29	266.12	265.95	265.77	265.60	265.43	265.26	265.08	264.91	264.74	264.56	-0.40
-0.30	268.01	267.84	267.67	267.50	267.33	267.15	266.98	266.81	266.64	266.46	266.29	-0.30
-0.20	269.73	269.56	269.39	269.22	269.05	268.87	268.70	268.53	268.36	268.19	268.01	-0.20
-0.10	271.44	271.27	271.10	270.93	270.76	270.59	270.42	270.25	270.07	269.90	269.73	-0.10
0.00	273.15	272.98	272.81	272.64	272.47	272.30	272.13	271.96	271.79	271.61	271.44	0.00
mV	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	mV

TEMPERATURES IN K

mV	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	mV
-6.40	23.90	21.81	19.48	16.80	13.57	9.23						-6.40
-6.30	38.83	37.62	36.36	35.06	33.70	32.28	30.80	29.23	27.58	25.81	23.90	-6.30
-6.20	49.37	48.42	47.45	46.46	45.45	44.42	43.36	42.27	41.16	40.01	38.83	-6.20
-6.10	58.07	57.26	56.44	55.60	54.75	53.89	53.02	52.13	51.23	50.31	49.37	-6.10
-6.00	65.69	64.97	64.24	63.49	62.75	61.99	61.23	60.45	59.67	58.88	58.07	-6.00
-5.90	72.58	71.92	71.25	70.58	69.90	69.21	68.52	67.83	67.12	66.41	65.69	-5.90
-5.80	78.93	78.32	77.70	77.08	76.45	75.82	75.18	74.54	73.89	73.24	72.58	-5.80
-5.70	84.87	84.29	83.71	83.13	82.54	81.95	81.35	80.75	80.15	79.55	78.93	-5.70
-5.60	90.47	89.92	89.37	88.82	88.27	87.71	87.15	86.58	86.01	85.44	84.87	-5.60
-5.50	95.79	95.27	94.75	94.22	93.69	93.16	92.63	92.09	91.55	91.01	90.47	-5.50
-5.40	100.87	100.37	99.87	99.37	98.87	98.36	97.85	97.34	96.82	96.31	95.79	-5.40
-5.30	105.75	105.27	104.79	104.31	103.82	103.34	102.85	102.36	101.86	101.37	100.87	-5.30
-5.20	110.45	109.99	109.53	109.06	108.59	108.12	107.65	107.18	106.71	106.23	105.75	-5.20
-5.10	115.00	114.55	114.10	113.65	113.20	112.74	112.29	111.83	111.37	110.91	110.45	-5.10
-5.00	119.40	118.97	118.53	118.09	117.65	117.21	116.77	116.33	115.89	115.44	115.00	-5.00
-4.90	123.68	123.25	122.83	122.41	121.98	121.55	121.13	120.70	120.27	119.83	119.40	-4.90
-4.80	127.84	127.43	127.02	126.60	126.19	125.77	125.36	124.94	124.52	124.10	123.68	-4.80
-4.70	131.90	131.50	131.10	130.69	130.29	129.88	129.48	129.07	128.66	128.25	127.84	-4.70
-4.60	135.86	135.47	135.08	134.68	134.29	133.89	133.50	133.10	132.70	132.30	131.90	-4.60
-4.50	139.74	139.36	138.97	138.59	138.20	137.81	137.42	137.04	136.65	136.26	135.86	-4.50
-4.40	143.54	143.16	142.78	142.41	142.03	141.65	141.27	140.89	140.51	140.12	139.74	-4.40
-4.30	147.26	146.89	146.52	146.15	145.78	145.41	145.04	144.66	144.29	143.91	143.54	-4.30
-4.20	150.91	150.55	150.19	149.82	149.46	149.09	148.73	148.36	148.00	147.63	147.26	-4.20
-4.10	154.50	154.14	153.79	153.43	153.07	152.71	152.36	152.00	151.64	151.27	150.91	-4.10
-4.00	158.03	157.68	157.33	156.98	156.62	156.27	155.92	155.57	155.21	154.86	154.50	-4.00
-3.90	161.50	161.16	160.81	160.47	160.12	159.77	159.42	159.08	158.73	158.38	158.03	-3.90
-3.80	164.92	164.58	164.24	163.90	163.56	163.22	162.87	162.53	162.19	161.85	161.50	-3.80
-3.70	168.29	167.95	167.62	167.28	166.95	166.61	166.27	165.94	165.60	165.26	164.92	-3.70
-3.60	171.61	171.28	170.95	170.62	170.29	169.96	169.62	169.29	168.96	168.62	168.29	-3.60
-3.50	174.89	174.56	174.24	173.91	173.58	173.26	172.93	172.60	172.27	171.94	171.61	-3.50
-3.40	178.13	177.80	177.48	177.16	176.84	176.51	176.19	175.86	175.54	175.22	174.89	-3.40
-3.30	181.32	181.00	180.69	180.37	180.05	179.73	179.41	179.09	178.77	178.45	178.13	-3.30
-3.20	184.48	184.17	183.85	183.54	183.22	182.91	182.59	182.27	181.96	181.64	181.32	-3.20
-3.10	187.61	187.29	186.98	186.67	186.36	186.05	185.74	185.42	185.11	184.80	184.48	-3.10
-3.00	190.69	190.39	190.08	189.77	189.46	189.15	188.84	188.54	188.23	187.92	187.61	-3.00
-2.90	193.75	193.45	193.14	192.84	192.53	192.23	191.92	191.62	191.31	191.00	190.69	-2.90
-2.80	196.78	196.48	196.18	195.87	195.57	195.27	194.97	194.66	194.36	194.06	193.75	-2.80
-2.70	199.78	199.48	199.18	198.88	198.58	198.28	197.98	197.68	197.38	197.08	196.78	-2.70
-2.60	202.75	202.45	202.15	201.86	201.56	201.26	200.97	200.67	200.37	200.07	199.78	-2.60
-2.50	205.69	205.39	205.10	204.81	204.51	204.22	203.93	203.63	203.34	203.04	202.75	-2.50
-2.40	208.60	208.31	208.02	207.73	207.44	207.15	206.86	206.57	206.27	205.98	205.69	-2.40
-2.30	211.50	211.21	210.92	210.63	210.34	210.05	209.76	209.48	209.19	208.90	208.60	-2.30
-2.20	214.37	214.08	213.80	213.51	213.22	212.94	212.65	212.36	212.07	211.79	211.50	-2.20
-2.10	217.21	216.93	216.65	216.36	216.08	215.79	215.51	215.22	214.94	214.65	214.37	-2.10
-2.00	220.04	219.76	219.48	219.19	218.91	218.63	218.35	218.06	217.78	217.50	217.21	-2.00
-1.90	222.84	222.57	222.29	222.01	221.73	221.44	221.16	220.88	220.60	220.32	220.04	-1.90
-1.80	225.63	225.35	225.07	224.80	224.52	224.24	223.96	223.68	223.40	223.12	222.84	-1.80
-1.70	228.40	228.12	227.84	227.57	227.29	227.02	226.74	226.46	226.18	225.91	225.63	-1.70
-1.60	231.14	230.87	230.60	230.32	230.05	229.77	229.50	229.22	228.95	228.67	228.40	-1.60
-1.50	233.88	233.60	233.33	233.06	232.79	232.51	232.24	231.97	231.69	231.42	231.14	-1.50
-1.40	236.59	236.32	236.05	235.78	235.51	235.23	234.96	234.69	234.42	234.15	233.88	-1.40
-1.30	239.29	239.02	238.75	238.48	238.21	237.94	237.67	237.40	237.13	236.86	236.59	-1.30
-1.20	241.97	241.70	241.44	241.17	240.90	240.63	240.36	240.09	239.83	239.56	239.29	-1.20
-1.10	244.64	244.37	244.11	243.84	243.57	243.31	243.04	242.77	242.51	242.24	241.97	-1.10
-1.00	247.29	247.03	246.76	246.50	246.23	245.97	245.70	245.44	245.17	244.90	244.64	-1.00
-0.90	249.93	249.67	249.40	249.14	248.88	248.61	248.35	248.08	247.82	247.56	247.29	-0.90
-0.80	252.56	252.30	252.03	251.77	251.51	251.25	250.98	250.72	250.46	250.19	249.93	-0.80
-0.70	255.17	254.91	254.65	254.39	254.13	253.87	253.60	253.34	253.08	252.82	252.56	-0.70
-0.60	257.77	257.51	257.25	256.99	256.73	256.47	256.21	255.95	255.69	255.43	255.17	-0.60
-0.50	260.36	260.10	259.85	259.59	259.33	259.07	258.81	258.55	258.29	258.03	257.77	-0.50
-0.40	262.94	262.68	262.43	262.17	261.91	261.65	261.39	261.14	260.88	260.62	260.36	-0.40
-0.30	265.51	265.25	265.00	264.74	264.48	264.23	263.97	263.71	263.45	263.20	262.94	-0.30
-0.20	268.07	267.81	267.55	267.30	267.04	266.79	266.53	266.28	266.02	265.76	265.51	-0.20
-0.10	270.61	270.36	270.10	269.85	269.59	269.34	269.09	268.83	268.58	268.32	268.07	-0.10
0.00	273.15	272.90	272.64	272.39	272.14	271.88	271.63	271.37	271.12	270.87	270.61	0.00
mV	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	mV

TABLE 20. *Type T—reduced precision tables,* T(E)

TEMPERATURES IN K

mV	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	mV
-6.20	19.87	17.99	15.93	13.61	10.90	7.46						-6.20
-6.10	33.73	32.58	31.40	30.18	28.91	27.59	26.21	24.76	23.23	21.61	19.87	-6.10
-6.00	43.77	42.85	41.92	40.97	40.01	39.02	38.01	36.98	35.92	34.84	33.73	-6.00
-5.90	52.24	51.44	50.63	49.82	48.99	48.15	47.30	46.43	45.56	44.67	43.77	-5.90
-5.80	59.82	59.10	58.36	57.62	56.88	56.12	55.36	54.59	53.82	53.04	52.24	-5.80
-5.70	66.80	66.13	65.45	64.76	64.07	63.38	62.68	61.97	61.26	60.55	59.82	-5.70
-5.60	73.34	72.70	72.06	71.42	70.77	70.12	69.46	68.81	68.14	67.47	66.80	-5.60
-5.50	79.51	78.91	78.30	77.69	77.08	76.46	75.84	75.22	74.60	73.97	73.34	-5.50
-5.40	85.38	84.81	84.23	83.65	83.07	82.48	81.89	81.30	80.71	80.11	79.51	-5.40
-5.30	91.00	90.45	89.90	89.34	88.78	88.22	87.66	87.09	86.53	85.95	85.38	-5.30
-5.20	96.40	95.87	95.33	94.80	94.26	93.72	93.18	92.64	92.10	91.55	91.00	-5.20
-5.10	101.60	101.08	100.57	100.05	99.54	99.02	98.50	97.98	97.45	96.92	96.40	-5.10
-5.00	106.62	106.13	105.63	105.13	104.63	104.13	103.63	103.12	102.61	102.11	101.60	-5.00
-4.90	111.49	111.01	110.53	110.04	109.56	109.07	108.59	108.10	107.61	107.11	106.62	-4.90
-4.80	116.22	115.75	115.28	114.81	114.34	113.87	113.40	112.92	112.45	111.97	111.49	-4.80
-4.70	120.82	120.36	119.91	119.45	118.99	118.53	118.07	117.61	117.15	116.68	116.22	-4.70
-4.60	125.30	124.85	124.41	123.96	123.52	123.07	122.62	122.17	121.72	121.27	120.82	-4.60
-4.50	129.67	129.24	128.80	128.37	127.93	127.50	127.06	126.62	126.18	125.74	125.30	-4.50
-4.40	133.94	133.52	133.10	132.67	132.25	131.82	131.39	130.96	130.53	130.10	129.67	-4.40
-4.30	138.12	137.71	137.29	136.88	136.46	136.04	135.62	135.21	134.79	134.36	133.94	-4.30
-4.20	142.21	141.81	141.40	140.99	140.59	140.18	139.77	139.36	138.95	138.53	138.12	-4.20
-4.10	146.22	145.83	145.43	145.03	144.63	144.23	143.83	143.42	143.02	142.62	142.21	-4.10
-4.00	150.16	149.77	149.38	148.98	148.59	148.20	147.81	147.41	147.02	146.62	146.22	-4.00
-3.90	154.02	153.63	153.25	152.87	152.48	152.10	151.71	151.32	150.93	150.55	150.16	-3.90
-3.80	157.81	157.43	157.06	156.68	156.30	155.92	155.54	155.16	154.78	154.40	154.02	-3.80
-3.70	161.54	161.17	160.80	160.43	160.06	159.68	159.31	158.94	158.56	158.19	157.81	-3.70
-3.60	165.21	164.85	164.48	164.12	163.75	163.38	163.02	162.65	162.28	161.91	161.54	-3.60
-3.50	168.82	168.46	168.11	167.75	167.39	167.02	166.66	166.30	165.94	165.57	165.21	-3.50
-3.40	172.38	172.03	171.67	171.32	170.97	170.61	170.25	169.90	169.54	169.18	168.82	-3.40
-3.30	175.89	175.54	175.19	174.84	174.49	174.14	173.79	173.44	173.09	172.74	172.38	-3.30
-3.20	179.35	179.01	178.66	178.32	177.97	177.63	177.28	176.93	176.59	176.24	175.89	-3.20
-3.10	182.76	182.42	182.08	181.74	181.40	181.06	180.72	180.38	180.04	179.69	179.35	-3.10
-3.00	186.13	185.80	185.46	185.13	184.79	184.45	184.12	183.78	183.44	183.10	182.76	-3.00
-2.90	189.46	189.13	188.80	188.46	188.13	187.80	187.47	187.13	186.80	186.47	186.13	-2.90
-2.80	192.74	192.42	192.09	191.76	191.43	191.11	190.78	190.45	190.12	189.79	189.46	-2.80
-2.70	195.99	195.67	195.34	195.02	194.70	194.37	194.05	193.72	193.40	193.07	192.74	-2.70
-2.60	199.20	198.88	198.56	198.24	197.92	197.60	197.28	196.96	196.64	196.31	195.99	-2.60
-2.50	202.38	202.06	201.74	201.43	201.11	200.79	200.48	200.16	199.84	199.52	199.20	-2.50
-2.40	205.52	205.20	204.89	204.58	204.26	203.95	203.64	203.32	203.01	202.69	202.38	-2.40
-2.30	208.62	208.31	208.00	207.69	207.38	207.07	206.76	206.45	206.14	205.83	205.52	-2.30
-2.20	211.70	211.39	211.09	210.78	210.47	210.16	209.86	209.55	209.24	208.93	208.62	-2.20
-2.10	214.74	214.44	214.14	213.83	213.53	213.22	212.92	212.61	212.31	212.00	211.70	-2.10
-2.00	217.76	217.46	217.16	216.86	216.55	216.25	215.95	215.65	215.35	215.04	214.74	-2.00
-1.90	220.74	220.45	220.15	219.85	219.55	219.25	218.95	218.66	218.36	218.06	217.76	-1.90
-1.80	223.70	223.41	223.11	222.82	222.52	222.23	221.93	221.63	221.34	221.04	220.74	-1.80
-1.70	226.64	226.34	226.05	225.76	225.47	225.17	224.88	224.59	224.29	224.00	223.70	-1.70
-1.60	229.54	229.25	228.96	228.67	228.38	228.09	227.80	227.51	227.22	226.93	226.64	-1.60
-1.50	232.43	232.14	231.85	231.56	231.28	230.99	230.70	230.41	230.12	229.83	229.54	-1.50
-1.40	235.28	235.00	234.71	234.43	234.14	233.86	233.57	233.29	233.00	232.71	232.43	-1.40
-1.30	238.12	237.84	237.55	237.27	236.99	236.71	236.42	236.14	235.85	235.57	235.28	-1.30
-1.20	240.93	240.65	240.37	240.09	239.81	239.53	239.25	238.97	238.68	238.40	238.12	-1.20
-1.10	243.73	243.45	243.17	242.89	242.61	242.33	242.05	241.77	241.49	241.21	240.93	-1.10
-1.00	246.50	246.22	245.94	245.67	245.39	245.11	244.84	244.56	244.28	244.00	243.73	-1.00
-0.90	249.24	248.97	248.70	248.42	248.15	247.87	247.60	247.32	247.05	246.77	246.50	-0.90
-0.80	251.97	251.70	251.43	251.16	250.88	250.61	250.34	250.07	249.79	249.52	249.24	-0.80
-0.70	254.68	254.41	254.14	253.87	253.60	253.33	253.06	252.79	252.52	252.25	251.97	-0.70
-0.60	257.37	257.11	256.84	256.57	256.30	256.03	255.76	255.49	255.22	254.95	254.68	-0.60
-0.50	260.05	259.78	259.51	259.25	258.98	258.71	258.45	258.18	257.91	257.64	257.37	-0.50
-0.40	262.70	262.44	262.17	261.91	261.64	261.38	261.11	260.84	260.58	260.31	260.05	-0.40
-0.30	265.34	265.07	264.81	264.55	264.28	264.02	263.76	263.49	263.23	262.96	262.70	-0.30
-0.20	267.96	267.70	267.43	267.17	266.91	266.65	266.39	266.12	265.86	265.60	265.34	-0.20
-0.10	270.56	270.30	270.04	269.78	269.52	269.26	269.00	268.74	268.48	268.22	267.96	-0.10
0.00	273.15	272.89	272.63	272.37	272.12	271.86	271.60	271.34	271.08	270.82	270.56	0.00
mV	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10	mV

TABLE 21. *Type KP (or EP) versus* Pt—*thermoelectric voltage,* E(T), *Seebeck coefficient,* S(T), *and derivative of the Seebeck coefficient,* dS(T)

T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²
0	0.79	0.882	-18.8	60	90.46	3.328	114.7	120	537.51	11.692	134.4
1	1.66	0.866	-12.9	61	93.85	3.444	117.0	121	549.27	11.826	133.8
2	2.52	0.855	-8.0	62	97.35	3.562	119.3	122	561.16	11.960	133.3
3	3.38	0.850	-3.9	63	100.98	3.683	121.5	123	573.19	12.093	132.7
4	4.22	0.847	-0.6	64	104.72	3.805	123.5	124	585.35	12.225	132.1
5	5.07	0.848	2.1	65	108.59	3.930	125.5	125	597.64	12.357	131.5
6	5.92	0.851	4.2	66	112.58	4.056	127.4	126	610.06	12.488	131.0
7	6.77	0.856	5.8	67	116.70	4.185	129.2	127	622.61	12.619	130.4
8	7.63	0.863	7.1	68	120.95	4.315	130.9	128	635.30	12.749	129.8
9	8.50	0.871	8.1	69	125.33	4.446	132.5	129	648.11	12.878	129.3
10	9.38	0.879	8.9	70	129.84	4.580	134.0	130	661.05	13.007	128.7
11	10.[illegible]6	0.888	9.5	71	134.49	4.714	135.4	131	674.13	13.136	128.1
12	11.15	0.898	9.9	72	139.27	4.850	136.7	132	687.33	13.264	127.5
13	12.06	0.908	10.3	73	144.19	4.988	138.0	133	700.65	13.391	126.9
14	12.97	0.919	10.7	74	149.25	5.126	139.1	134	714.11	13.518	126.4
15	13.89	0.929	11.0	75	154.44	5.266	140.1	135	727.69	13.644	125.8
16	14.83	0.941	11.4	76	159.78	5.406	141.1	136	741.39	13.769	125.2
17	15.77	0.952	11.8	77	165.26	5.548	142.0	137	755.23	13.894	124.6
18	16.73	0.964	12.3	78	170.88	5.690	142.8	138	769.18	14.018	124.0
19	17.70	0.977	12.9	79	176.64	5.834	143.5	139	783.26	14.142	123.4
20	18.69	0.990	13.6	80	182.54	5.977	144.1	140	797.47	14.265	122.8
21	19.68	1.004	14.4	81	188.59	6.122	144.7	141	811.79	14.388	122.2
22	20.70	1.019	15.4	82	194.79	6.267	145.2	142	826.24	14.510	121.6
23	21.72	1.035	16.5	83	201.13	6.412	145.6	143	840.81	14.631	121.0
24	22.77	1.052	17.8	84	207.61	6.558	145.9	144	855.50	14.752	120.4
25	23.83	1.071	19.2	85	214.24	6.704	146.2	145	870.32	14.872	119.8
26	24.91	1.091	20.8	86	221.02	6.850	146.4	146	885.25	14.991	119.2
27	26.01	1.112	22.5	87	227.94	6.997	146.6	147	900.30	15.110	118.6
28	27.13	1.136	24.3	88	235.01	7.143	146.7	148	915.47	15.229	118.0
29	28.28	1.161	26.3	89	242.23	7.290	146.8	149	930.75	15.346	117.4
30	29.45	1.188	28.4	90	249.59	7.437	146.8	150	946.16	15.463	116.7
31	30.66	1.218	30.7	91	257.10	7.584	146.7	151	961.68	15.580	116.1
32	31.89	1.250	33.1	92	264.76	7.730	146.6	152	977.32	15.696	115.5
33	33.16	1.284	35.6	93	272.56	7.877	146.5	153	993.07	15.811	114.8
34	34.46	1.321	38.2	94	280.51	8.023	146.3	154	1008.94	15.925	114.2
35	35.80	1.360	40.9	95	288.61	8.170	146.1	155	1024.92	16.039	113.6
36	37.18	1.403	43.7	96	296.85	8.316	145.9	156	1041.02	16.152	112.9
37	38.61	1.448	46.6	97	305.24	8.461	145.6	157	1057.23	16.265	112.3
38	40.08	1.496	49.5	98	313.78	8.607	145.3	158	1073.55	16.377	111.6
39	41.60	1.547	52.5	99	322.46	8.752	144.9	159	1089.98	16.488	111.0
40	43.17	1.601	55.6	100	331.28	8.897	144.6	160	1106.52	16.599	110.4
41	44.80	1.658	58.7	101	340.25	9.041	144.2	161	1123.18	16.709	109.7
42	46.49	1.718	61.8	102	349.36	9.185	143.8	162	1139.94	16.818	109.1
43	48.24	1.782	65.0	103	358.62	9.328	143.3	163	1156.81	16.927	108.4
44	50.05	1.848	68.2	104	368.02	9.472	142.9	164	1173.80	17.035	107.8
45	51.94	1.918	71.3	105	377.56	9.614	142.4	165	1190.88	17.143	107.1
46	53.89	1.991	74.5	106	387.25	9.756	141.9	166	1208.08	17.249	106.5
47	55.92	2.067	77.7	107	397.07	9.898	141.5	167	1225.38	17.356	105.9
48	58.03	2.146	80.8	108	407.04	10.039	140.9	168	1242.79	17.461	105.2
49	60.21	2.229	83.9	109	417.15	10.180	140.4	169	1260.30	17.566	104.6
50	62.48	2.314	87.0	110	427.40	10.320	139.9	170	1277.92	17.670	104.0
51	64.84	2.403	90.1	111	437.79	10.460	139.4	171	1295.65	17.774	103.3
52	67.29	2.494	93.1	112	448.32	10.599	138.8	172	1313.47	17.877	102.7
53	69.83	2.589	96.0	113	458.99	10.738	138.3	173	1331.40	17.979	102.1
54	72.47	2.686	98.9	114	469.80	10.876	137.8	174	1349.43	18.081	101.5
55	75.20	2.786	101.7	115	480.74	11.013	137.2	175	1367.56	18.182	100.9
56	78.04	2.890	104.5	116	491.82	11.150	136.6	176	1385.79	18.283	100.3
57	80.98	2.995	107.1	117	503.04	11.286	136.1	177	1404.13	18.383	99.7
58	84.03	3.104	109.7	118	514.40	11.422	135.5	178	1422.56	18.482	99.1
59	87.19	3.215	112.3	119	525.89	11.557	135.0	179	1441.09	18.581	98.5
60	90.46	3.328	114.7	120	537.51	11.692	134.4	180	1459.72	18.679	98.0

Table 21. *Type KP (or EP) versus Pt—thermoelectric voltage,* E(T), *Seebeck coefficient,* S(T), *and derivative of the Seebeck coefficient,* dS(T) —Continued

T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²
180	1459.72	18.679	98.0	240	2739.43	23.698	69.2				
181	1478.45	18.777	97.4	241	2763.16	23.766	68.7				
182	1497.27	18.874	96.8	242	2786.96	23.835	68.3				
183	1516.20	18.971	96.3	243	2810.83	23.903	67.9				
184	1535.22	19.067	95.8	244	2834.76	23.971	67.5				
185	1554.33	19.162	95.2	245	2858.77	24.038	67.2				
186	1573.54	19.257	94.7	246	2882.84	24.105	66.8				
187	1592.84	19.352	94.2	247	2906.98	24.172	66.5				
188	1612.2[illegible]	19.446	93.7	248	2931.18	24.238	66.3				
189	1631.74	19.539	93.2	249	2955.46	24.304	66.0				
190	1651.32	19.632	92.7	250	2979.79	24.370	65.8				
191	1671.00	19.724	92.2	251	3004.20	24.436	65.6				
192	1690.77	19.816	91.7	252	3028.67	24.502	65.5				
193	1710.63	19.908	91.3	253	3053.20	24.567	65.3				
194	1730.58	19.999	90.8	254	3077.80	24.632	65.2				
195	1750.63	20.089	90.4	255	3102.46	24.697	65.1				
196	1770.76	20.180	89.9	256	3127.19	24.762	65.0				
197	1790.99	20.269	89.5	257	3151.99	24.827	65.0				
198	1811.30	20.359	89.0	258	3176.85	24.892	64.9				
199	1831.70	20.447	88.6	259	3201.77	24.957	64.8				
200	1852.20	20.536	88.2	260	3226.76	25.022	64.8				
201	1872.78	20.624	87.7	261	3251.82	25.087	64.7				
202	1893.44	20.711	87.3	262	3276.94	25.151	64.5				
203	1914.20	20.798	86.9	263	3302.12	25.216	64.3				
204	1935.04	20.885	86.5	264	3327.37	25.280	64.1				
205	1955.97	20.971	86.0	265	3352.68	25.344	63.7				
206	1976.98	21.057	85.6	266	3378.06	25.407	63.3				
207	1998.08	21.142	85.2	267	3403.49	25.470	62.7				
208	2019.27	21.227	84.8	268	3429.00	25.533	62.0				
209	2040.54	21.312	84.4	269	3454.56	25.594	61.1				
210	2061.89	21.396	83.9	270	3480.18	25.655	59.9				
211	2083.33	21.480	83.5	271	3505.87	25.714	58.5				
212	2104.85	21.563	83.1	272	3531.61	25.772	56.8				
213	2126.45	21.646	82.6	273	3557.41	25.828	54.7				
214	2148.14	21.728	82.2	274	3583.27	25.881	52.3				
215	2169.91	21.810	81.7	275	3609.17	25.932	49.4				
216	2191.76	21.892	81.3	276	3635.13	25.980	46.0				
217	2213.69	21.973	80.8	277	3661.13	26.024	42.0				
218	2235.71	22.053	80.3	278	3687.18	26.063	37.3				
219	2257.80	22.133	79.8	279	3713.26	26.098	32.0				
220	2279.97	22.213	79.4	280	3739.37	26.127	25.8				
221	2302.23	22.292	78.9								
222	2324.56	22.371	78.4								
223	2346.97	22.449	77.9								
224	2369.46	22.527	77.4								
225	2392.02	22.604	76.8								
226	2414.66	22.680	76.3								
227	2437.38	22.756	75.8								
228	2460.18	22.832	75.3								
229	2483.05	22.907	74.7								
230	2505.99	22.981	74.2								
231	2529.01	23.055	73.7								
232	2552.10	23.129	73.2								
233	2575.27	23.202	72.6								
234	2598.50	23.274	72.1								
235	2621.81	23.346	71.6								
236	2645.19	23.417	71.1								
237	2668.65	23.488	70.6								
238	2692.17	23.558	70.1								
239	2715.76	23.628	69.6								
240	2739.43	23.698	69.2								

Table 22. *Type Pt versus TN (or EN)—thermoelectric voltage,* E(T), *Seebeck coefficient,* S(T), *and derivative of the Seebeck coefficient,* dS(T)

T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²
0	0.00	-1.355	693.1	60	614.42	18.311	164.6	120	1907.67	23.921	64.8
1	-1.02	-0.688	642.1	61	632.81	18.473	159.9	121	1931.62	23.985	64.5
2	-1.39	-0.069	597.8	62	651.36	18.631	155.3	122	1955.64	24.050	64.2
3	-1.17	0.509	559.3	63	670.07	18.784	150.9	123	1979.72	24.114	63.9
4	-0.39	1.051	526.0	64	688.93	18.933	146.6	124	2003.86	24.177	63.6
5	0.92	1.563	497.4	65	707.93	19.077	142.5	125	2028.07	24.241	63.3
6	2.73	2.047	472.9	66	727.08	19.218	138.5	126	2052.34	24.304	63.0
7	5.01	2.510	452.0	67	746.37	19.354	134.7	127	2076.68	24.367	62.8
8	7.74	2.953	434.3	68	765.79	19.487	131.1	128	2101.08	24.430	62.6
9	10.91	3.379	419.3	69	785.34	19.617	127.6	129	2125.54	24.492	62.4
10	14.50	3.792	406.6	70	805.02	19.743	124.3	130	2150.06	24.554	62.2
11	18.49	4.193	396.0	71	824.82	19.865	121.1	131	2174.65	24.616	62.0
12	22.88	4.585	387.2	72	844.75	19.985	118.0	132	2199.30	24.678	61.8
13	27.66	4.968	379.8	73	864.79	20.101	115.1	133	2224.00	24.740	61.6
14	32.81	5.345	373.6	74	884.95	20.215	112.4	134	2248.78	24.802	61.5
15	38.34	5.715	368.4	75	905.22	20.326	109.8	135	2273.61	24.863	61.4
16	44.24	6.082	364.1	76	925.60	20.435	107.3	136	2298.50	24.924	61.2
17	50.51	6.444	360.4	77	946.09	20.541	104.9	137	2323.46	24.985	61.1
18	57.13	6.803	357.2	78	966.68	20.645	102.7	138	2348.47	25.047	61.1
19	64.11	7.158	354.3	79	987.38	20.746	100.5	139	2373.55	25.108	61.0
20	71.44	7.511	351.7	80	1008.18	20.846	98.5	140	2398.69	25.168	60.9
21	79.13	7.862	349.3	81	1029.07	20.943	96.6	141	2423.89	25.229	60.9
22	87.17	8.210	346.9	82	1050.06	21.039	94.8	142	2449.15	25.290	60.8
23	95.55	8.556	344.5	83	1071.15	21.133	93.1	143	2474.47	25.351	60.8
24	104.28	8.899	342.1	84	1092.33	21.225	91.5	144	2499.85	25.412	60.8
25	113.35	9.240	339.6	85	1113.60	21.316	90.0	145	2525.29	25.473	60.8
26	122.76	9.578	336.9	86	1134.96	21.405	88.5	146	2550.79	25.533	60.8
27	132.50	9.913	334.0	87	1156.41	21.493	87.2	147	2576.36	25.594	60.8
28	142.58	10.246	330.9	88	1177.94	21.579	85.9	148	2601.98	25.655	60.8
29	152.99	10.575	327.6	89	1199.57	21.665	84.7	149	2627.67	25.716	60.8
30	163.73	10.901	324.1	90	1221.27	21.749	83.5	150	2653.41	25.776	60.8
31	174.79	11.223	320.4	91	1243.06	21.832	82.4	151	2679.22	25.837	60.8
32	186.18	11.542	316.4	92	1264.94	21.914	81.4	152	2705.09	25.898	60.9
33	197.88	11.856	312.2	93	1286.89	21.994	80.4	153	2731.02	25.959	60.9
34	209.89	12.166	307.8	94	1308.92	22.074	79.5	154	2757.00	26.020	60.9
35	222.21	12.472	303.1	95	1331.04	22.153	78.6	155	2783.05	26.081	61.0
36	234.83	12.772	298.3	96	1353.23	22.232	77.7	156	2809.17	26.142	61.0
37	247.75	13.068	293.2	97	1375.50	22.309	76.9	157	2835.34	26.203	61.0
38	260.96	13.359	288.0	98	1397.85	22.385	76.1	158	2861.57	26.264	61.1
39	274.47	13.644	282.6	99	1420.27	22.461	75.4	159	2887.87	26.325	61.1
40	288.25	13.924	277.1	100	1442.77	22.536	74.7	160	2914.22	26.386	61.1
41	302.31	14.198	271.5	101	1465.34	22.611	74.0	161	2940.64	26.447	61.1
42	316.65	14.467	265.8	102	1487.99	22.684	73.4	162	2967.12	26.508	61.2
43	331.24	14.730	260.0	103	1510.71	22.757	72.8	163	2993.65	26.569	61.2
44	346.10	14.987	254.1	104	1533.51	22.830	72.2	164	3020.25	26.631	61.2
45	361.22	15.238	248.2	105	1556.37	22.902	71.6	165	3046.92	26.692	61.2
46	376.58	15.483	242.3	106	1579.31	22.973	71.0	166	3073.64	26.753	61.2
47	392.18	15.723	236.3	107	1602.32	23.044	70.5	167	3100.42	26.814	61.1
48	408.02	15.956	230.4	108	1625.40	23.114	69.9	168	3127.27	26.875	61.1
49	424.09	16.183	224.4	109	1648.55	23.184	69.4	169	3154.17	26.936	61.1
50	440.38	16.405	218.6	110	1671.76	23.253	68.9	170	3181.14	26.997	61.1
51	456.90	16.620	212.7	111	1695.05	23.322	68.5	171	3208.17	27.058	61.0
52	473.62	16.830	207.0	112	1718.41	23.390	68.0	172	3235.26	27.119	61.0
53	490.56	17.034	201.3	113	1741.83	23.458	67.6	173	3262.41	27.180	60.9
54	507.69	17.233	195.7	114	1765.32	23.525	67.1	174	3289.62	27.241	60.8
55	525.02	17.426	190.2	115	1788.88	23.592	66.7	175	3316.89	27.302	60.8
56	542.54	17.613	184.8	116	1812.51	23.658	66.3	176	3344.22	27.363	60.7
57	560.24	17.795	179.6	117	1836.20	23.724	65.9	177	3371.61	27.423	60.6
58	578.13	17.972	174.4	118	1859.95	23.790	65.5	178	3399.07	27.484	60.5
59	596.19	18.144	169.4	119	1883.78	23.856	65.2	179	3426.58	27.544	60.4
60	614.42	18.311	164.6	120	1907.67	23.921	64.8	180	3454.16	27.605	60.3

T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²
180	3454.16	27.605	60.3	240	5215.64	31.080	55.8				
181	3481.79	27.665	60.2	241	5246.75	31.135	55.6				
182	3509.49	27.725	60.0	242	5277.91	31.191	55.5				
183	3537.24	27.785	59.9	243	5309.13	31.246	55.3				
184	3565.06	27.845	59.8	244	5340.40	31.301	55.1				
185	3592.93	27.905	59.7	245	5371.73	31.356	54.9				
186	3620.86	27.964	59.5	246	5403.11	31.411	54.8				
187	3648.86	28.024	59.4	247	5434.55	31.466	54.6				
188	3676.91	28.083	59.3	248	5466.05	31.521	54.5				
189	3705.02	28.142	59.2	249	5497.59	31.575	54.4				
190	3733.20	28.201	59.0	250	5529.20	31.629	54.3				
191	3761.43	28.260	58.9	251	5560.85	31.684	54.3				
192	3789.72	28.319	58.8	252	5592.56	31.738	54.2				
193	3818.07	28.378	58.7	253	5624.33	31.792	54.2				
194	3846.47	28.436	58.5	254	5656.15	31.847	54.3				
195	3874.94	28.495	58.4	255	5688.02	31.901	54.3				
196	3903.46	28.553	58.3	256	5719.95	31.955	54.4				
197	3932.04	28.612	58.2	257	5751.93	32.010	54.5				
198	3960.69	28.670	58.1	258	5783.97	32.064	54.6				
199	3989.38	28.728	58.0	259	5816.06	32.119	54.7				
200	4018.14	28.786	58.0	260	5848.21	32.174	54.9				
201	4046.96	28.844	57.9	261	5880.41	32.228	55.0				
202	4075.83	28.902	57.8	262	5912.66	32.284	55.1				
203	4104.76	28.959	57.8	263	5944.97	32.339	55.2				
204	4133.75	29.017	57.7	264	5977.34	32.394	55.2				
205	4162.79	29.075	57.7	265	6009.76	32.449	55.2				
206	4191.90	29.133	57.6	266	6042.24	32.504	55.0				
207	4221.06	29.190	57.6	267	6074.77	32.559	54.7				
208	4250.28	29.248	57.6	268	6107.36	32.614	54.3				
209	4279.55	29.305	57.6	269	6140.00	32.668	53.6				
210	4308.89	29.363	57.6	270	6172.69	32.721	52.7				
211	4338.28	29.420	57.6	271	6205.44	32.773	51.4				
212	4367.73	29.478	57.6	272	6238.24	32.823	49.8				
213	4397.24	29.536	57.6	273	6271.08	32.872	47.7				
214	4426.80	29.593	57.6	274	6303.98	32.919	45.0				
215	4456.42	29.651	57.6	275	6336.92	32.962	41.7				
216	4486.10	29.708	57.6	276	6369.90	33.002	37.6				
217	4515.84	29.766	57.6	277	6402.92	33.037	32.7				
218	4545.63	29.823	57.6	278	6435.98	33.067	26.7				
219	4575.49	29.881	57.6	279	6469.05	33.090	19.6				
220	4605.40	29.939	57.6	280	6502.15	33.105	11.2				
221	4635.36	29.996	57.6								
222	4665.39	30.054	57.6								
223	4695.47	30.111	57.6								
224	4725.61	30.169	57.6								
225	4755.81	30.227	57.5								
226	4786.06	30.284	57.5								
227	4816.28	30.342	57.4								
228	4846.75	30.399	57.4								
229	4877.18	30.456	57.3								
230	4907.66	30.514	57.2								
231	4938.20	30.571	57.1								
232	4968.80	30.628	57.0								
233	4999.46	30.685	56.9								
234	5030.17	30.742	56.8								
235	5060.94	30.798	56.6								
236	5091.77	30.855	56.5								
237	5122.65	30.911	56.3								
238	5153.59	30.968	56.2								
239	5184.59	31.024	56.0								
240	5215.64	31.080	55.8								

TABLE 23. *Type* Pt *versus KN—thermoelectric voltage,* E(T), *Seebeck coefficient.* S(T), *and derivative of the Seebeck coefficient,* dS(T)

T K	E µV	S µV/K	dS/dT nV/K²	T K	E µV	S µV/K	dS/dT nV/K²	T K	E µV	S µV/K	dS/dT nV/K²
0	-0.22	-0.813	203.5	60	293.10	9.435	82.2	120	935.66	11.456	19.8
1	-0.93	-0.611	199.4	61	302.58	9.515	78.8	121	947.12	11.476	19.8
2	-1.44	-0.414	196.3	62	312.13	9.593	75.5	122	958.61	11.496	19.7
3	-1.76	-0.218	194.3	63	321.76	9.666	72.3	123	970.11	11.515	19.7
4	-1.88	-0.025	193.0	64	331.46	9.737	69.2	124	981.64	11.535	19.7
5	-1.81	0.168	192.5	65	341.23	9.805	66.2	125	993.18	11.555	19.6
6	-1.55	0.360	192.5	66	351.07	9.869	63.3	126	1004.75	11.574	19.6
7	-1.09	0.553	193.0	67	360.97	9.931	60.5	127	1016.33	11.594	19.5
8	-0.44	0.747	193.9	68	370.93	9.991	57.8	128	1027.94	11.613	19.5
9	0.40	0.941	195.0	69	380.95	10.047	55.3	129	1039.56	11.633	19.5
10	1.44	1.137	196.3	70	391.03	10.101	52.9	130	1051.20	11.652	19.4
11	2.68	1.334	197.7	71	401.15	10.153	50.6	131	1062.86	11.672	19.4
12	4.11	1.532	199.1	72	411.33	10.202	48.4	132	1074.55	11.691	19.4
13	5.74	1.732	200.5	73	421.56	10.250	46.3	133	1086.25	11.710	19.3
14	7.57	1.933	201.9	74	431.83	10.295	44.3	134	1097.97	11.730	19.3
15	9.61	2.135	203.1	75	442.15	10.338	42.4	135	1109.71	11.749	19.3
16	11.85	2.339	204.3	76	452.50	10.380	40.6	136	1121.46	11.768	19.2
17	14.29	2.544	205.2	77	462.90	10.419	38.9	137	1133.24	11.787	19.2
18	16.93	2.750	206.0	78	473.34	10.458	37.4	138	1145.04	11.807	19.2
19	19.79	2.956	206.5	79	483.82	10.494	35.9	139	1156.86	11.826	19.2
20	22.85	3.162	206.8	80	494.33	10.529	34.5	140	1168.69	11.845	19.2
21	26.11	3.369	206.8	81	504.88	10.563	33.2	141	1180.55	11.864	19.1
22	29.58	3.576	206.6	82	515.46	10.596	32.0	142	1192.42	11.883	19.1
23	33.26	3.782	206.2	83	526.07	10.627	30.9	143	1204.31	11.902	19.1
24	37.15	3.988	205.4	84	536.71	10.658	29.8	144	1216.22	11.922	19.1
25	41.24	4.193	204.4	85	547.38	10.687	28.9	145	1228.15	11.941	19.1
26	45.54	4.397	203.2	86	558.09	10.715	28.0	146	1240.11	11.960	19.2
27	50.03	4.600	201.7	87	568.81	10.743	27.2	147	1252.07	11.979	19.2
28	54.73	4.800	199.9	88	579.57	10.770	26.4	148	1264.06	11.998	19.2
29	59.63	4.999	197.9	89	590.35	10.796	25.7	149	1276.07	12.017	19.2
30	64.73	5.196	195.6	90	601.16	10.821	25.1	150	1288.10	12.037	19.2
31	70.02	5.390	193.2	91	612.00	10.846	24.5	151	1300.14	12.056	19.3
32	75.51	5.582	190.5	92	622.85	10.870	24.0	152	1312.21	12.075	19.3
33	81.19	5.771	187.6	93	633.74	10.894	23.5	153	1324.29	12.094	19.4
34	87.05	5.957	184.5	94	644.64	10.917	23.1	154	1336.40	12.114	19.4
35	93.10	6.140	181.3	95	655.57	10.940	22.7	155	1348.52	12.133	19.5
36	99.33	6.320	177.9	96	666.52	10.963	22.4	156	1360.66	12.153	19.5
37	105.74	6.496	174.3	97	677.50	10.985	22.1	157	1372.83	12.172	19.6
38	112.32	6.669	170.6	98	688.49	11.007	21.8	158	1385.01	12.192	19.6
39	119.08	6.837	166.8	99	699.51	11.029	21.5	159	1397.21	12.212	19.7
40	126.00	7.002	162.9	100	710.55	11.050	21.3	160	1409.43	12.231	19.7
41	133.08	7.163	158.9	101	721.61	11.071	21.1	161	1421.67	12.251	19.8
42	140.32	7.320	154.8	102	732.69	11.092	21.0	162	1433.93	12.271	19.9
43	147.72	7.473	150.7	103	743.80	11.113	20.8	163	1446.22	12.291	19.9
44	155.27	7.621	146.5	104	754.92	11.134	20.7	164	1458.52	12.311	20.0
45	162.96	7.766	142.3	105	766.06	11.155	20.6	165	1470.84	12.331	20.0
46	170.80	7.906	138.1	106	777.23	11.175	20.5	166	1483.18	12.351	20.1
47	178.77	8.042	133.8	107	788.41	11.196	20.4	167	1495.54	12.371	20.1
48	186.88	8.174	129.6	108	799.62	11.216	20.3	168	1507.92	12.391	20.2
49	195.12	8.301	125.3	109	810.85	11.236	20.2	169	1520.32	12.411	20.2
50	203.48	8.424	121.1	110	822.09	11.256	20.2	170	1532.74	12.432	20.3
51	211.96	8.543	117.0	111	833.36	11.277	20.1	171	1545.18	12.452	20.3
52	220.56	8.658	112.8	112	844.64	11.297	20.1	172	1557.65	12.472	20.3
53	229.28	8.769	108.7	113	855.95	11.317	20.0	173	1570.13	12.493	20.4
54	238.10	8.876	104.7	114	867.28	11.337	20.0	174	1582.63	12.513	20.4
55	247.03	8.978	100.8	115	878.62	11.357	20.0	175	1595.15	12.533	20.4
56	256.06	9.077	96.9	116	889.99	11.377	19.9	176	1607.70	12.554	20.4
57	265.18	9.172	93.1	117	901.38	11.397	19.9	177	1620.26	12.574	20.3
58	274.40	9.263	89.4	118	912.78	11.416	19.9	178	1632.85	12.594	20.3
59	283.71	9.351	85.7	119	924.21	11.436	19.8	179	1645.45	12.615	20.3
60	293.10	9.435	82.2	120	935.66	11.456	19.8	180	1658.08	12.635	20.2

T K	E µV	S µV/K	dS/dT nV/K²	T K	E µV	S µV/K	dS/dT nV/K²	T K	E µV	S µV/K	dS/dT nV/K²
180	1658.08	12.635	20.2	240	2446.37	13.528	10.3				
181	1670.72	12.655	20.2	241	2459.91	13.538	10.1				
182	1683.39	12.675	20.1	242	2473.45	13.548	9.9				
183	1696.07	12.695	20.0	243	2487.00	13.558	9.7				
184	1708.78	12.715	19.9	244	2500.57	13.568	9.5				
185	1721.50	12.735	19.8	245	2514.14	13.577	9.2				
186	1734.25	12.755	19.7	246	2527.72	13.586	8.9				
187	1747.01	12.775	19.6	247	2541.31	13.595	8.5				
188	1759.80	12.794	19.4	248	2554.91	13.603	8.1				
189	1772.60	12.813	19.3	249	2568.52	13.611	7.7				
190	1785.42	12.833	19.1	250	2582.13	13.619	7.2				
191	1798.26	12.852	19.0	251	2595.75	13.626	6.7				
192	1811.13	12.871	18.8	252	2609.38	13.632	6.1				
193	1824.01	12.889	18.6	253	2623.02	13.638	5.5				
194	1836.90	12.908	18.4	254	2636.66	13.643	4.9				
195	1849.82	12.926	18.1	255	2650.30	13.648	4.2				
196	1862.76	12.944	17.9	256	2663.95	13.652	3.5				
197	1875.71	12.962	17.7	257	2677.61	13.655	2.8				
198	1888.68	12.979	17.5	258	2691.26	13.657	2.1				
199	1901.67	12.997	17.2	259	2704.92	13.659	1.3				
200	1914.67	13.014	17.0	260	2718.58	13.660	0.6				
201	1927.70	13.031	16.7	261	2732.24	13.660	-0.1				
202	1940.73	13.047	16.4	262	2745.90	13.659	-0.8				
203	1953.79	13.064	16.2	263	2759.56	13.658	-1.5				
204	1966.86	13.080	15.9	264	2773.22	13.657	-2.1				
205	1979.95	13.095	15.7	265	2786.87	13.654	-2.6				
206	1993.05	13.111	15.4	266	2800.52	13.651	-2.9				
207	2006.17	13.126	15.1	267	2814.17	13.648	-3.2				
208	2019.30	13.141	14.9	268	2827.82	13.645	-3.2				
209	2032.45	13.156	14.6	269	2841.47	13.642	-3.0				
210	2045.62	13.170	14.4	270	2855.11	13.639	-2.6				
211	2058.79	13.185	14.1	271	2868.74	13.637	-1.9				
212	2071.99	13.199	13.9	272	2882.38	13.636	-0.8				
213	2085.19	13.212	13.7	273	2896.01	13.635	0.8				
214	2098.41	13.226	13.4	274	2909.65	13.637	2.8				
215	2111.64	13.239	13.2	275	2923.29	13.641	5.4				
216	2124.89	13.252	13.0	276	2936.93	13.648	8.6				
217	2138.15	13.265	12.8	277	2950.59	13.659	12.5				
218	2151.42	13.278	12.6	278	2964.25	13.673	17.2				
219	2164.70	13.291	12.5	279	2977.94	13.693	22.9				
220	2178.00	13.303	12.3	280	2991.64	13.720	29.6				
221	2191.31	13.315	12.1								
222	2204.63	13.327	12.0								
223	2217.96	13.339	11.9								
224	2231.31	13.351	11.8								
225	2244.67	13.363	11.7								
226	2258.04	13.374	11.6								
227	2271.42	13.386	11.5								
228	2284.81	13.397	11.4								
229	2298.21	13.409	11.3								
230	2311.62	13.420	11.2								
231	2325.05	13.431	11.2								
232	2338.49	13.442	11.1								
233	2351.93	13.453	11.0								
234	2365.39	13.464	10.9								
235	2378.86	13.475	10.9								
236	2392.34	13.486	10.8								
237	2405.84	13.497	10.7								
238	2419.34	13.507	10.6								
239	2432.85	13.518	10.4								
240	2446.37	13.528	10.3								

Table 24. *Type* Pt *versus TP—thermoelectric voltage,* E(T), *Seebeck coefficient,* S(T), *and derivative of the Seebeck coefficient,* dS(T)

T K	E µV	S µV/K	dS/dT nV/K²	T K	E µV	S µV/K	dS/dT nV/K²	T K	E µV	S µV/K	dS/dT nV/K²
0	1.39	-1.464	310.1	60	153.38	4.480	9.1	120	366.96	1.982	-61.5
1	0.08	-1.167	284.4	61	157.86	4.488	6.2	121	368.91	1.920	-61.5
2	-0.95	-0.894	261.5	62	162.35	4.492	3.3	122	370.80	1.859	-61.6
3	-1.72	-0.643	241.1	63	166.84	4.494	0.5	123	372.63	1.797	-61.6
4	-2.25	-0.411	222.9	64	171.34	4.493	-2.2	124	374.39	1.735	-61.7
5	-2.55	-0.197	206.8	65	175.83	4.490	-4.9	125	376.10	1.674	-61.7
6	-2.64	0.003	192.6	66	180.32	4.484	-7.6	126	377.74	1.612	-61.7
7	-2.55	0.189	180.1	67	184.80	4.475	-10.1	127	379.32	1.550	-61.8
8	-2.27	0.363	169.0	68	189.26	4.463	-12.6	128	380.84	1.488	-61.8
9	-1.82	0.528	159.3	69	193.72	4.449	-15.1	129	382.30	1.427	-61.8
10	-1.22	0.682	150.8	70	198.16	4.433	-17.5	130	383.70	1.365	-61.8
11	-0.46	0.829	143.3	71	202.59	4.415	-19.8	131	385.03	1.303	-61.8
12	0.44	0.969	136.8	72	206.99	4.394	-22.0	132	386.30	1.241	-61.7
13	1.48	1.103	131.2	73	211.37	4.371	-24.1	133	387.51	1.180	-61.7
14	2.64	1.232	126.2	74	215.73	4.345	-26.2	134	388.66	1.118	-61.7
15	3.94	1.356	121.9	75	220.06	4.318	-28.2	135	389.75	1.056	-61.7
16	5.35	1.476	118.1	76	224.37	4.289	-30.2	136	390.77	0.995	-61.6
17	6.89	1.592	114.8	77	228.64	4.258	-32.0	137	391.74	0.933	-61.6
18	8.54	1.706	111.9	78	232.88	4.225	-33.8	138	392.64	0.871	-61.5
19	10.30	1.816	109.3	79	237.09	4.190	-35.5	139	393.48	0.810	-61.5
20	12.17	1.924	106.9	80	241.26	4.154	-37.2	140	394.26	0.748	-61.4
21	14.15	2.030	104.8	81	245.40	4.116	-38.7	141	394.98	0.687	-61.3
22	16.23	2.134	102.9	82	249.49	4.077	-40.2	142	395.63	0.626	-61.2
23	18.42	2.236	101.1	83	253.55	4.036	-41.6	143	396.23	0.565	-61.1
24	20.70	2.336	99.3	84	257.56	3.993	-43.0	144	396.76	0.504	-61.0
25	23.09	2.435	97.7	85	261.54	3.950	-44.3	145	397.24	0.443	-60.9
26	25.57	2.531	96.0	86	265.46	3.905	-45.5	146	397.65	0.382	-60.8
27	28.15	2.627	94.4	87	269.35	3.859	-46.7	147	398.00	0.321	-60.7
28	30.82	2.720	92.8	88	273.18	3.811	-47.8	148	398.29	0.260	-60.6
29	33.59	2.812	91.1	89	276.97	3.763	-48.8	149	398.52	0.200	-60.5
30	36.45	2.902	89.4	90	280.71	3.714	-49.8	150	398.69	0.139	-60.3
31	39.39	2.991	87.6	91	284.39	3.664	-50.7	151	398.80	0.079	-60.2
32	42.43	3.078	85.8	92	288.03	3.612	-51.6	152	398.85	0.019	-60.0
33	45.55	3.162	83.8	93	291.62	3.561	-52.4	153	398.84	-0.041	-59.9
34	48.75	3.245	81.8	94	295.15	3.508	-53.1	154	398.77	-0.101	-59.7
35	52.04	3.326	79.7	95	298.63	3.454	-53.8	155	398.63	-0.160	-59.5
36	55.40	3.405	77.6	96	302.06	3.400	-54.5	156	398.44	-0.220	-59.4
37	58.85	3.481	75.3	97	305.43	3.345	-55.1	157	398.20	-0.279	-59.2
38	62.37	3.555	73.0	98	308.75	3.290	-55.7	158	397.89	-0.338	-59.0
39	65.96	3.627	70.5	99	312.01	3.234	-56.3	159	397.52	-0.397	-58.8
40	69.62	3.696	68.0	100	315.22	3.177	-56.8	160	397.09	-0.456	-58.6
41	73.35	3.763	65.4	101	318.37	3.120	-57.2	161	396.61	-0.514	-58.4
42	77.14	3.827	62.8	102	321.46	3.063	-57.7	162	396.06	-0.573	-58.2
43	81.00	3.889	60.0	103	324.49	3.005	-58.1	163	395.46	-0.631	-58.0
44	84.92	3.947	57.2	104	327.47	2.947	-58.4	164	394.80	-0.689	-57.8
45	88.90	4.003	54.4	105	330.39	2.888	-58.8	165	394.09	-0.746	-57.6
46	92.93	4.056	51.5	106	333.25	2.829	-59.1	166	393.31	-0.804	-57.3
47	97.01	4.106	48.5	107	336.05	2.770	-59.4	167	392.48	-0.861	-57.1
48	101.14	4.153	45.5	108	338.79	2.710	-59.6	168	391.59	-0.918	-56.9
49	105.31	4.197	42.5	109	341.47	2.651	-59.9	169	390.64	-0.975	-56.7
50	109.53	4.238	39.5	110	344.09	2.591	-60.1	170	389.64	-1.031	-56.4
51	113.79	4.276	36.4	111	346.65	2.530	-60.3	171	388.58	-1.087	-56.2
52	118.08	4.311	33.3	112	349.15	2.470	-60.5	172	387.47	-1.144	-56.0
53	122.41	4.343	30.3	113	351.59	2.409	-60.7	173	386.29	-1.199	-55.7
54	126.77	4.372	27.2	114	353.97	2.349	-60.8	174	385.07	-1.255	-55.5
55	131.15	4.397	24.1	115	356.29	2.288	-61.0	175	383.78	-1.310	-55.3
56	135.56	4.420	21.1	116	358.54	2.227	-61.1	176	382.45	-1.366	-55.1
57	139.99	4.439	18.0	117	360.74	2.166	-61.2	177	381.05	-1.421	-54.8
58	144.44	4.456	15.0	118	362.87	2.104	-61.3	178	379.60	-1.475	-54.6
59	148.90	4.469	12.0	119	364.95	2.043	-61.4	179	378.10	-1.530	-54.4
60	153.38	4.480	9.1	120	366.96	1.982	-61.5	180	376.55	-1.584	-54.2

T K	E μV	S μV/K	dS/dT nV/K²
180	376.55	-1.584	-54.2
181	374.93	-1.638	-54.0
182	373.27	-1.692	-53.7
183	371.55	-1.746	-53.5
184	369.78	-1.799	-53.3
185	367.95	-1.852	-53.1
186	366.07	-1.905	-52.9
187	364.14	-1.958	-52.7
188	362.16	-2.011	-52.6
189	360.12	-2.063	-52.4
190	358.03	-2.116	-52.2
191	355.89	-2.168	-52.0
192	353.70	-2.220	-51.9
193	351.45	-2.271	-51.7
194	349.15	-2.323	-51.5
195	346.80	-2.374	-51.4
196	344.40	-2.426	-51.2
197	341.95	-2.477	-51.1
198	339.45	-2.528	-51.0
199	336.90	-2.579	-50.8
200	334.29	-2.630	-50.7
201	331.64	-2.680	-50.5
202	328.93	-2.731	-50.4
203	326.18	-2.781	-50.3
204	323.37	-2.831	-50.1
205	320.51	-2.881	-50.0
206	317.61	-2.931	-49.9
207	314.65	-2.981	-49.7
208	311.65	-3.031	-49.6
209	308.59	-3.080	-49.5
210	305.49	-3.130	-49.3
211	302.33	-3.179	-49.2
212	299.13	-3.228	-49.0
213	295.87	-3.277	-48.9
214	292.57	-3.326	-48.7
215	289.22	-3.375	-48.6
216	285.82	-3.423	-48.4
217	282.38	-3.471	-48.2
218	278.88	-3.520	-48.1
219	275.34	-3.568	-47.9
220	271.75	-3.615	-47.7
221	268.11	-3.663	-47.5
222	264.42	-3.710	-47.3
223	260.69	-3.758	-47.1
224	256.91	-3.804	-46.9
225	253.08	-3.851	-46.6
226	249.20	-3.898	-46.4
227	245.28	-3.944	-46.2
228	241.32	-3.990	-45.9
229	237.30	-4.036	-45.7
230	233.24	-4.082	-45.4
231	229.14	-4.127	-45.2
232	224.99	-4.172	-44.9
233	220.80	-4.217	-44.7
234	216.56	-4.261	-44.4
235	212.27	-4.305	-44.2
236	207.95	-4.350	-43.9
237	203.57	-4.393	-43.7
238	199.16	-4.437	-43.4
239	194.70	-4.480	-43.2
240	190.20	-4.523	-42.9

T K	E μV	S μV/K	dS/dT nV/K²
240	190.20	-4.523	-42.9
241	185.65	-4.566	-42.7
242	181.07	-4.609	-42.5
243	176.44	-4.651	-42.3
244	171.77	-4.693	-42.2
245	167.05	-4.735	-42.0
246	162.29	-4.777	-41.9
247	157.50	-4.819	-41.7
248	152.66	-4.861	-41.6
249	147.77	-4.902	-41.6
250	142.85	-4.944	-41.5
251	137.89	-4.985	-41.5
252	132.88	-5.027	-41.5
253	127.83	-5.068	-41.5
254	122.74	-5.110	-41.5
255	117.61	-5.151	-41.6
256	112.44	-5.193	-41.6
257	107.23	-5.235	-41.7
258	101.97	-5.276	-41.8
259	96.68	-5.318	-41.9
260	91.34	-5.360	-42.0
261	85.96	-5.402	-42.1
262	80.53	-5.444	-42.2
263	75.07	-5.487	-42.2
264	69.56	-5.529	-42.2
265	64.01	-5.571	-42.2
266	58.42	-5.613	-42.1
267	52.78	-5.655	-41.9
268	47.11	-5.697	-41.6
269	41.39	-5.738	-41.1
270	35.63	-5.779	-40.6
271	29.83	-5.819	-39.8
272	23.99	-5.859	-38.8
273	18.11	-5.897	-37.6
274	12.20	-5.934	-36.1
275	6.25	-5.969	-34.3
276	0.26	-6.002	-32.0
277	-5.76	-6.033	-29.4
278	-11.80	-6.061	-26.3
279	-17.88	-6.085	-22.6
280	-23.97	-6.106	-18.3

T K	E μV	S μV/K	dS/dT nV/K²

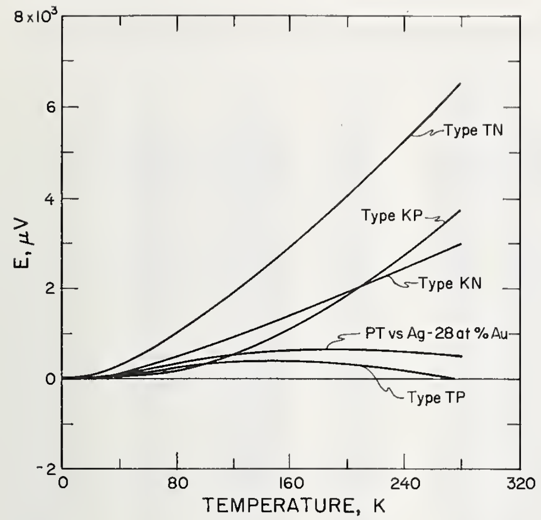

FIGURE 15. *Thermoelectric voltage for thermocouple materials versus Pt.*

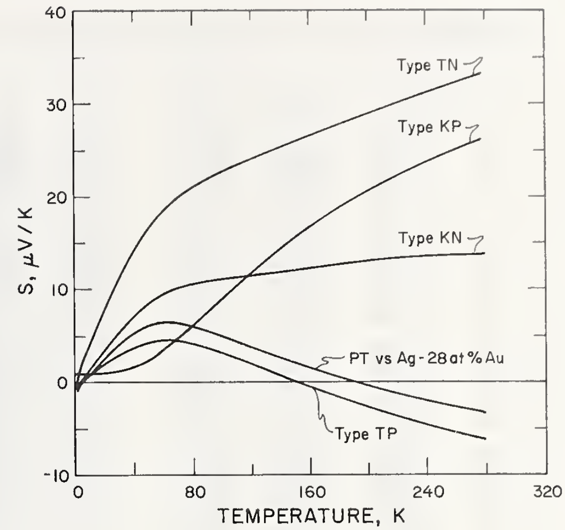

FIGURE 16. *Seebeck coefficient for thermocouple materials versus Pt.*

Table 25. *Type KP (or EP) versus* Ag–28 *at%* Au—*thermoelectric voltage,* E(T), *Seebeck coefficient,* S(T), *and derivative of the Seebeck coefficient,* dS(T)

T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²
0	0.79	-0.361	245.3	60	301.08	9.749	127.9	120	1075.21	15.542	74.1
1	0.55	-0.123	229.7	61	310.89	9.876	126.3	121	1090.79	15.616	73.6
2	0.54	0.099	216.6	62	320.83	10.002	124.8	122	1106.44	15.689	73.0
3	0.74	0.311	205.8	63	330.89	10.126	123.2	123	1122.17	15.762	72.5
4	1.16	0.512	197.0	64	341.08	10.248	121.8	124	1137.97	15.835	72.0
5	1.77	0.705	189.8	65	351.39	10.369	120.3	125	1153.84	15.906	71.5
6	2.56	0.892	184.2	66	361.82	10.489	118.9	126	1169.78	15.978	71.0
7	3.55	1.074	179.8	67	372.37	10.607	117.6	127	1185.79	16.048	70.5
8	4.71	1.252	176.6	68	383.03	10.724	116.3	128	1201.87	16.119	70.0
9	6.05	1.427	174.2	69	393.82	10.840	115.0	129	1218.03	16.188	69.6
10	7.56	1.601	172.6	70	404.71	10.954	113.8	130	1234.25	16.258	69.1
11	9.25	1.773	171.6	71	415.73	11.067	112.6	131	1250.54	16.327	68.7
12	11.11	1.944	171.2	72	426.85	11.179	111.4	132	1266.90	16.395	68.2
13	13.14	2.115	171.2	73	438.08	11.290	110.3	133	1283.33	16.463	67.8
14	15.34	2.287	171.4	74	449.43	11.400	109.2	134	1299.83	16.531	67.4
15	17.71	2.458	172.0	75	460.88	11.509	108.1	135	1316.39	16.598	67.0
16	20.26	2.631	172.6	76	472.45	11.616	107.1	136	1333.02	16.665	66.6
17	22.97	2.804	173.4	77	484.12	11.723	106.1	137	1349.72	16.731	66.2
18	25.86	2.977	174.2	78	495.89	11.829	105.1	138	1366.49	16.797	65.8
19	28.93	3.152	175.1	79	507.77	11.933	104.1	139	1383.32	16.863	65.4
20	32.17	3.327	175.9	80	519.76	12.037	103.2	140	1400.21	16.928	65.1
21	35.58	3.504	176.6	81	531.85	12.140	102.3	141	1417.17	16.993	64.7
22	39.18	3.681	177.2	82	544.04	12.241	101.4	142	1434.20	17.057	64.3
23	42.95	3.858	177.7	83	556.33	12.342	100.5	143	1451.29	17.121	64.0
24	46.89	4.036	178.1	84	568.72	12.443	99.7	144	1468.44	17.185	63.6
25	51.02	4.214	178.4	85	581.21	12.542	98.8	145	1485.66	17.249	63.2
26	55.32	4.393	178.4	86	593.80	12.640	98.0	146	1502.94	17.312	62.9
27	59.80	4.571	178.4	87	606.49	12.738	97.1	147	1520.28	17.374	62.5
28	64.46	4.749	178.2	88	619.28	12.834	96.3	148	1537.68	17.437	62.2
29	69.30	4.927	177.8	89	632.16	12.930	95.5	149	1555.15	17.499	61.8
30	74.32	5.105	177.3	90	645.14	13.025	94.7	150	1572.68	17.560	61.5
31	79.51	5.282	176.6	91	658.21	13.120	94.0	151	1590.27	17.622	61.1
32	84.88	5.458	175.8	92	671.38	13.213	93.2	152	1607.93	17.683	60.8
33	90.43	5.633	174.8	93	684.64	13.306	92.4	153	1625.64	17.743	60.4
34	96.15	5.808	173.7	94	697.99	13.398	91.6	154	1643.41	17.804	60.1
35	102.04	5.981	172.5	95	711.44	13.489	90.9	155	1661.25	17.863	59.7
36	108.11	6.153	171.2	96	724.97	13.580	90.1	156	1679.14	17.923	59.4
37	114.35	6.323	169.8	97	738.60	13.670	89.4	157	1697.09	17.982	59.0
38	120.75	6.492	168.2	98	752.31	13.759	88.7	158	1715.10	18.041	58.7
39	127.33	6.660	166.6	99	766.11	13.847	87.9	159	1733.17	18.100	58.3
40	134.07	6.825	165.0	100	780.00	13.935	87.2	160	1751.30	18.158	57.9
41	140.98	6.990	163.2	101	793.98	14.021	86.5	161	1769.49	18.215	57.5
42	148.05	7.152	161.4	102	808.05	14.108	85.7	162	1787.73	18.273	57.2
43	155.28	7.312	159.6	103	822.20	14.193	85.0	163	1806.03	18.330	56.8
44	162.68	7.471	157.7	104	836.43	14.278	84.3	164	1824.39	18.386	56.4
45	170.23	7.628	155.8	105	850.75	14.362	83.6	165	1842.81	18.443	56.0
46	177.93	7.782	153.8	106	865.15	14.445	82.9	166	1861.28	18.498	55.6
47	185.79	7.935	151.9	107	879.64	14.527	82.3	167	1879.80	18.554	55.3
48	193.80	8.086	149.9	108	894.21	14.609	81.6	168	1898.38	18.609	54.9
49	201.96	8.235	148.0	109	908.86	14.691	80.9	169	1917.02	18.664	54.5
50	210.27	8.382	146.0	110	923.59	14.771	80.2	170	1935.71	18.718	54.1
51	218.72	8.527	144.1	111	938.40	14.851	79.6	171	1954.46	18.772	53.7
52	227.32	8.670	142.2	112	953.29	14.930	78.9	172	1973.25	18.825	53.3
53	236.06	8.812	140.3	113	968.26	15.009	78.3	173	1992.11	18.878	52.9
54	244.95	8.951	138.4	114	983.31	15.087	77.7	174	2011.01	18.931	52.5
55	253.97	9.088	136.6	115	998.44	15.164	77.1	175	2029.97	18.983	52.1
56	263.12	9.224	134.8	116	1013.64	15.241	76.5	176	2048.98	19.035	51.8
57	272.41	9.358	133.0	117	1028.92	15.317	75.9	177	2068.04	19.087	51.4
58	281.84	9.490	131.3	118	1044.27	15.393	75.3	178	2087.15	19.138	51.0
59	291.39	9.621	129.6	119	1059.70	15.468	74.7	179	2106.31	19.189	50.6
60	301.08	9.749	127.9	120	1075.21	15.542	74.1	180	2125.53	19.239	50.3

Table 25. *Type KP (or EP) versus Ag–28 at% Au—thermoelectric voltage,* E(T), *Seebeck coefficient,* S(T), *and derivative of the Seebeck coefficient,* dS(T)—Continued

T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²
180	2125.53	19.239	50.3	240	3360.75	21.783	33.0				
181	2144.79	19.289	49.9	241	3382.55	21.815	32.6				
182	2164.11	19.339	49.5	242	3404.38	21.848	32.2				
183	2183.47	19.389	49.2	243	3426.25	21.880	31.9				
184	2202.88	19.438	48.9	244	3448.14	21.912	31.6				
185	2222.35	19.486	48.5	245	3470.07	21.943	31.4				
186	2241.86	19.535	48.2	246	3492.03	21.974	31.2				
187	2261.42	19.583	47.9	247	3514.02	22.005	31.0				
188	2281.02	19.630	47.6	248	3536.04	22.036	30.9				
189	2300.68	19.678	47.3	249	3558.09	22.067	30.8				
190	2320.38	19.725	47.0	250	3580.18	22.098	30.8				
191	2340.13	19.772	46.7	251	3602.29	22.129	30.9				
192	2359.92	19.818	46.4	252	3624.43	22.160	31.0				
193	2379.76	19.865	46.2	253	3646.61	22.191	31.2				
194	2399.65	19.911	45.9	254	3668.82	22.222	31.4				
195	2419.58	19.956	45.7	255	3691.05	22.254	31.7				
196	2439.56	20.002	45.5	256	3713.32	22.285	32.0				
197	2459.59	20.047	45.2	257	3735.62	22.318	32.4				
198	2479.66	20.093	45.0	258	3757.96	22.350	32.8				
199	2499.77	20.137	44.8	259	3780.32	22.383	33.2				
200	2519.93	20.182	44.6	260	3802.72	22.417	33.6				
201	2540.14	20.227	44.4	261	3825.16	22.450	34.0				
202	2560.39	20.271	44.3	262	3847.63	22.484	34.3				
203	2580.68	20.315	44.1	263	3870.13	22.519	34.6				
204	2601.02	20.359	43.9	264	3892.66	22.554	34.7				
205	2621.40	20.403	43.7	265	3915.23	22.588	34.7				
206	2641.82	20.447	43.6	266	3937.84	22.623	34.5				
207	2662.29	20.490	43.4	267	3960.48	22.657	34.1				
208	2682.80	20.534	43.2	268	3983.15	22.691	33.3				
209	2703.36	20.577	43.1	269	4005.86	22.724	32.2				
210	2723.96	20.620	42.9	270	4028.60	22.755	30.6				
211	2744.60	20.663	42.7	271	4051.37	22.785	28.4				
212	2765.28	20.705	42.6	272	4074.17	22.812	25.6				
213	2786.01	20.748	42.4	273	4096.99	22.836	22.1				
214	2806.78	20.790	42.2	274	4119.84	22.856	17.6				
215	2827.59	20.832	42.0	275	4142.70	22.871	12.1				
216	2848.44	20.874	41.8	276	4165.58	22.879	5.4				
217	2869.34	20.916	41.6	277	4188.46	22.881	-2.7				
218	2890.27	20.957	41.3	278	4211.34	22.874	-12.3				
219	2911.25	20.998	41.1	279	4234.20	22.856	-23.7				
220	2932.27	21.039	40.8	280	4257.05	22.826	-37.1				
221	2953.33	21.080	40.5								
222	2974.43	21.120	40.2								
223	2995.57	21.160	39.9								
224	3016.75	21.200	39.6								
225	3037.97	21.240	39.3								
226	3059.23	21.279	38.9								
227	3080.52	21.317	38.5								
228	3101.86	21.356	38.1								
229	3123.24	21.394	37.7								
230	3144.65	21.431	37.3								
231	3166.10	21.468	36.9								
232	3187.59	21.505	36.5								
233	3209.11	21.541	36.0								
234	3230.67	21.577	35.6								
235	3252.26	21.612	35.1								
236	3273.89	21.647	34.7								
237	3295.56	21.682	34.2								
238	3317.26	21.716	33.8								
239	3338.99	21.749	33.4								
240	3360.75	21.783	33.0								

Table 26. *Type Ag–28 at% Au versus TN (or EN)—thermoelectric voltage,* E(T), *Seebeck coefficient,* S(T), *and derivative of the Seebeck coefficient,* dS(T)

T K	E μV	S μV/K	dS/dT nV/K^2	T K	E μV	S μV/K	dS/dT nV/K^2	T K	E μV	S μV/K	dS/dT nV/K^2
0	0.00	-0.113	429.0	60	403.80	11.890	151.3	120	1369.97	20.070	125.1
1	0.10	0.301	399.5	61	415.77	12.041	150.6	121	1390.10	20.195	124.7
2	0.59	0.687	373.2	62	427.88	12.191	149.8	122	1410.36	20.320	124.4
3	1.46	1.048	349.6	63	440.15	12.341	149.1	123	1430.74	20.444	124.1
4	2.68	1.387	328.5	64	452.57	12.490	148.4	124	1451.25	20.568	123.7
5	4.23	1.706	309.7	65	465.13	12.638	147.7	125	1471.87	20.691	123.4
6	6.09	2.007	292.9	66	477.84	12.785	147.0	126	1492.63	20.815	123.0
7	8.24	2.292	278.0	67	490.70	12.932	146.4	127	1513.50	20.937	122.7
8	10.67	2.564	264.9	68	503.70	13.078	145.7	128	1534.50	21.060	122.4
9	13.36	2.822	253.2	69	516.85	13.223	145.1	129	1555.62	21.182	122.0
10	16.31	3.070	242.9	70	530.15	13.368	144.5	130	1576.87	21.304	121.7
11	19.50	3.309	233.9	71	543.59	13.512	143.9	131	1598.23	21.426	121.4
12	22.92	3.539	225.9	72	557.17	13.656	143.4	132	1619.72	21.547	121.1
13	26.57	3.761	218.9	73	570.90	13.799	142.8	133	1641.33	21.668	120.8
14	30.44	3.977	212.8	74	584.77	13.941	142.3	134	1663.05	21.788	120.5
15	34.52	4.187	207.5	75	598.78	14.083	141.8	135	1684.90	21.909	120.2
16	38.81	4.392	202.8	76	612.94	14.225	141.3	136	1706.87	22.029	119.9
17	43.31	4.593	198.7	77	627.23	14.366	140.8	137	1728.96	22.148	119.6
18	48.00	4.789	195.2	78	641.67	14.506	140.3	138	1751.17	22.268	119.3
19	52.88	4.983	192.1	79	656.25	14.647	139.9	139	1773.50	22.387	119.0
20	57.96	5.174	189.5	80	670.96	14.786	139.4	140	1795.94	22.506	118.7
21	63.23	5.362	187.2	81	685.82	14.925	139.0	141	1818.51	22.624	118.4
22	68.69	5.548	185.1	82	700.81	15.064	138.6	142	1841.19	22.743	118.1
23	74.33	5.733	183.3	83	715.95	15.203	138.2	143	1863.99	22.861	117.9
24	80.15	5.915	181.8	84	731.22	15.341	137.8	144	1886.91	22.978	117.6
25	86.16	6.096	180.4	85	746.63	15.478	137.4	145	1909.95	23.096	117.3
26	92.34	6.276	179.2	86	762.17	15.615	137.0	146	1933.10	23.213	117.1
27	98.71	6.455	178.1	87	777.86	15.752	136.6	147	1956.38	23.330	116.8
28	105.25	6.632	177.1	88	793.68	15.889	136.3	148	1979.76	23.447	116.6
29	111.97	6.809	176.2	89	809.63	16.025	135.9	149	2003.27	23.563	116.3
30	118.87	6.984	175.3	90	825.73	16.160	135.5	150	2026.89	23.679	116.0
31	125.94	7.159	174.5	91	841.95	16.296	135.2	151	2050.63	23.795	115.8
32	133.19	7.333	173.7	92	858.32	16.431	134.8	152	2074.48	23.911	115.5
33	140.61	7.507	172.9	93	874.82	16.565	134.5	153	2098.45	24.026	115.3
34	148.20	7.679	172.2	94	891.45	16.700	134.1	154	2122.53	24.141	115.0
35	155.97	7.851	171.5	95	908.21	16.834	133.8	155	2146.73	24.256	114.8
36	163.90	8.022	170.7	96	925.12	16.967	133.4	156	2171.05	24.371	114.5
37	172.01	8.193	170.0	97	942.15	17.100	133.1	157	2195.47	24.485	114.3
38	180.29	8.362	169.3	98	959.32	17.233	132.8	158	2220.02	24.600	114.0
39	188.73	8.531	168.5	99	976.62	17.366	132.4	159	2244.67	24.714	113.8
40	197.35	8.699	167.8	100	994.05	17.498	132.1	160	2269.44	24.827	113.5
41	206.13	8.867	167.0	101	1011.61	17.630	131.7	161	2294.33	24.941	113.3
42	215.08	9.033	166.2	102	1029.31	17.762	131.4	162	2319.32	25.054	113.0
43	224.20	9.199	165.4	103	1047.14	17.893	131.1	163	2344.44	25.167	112.8
44	233.48	9.364	164.6	104	1065.09	18.024	130.7	164	2369.66	25.279	112.5
45	242.93	9.528	163.8	105	1083.18	18.154	130.4	165	2394.99	25.392	112.3
46	252.54	9.692	162.9	106	1101.40	18.285	130.0	166	2420.44	25.504	112.0
47	262.31	9.854	162.1	107	1119.75	18.414	129.7	167	2446.00	25.616	111.7
48	272.25	10.016	161.3	108	1138.23	18.544	129.3	168	2471.67	25.727	111.5
49	282.34	10.177	160.4	109	1156.84	18.673	129.0	169	2497.46	25.839	111.2
50	292.60	10.337	159.6	110	1175.58	18.802	128.6	170	2523.35	25.950	110.9
51	303.01	10.496	158.7	111	1194.44	18.930	128.3	171	2549.36	26.061	110.6
52	313.59	10.654	157.9	112	1213.44	19.058	127.9	172	2575.47	26.171	110.4
53	324.32	10.811	157.0	113	1232.56	19.186	127.6	173	2601.70	26.281	110.1
54	335.21	10.968	156.2	114	1251.81	19.313	127.2	174	2628.03	26.391	109.8
55	346.26	11.124	155.3	115	1271.19	19.440	126.8	175	2654.48	26.501	109.5
56	357.46	11.279	154.5	116	1290.69	19.567	126.5	176	2681.04	26.610	109.2
57	368.81	11.433	153.7	117	1310.32	19.693	126.1	177	2707.70	26.719	108.9
58	380.32	11.586	152.9	118	1330.08	19.819	125.8	178	2734.47	26.828	108.6
59	391.99	11.739	152.1	119	1349.96	19.945	125.4	179	2761.36	26.936	108.3
60	403.80	11.890	151.3	120	1369.97	20.070	125.1	180	2788.35	27.045	108.0

Table 26. *Type Ag–28 at% Au versus TN (or EN)—thermoelectric voltage,* E(T), *Seebeck coefficient,* S(T), *and derivative of the Seebeck coefficient,* dS(T) —Continued

T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²
180	2788.35	27.045	108.0	240	4594.31	32.995	92.0				
181	2815.45	27.152	107.7	241	4627.35	33.086	91.8				
182	2842.65	27.260	107.3	242	4660.48	33.178	91.5				
183	2869.97	27.367	107.0	243	4693.71	33.269	91.3				
184	2897.39	27.474	106.7	244	4727.02	33.361	91.0				
185	2924.91	27.581	106.4	245	4760.43	33.451	90.7				
186	2952.55	27.687	106.1	246	4793.92	33.542	90.5				
187	2980.29	27.793	105.7	247	4827.51	33.632	90.2				
188	3008.13	27.898	105.4	248	4861.19	33.722	89.9				
189	3036.08	28.003	105.1	249	4894.96	33.812	89.6				
190	3064.14	28.108	104.7	250	4928.81	33.902	89.3				
191	3092.30	28.213	104.4	251	4962.76	33.991	89.0				
192	3120.57	28.317	104.1	252	4996.80	34.080	88.7				
193	3148.93	28.421	103.8	253	5030.92	34.168	88.4				
194	3177.41	28.525	103.4	254	5065.13	34.257	88.1				
195	3205.98	28.628	103.1	255	5099.43	34.344	87.8				
196	3234.66	28.731	102.8	256	5133.82	34.432	87.4				
197	3263.45	28.834	102.4	257	5168.30	34.519	87.1				
198	3292.33	28.936	102.1	258	5202.86	34.606	86.7				
199	3321.32	29.038	101.8	259	5237.51	34.693	86.4				
200	3350.41	29.139	101.5	260	5272.24	34.779	86.0				
201	3379.60	29.241	101.2	261	5307.07	34.865	85.7				
202	3408.89	29.342	100.9	262	5341.97	34.950	85.3				
203	3438.28	29.442	100.6	263	5376.97	35.036	85.0				
204	3467.77	29.543	100.3	264	5412.05	35.120	84.6				
205	3497.36	29.643	100.0	265	5447.21	35.205	84.2				
206	3527.06	29.743	99.7	266	5482.45	35.289	83.8				
207	3556.85	29.842	99.4	267	5517.79	35.372	83.4				
208	3586.74	29.942	99.1	268	5553.20	35.455	82.9				
209	3616.73	30.041	98.8	269	5588.70	35.538	82.5				
210	3646.82	30.139	98.6	270	5624.28	35.620	82.0				
211	3677.01	30.238	98.3	271	5659.94	35.702	81.5				
212	3707.30	30.336	98.0	272	5695.68	35.783	80.9				
213	3737.68	30.434	97.8	273	5731.50	35.864	80.3				
214	3768.17	30.532	97.5	274	5767.41	35.944	79.7				
215	3798.75	30.629	97.3	275	5803.39	36.023	79.0				
216	3829.42	30.726	97.1	276	5839.45	36.102	78.2				
217	3860.20	30.823	96.8	277	5875.59	36.180	77.3				
218	3891.07	30.920	96.6	278	5911.81	36.257	76.4				
219	3922.04	31.016	96.4	279	5948.11	36.332	75.3				
220	3953.10	31.113	96.2	280	5984.48	36.407	74.0				
221	3984.26	31.209	95.9								
222	4015.52	31.304	95.7								
223	4046.87	31.400	95.5								
224	4078.32	31.495	95.3								
225	4109.86	31.591	95.1								
226	4141.50	31.686	94.9								
227	4173.23	31.781	94.7								
228	4205.06	31.875	94.5								
229	4236.98	31.970	94.3								
230	4269.00	32.064	94.1								
231	4301.11	32.158	93.9								
232	4333.32	32.252	93.7								
233	4365.62	32.345	93.5								
234	4398.01	32.439	93.3								
235	4430.49	32.532	93.1								
236	4463.07	32.625	92.9								
237	4495.74	32.718	92.7								
238	4528.51	32.810	92.4								
239	4561.36	32.902	92.2								
240	4594.31	32.995	92.0								

TABLE 27. *Type Ag–28 at% Au versus KN—thermoelectric voltage,* E(T)*, Seebeck coefficient,* S(T)*, and derivative of the Seebeck coefficient,* dS(T)

T K	E μV	S μV/K	dS/dT nV/K^2	T K	E μV	S μV/K	dS/dT nV/K^2	T K	E μV	S μV/K	dS/dT nV/K^2
0	-0.22	0.430	-60.6	60	82.49	3.014	69.0	120	397.96	7.606	80.0
1	0.18	0.378	-43.2	61	85.53	3.083	69.5	121	405.60	7.686	80.0
2	0.54	0.342	-28.3	62	88.65	3.153	70.0	122	413.33	7.766	79.9
3	0.87	0.321	-15.4	63	91.84	3.223	70.5	123	421.14	7.846	79.9
4	1.19	0.311	-4.5	64	95.10	3.294	70.9	124	429.02	7.926	79.8
5	1.50	0.311	4.7	65	98.43	3.365	71.3	125	436.99	8.005	79.7
6	1.81	0.320	12.5	66	101.83	3.437	71.7	126	445.03	8.085	79.6
7	2.14	0.336	19.0	67	105.30	3.509	72.1	127	453.16	8.164	79.4
8	2.48	0.358	24.5	68	108.85	3.581	72.5	128	461.36	8.244	79.3
9	2.86	0.384	28.9	69	112.46	3.653	72.8	129	469.64	8.323	79.2
10	3.25	0.415	32.6	70	116.15	3.726	73.1	130	478.01	8.402	79.0
11	3.69	0.449	35.5	71	119.92	3.800	73.4	131	486.45	8.481	78.8
12	4.15	0.486	37.8	72	123.75	3.873	73.7	132	494.97	8.560	78.6
13	4.66	0.525	39.7	73	127.66	3.947	73.9	133	503.57	8.638	78.5
14	5.20	0.565	41.1	74	131.65	4.021	74.2	134	512.25	8.717	78.3
15	5.79	0.607	42.2	75	135.71	4.095	74.4	135	521.00	8.795	78.1
16	6.42	0.649	43.0	76	139.84	4.170	74.6	136	529.83	8.873	77.8
17	7.09	0.693	43.6	77	144.05	4.245	74.8	137	538.75	8.950	77.6
18	7.80	0.736	44.0	78	148.33	4.319	75.0	138	547.74	9.028	77.4
19	8.56	0.781	44.3	79	152.68	4.395	75.2	139	556.80	9.105	77.2
20	9.36	0.825	44.6	80	157.12	4.470	75.4	140	565.95	9.182	76.9
21	10.21	0.870	44.7	81	161.62	4.545	75.6	141	575.17	9.259	76.7
22	11.10	0.914	44.9	82	166.21	4.621	75.8	142	584.46	9.336	76.5
23	12.04	0.959	45.0	83	170.87	4.697	76.0	143	593.84	9.412	76.2
24	13.02	1.004	45.1	84	175.60	4.773	76.1	144	603.29	9.488	76.0
25	14.05	1.050	45.3	85	180.41	4.849	76.3	145	612.81	9.564	75.7
26	15.12	1.095	45.5	86	185.30	4.926	76.5	146	622.42	9.640	75.5
27	16.24	1.141	45.7	87	190.26	5.002	76.6	147	632.09	9.715	75.2
28	17.40	1.187	46.0	88	195.30	5.079	76.8	148	641.85	9.790	75.0
29	18.61	1.233	46.4	89	200.42	5.156	77.0	149	651.67	9.865	74.7
30	19.87	1.279	46.8	90	205.62	5.233	77.1	150	661.58	9.939	74.5
31	21.17	1.326	47.3	91	210.89	5.310	77.3	151	671.55	10.014	74.2
32	22.52	1.374	47.8	92	216.24	5.387	77.5	152	681.60	10.088	74.0
33	23.92	1.422	48.3	93	221.66	5.465	77.6	153	691.73	10.162	73.8
34	25.37	1.471	49.0	94	227.17	5.543	77.8	154	701.93	10.235	73.5
35	26.86	1.520	49.6	95	232.75	5.620	77.9	155	712.20	10.309	73.3
36	28.41	1.570	50.3	96	238.41	5.698	78.1	156	722.54	10.382	73.1
37	30.00	1.621	51.1	97	244.14	5.777	78.2	157	732.96	10.455	72.8
38	31.65	1.672	51.9	98	249.96	5.855	78.4	158	743.45	10.528	72.6
39	33.35	1.724	52.7	99	255.85	5.933	78.5	159	754.02	10.600	72.4
40	35.10	1.778	53.5	100	261.83	6.012	78.7	160	764.65	10.673	72.2
41	36.90	1.831	54.4	101	267.88	6.091	78.8	161	775.36	10.745	72.0
42	38.76	1.886	55.2	102	274.01	6.170	79.0	162	786.14	10.816	71.8
43	40.67	1.942	56.1	103	280.22	6.249	79.1	163	797.00	10.888	71.5
44	42.64	1.999	57.0	104	286.51	6.328	79.2	164	807.92	10.960	71.3
45	44.67	2.056	57.9	105	292.87	6.407	79.4	165	818.92	11.031	71.1
46	46.76	2.114	58.8	106	299.32	6.487	79.5	166	829.98	11.102	70.9
47	48.90	2.173	59.6	107	305.85	6.566	79.6	167	841.12	11.173	70.7
48	51.10	2.234	60.5	108	312.45	6.646	79.7	168	852.33	11.243	70.5
49	53.37	2.294	61.3	109	319.14	6.726	79.8	169	863.61	11.314	70.3
50	55.69	2.356	62.1	110	325.90	6.805	79.9	170	874.95	11.384	70.1
51	58.08	2.419	62.9	111	332.75	6.885	79.9	171	886.37	11.454	69.9
52	60.53	2.482	63.7	112	339.67	6.965	80.0	172	897.86	11.524	69.7
53	63.04	2.546	64.5	113	346.68	7.045	80.0	173	909.42	11.594	69.5
54	65.62	2.611	65.2	114	353.77	7.125	80.1	174	921.05	11.663	69.3
55	68.27	2.677	65.9	115	360.93	7.205	80.1	175	932.75	11.732	69.1
56	70.98	2.743	66.6	116	368.18	7.285	80.1	176	944.51	11.801	68.9
57	73.75	2.810	67.2	117	375.50	7.366	80.1	177	956.35	11.870	68.7
58	76.60	2.877	67.8	118	382.91	7.446	80.1	178	968.25	11.938	68.4
59	79.51	2.945	68.4	119	390.39	7.526	80.1	179	980.23	12.007	68.2
60	82.49	3.014	69.0	120	397.96	7.606	80.0	180	992.27	12.075	67.9

TABLE 27. *Type Ag–28 at% Au versus KN—thermoelectric voltage,* E(T), *Seebeck coefficient,* S(T), *and derivative of the Seebeck coefficient,* dS(T) —Continued

T K	E μV	S μV/K	dS/dT nV/K^2	T K	E μV	S μV/K	dS/dT nV/K^2	T K	E μV	S μV/K	dS/dT nV/K^2
180	992.27	12.075	67.9	240	1825.04	15.443	46.5				
181	1004.38	12.143	67.7	241	1840.51	15.490	46.2				
182	1016.55	12.210	67.4	242	1856.02	15.536	46.0				
183	1028.80	12.277	67.1	243	1871.58	15.582	45.7				
184	1041.11	12.344	66.8	244	1887.19	15.627	45.4				
185	1053.48	12.411	66.5	245	1902.84	15.672	45.0				
186	1065.93	12.477	66.2	246	1918.53	15.717	44.5				
187	1078.44	12.544	65.9	247	1934.27	15.761	44.1				
188	1091.02	12.609	65.6	248	1950.05	15.805	43.5				
189	1103.66	12.675	65.2	249	1965.88	15.848	42.9				
190	1116.37	12.740	64.8	250	1981.75	15.891	42.2				
191	1129.14	12.804	64.5	251	1997.66	15.933	41.4				
192	1141.97	12.869	64.1	252	2013.62	15.974	40.6				
193	1154.87	12.932	63.7	253	2029.61	16.014	39.7				
194	1167.84	12.996	63.2	254	2045.64	16.053	38.7				
195	1180.87	13.059	62.8	255	2061.71	16.091	37.7				
196	1193.96	13.122	62.4	256	2077.82	16.128	36.6				
197	1207.11	13.184	61.9	257	2093.97	16.164	35.4				
198	1220.32	13.245	61.5	258	2110.15	16.199	34.2				
199	1233.60	13.307	61.0	259	2126.37	16.233	33.0				
200	1246.94	13.367	60.5	260	2142.62	16.265	31.8				
201	1260.33	13.428	60.0	261	2158.90	16.296	30.6				
202	1273.79	13.487	59.5	262	2175.21	16.326	29.4				
203	1287.31	13.547	59.0	263	2191.55	16.355	28.3				
204	1300.89	13.605	58.5	264	2207.92	16.383	27.3				
205	1314.52	13.664	58.0	265	2224.32	16.410	26.4				
206	1328.21	13.721	57.4	266	2240.74	16.436	25.8				
207	1341.96	13.778	56.9	267	2257.19	16.462	25.4				
208	1355.77	13.835	56.4	268	2273.66	16.487	25.4				
209	1369.63	13.891	55.9	269	2290.16	16.512	25.8				
210	1383.55	13.947	55.4	270	2306.69	16.539	26.7				
211	1397.53	14.002	54.9	271	2323.24	16.566	28.2				
212	1411.55	14.057	54.4	272	2339.82	16.595	30.4				
213	1425.64	14.111	53.9	273	2356.43	16.627	33.5				
214	1439.78	14.164	53.4	274	2373.08	16.663	37.5				
215	1453.97	14.218	52.9	275	2389.76	16.703	42.7				
216	1468.21	14.270	52.5	276	2406.48	16.748	49.2				
217	1482.51	14.323	52.1	277	2423.26	16.801	57.2				
218	1496.86	14.374	51.6	278	2440.09	16.863	66.9				
219	1511.26	14.426	51.2	279	2456.99	16.936	78.6				
220	1525.71	14.477	50.8	280	2473.97	17.021	92.4				
221	1540.21	14.528	50.5								
222	1554.76	14.578	50.1								
223	1569.37	14.628	49.8								
224	1584.02	14.678	49.5								
225	1598.72	14.727	49.2								
226	1613.47	14.776	49.0								
227	1628.27	14.825	48.7								
228	1643.12	14.873	48.5								
229	1658.02	14.922	48.3								
230	1672.97	14.970	48.1								
231	1687.96	15.018	47.9								
232	1703.00	15.066	47.8								
233	1718.09	15.114	47.6								
234	1733.23	15.161	47.5								
235	1748.41	15.209	47.3								
236	1763.65	15.256	47.2								
237	1778.93	15.303	47.0								
238	1794.25	15.350	46.9								
239	1809.63	15.397	46.7								
240	1825.04	15.443	46.5								

TABLE 28. *Type TP versus* Ag-28 at% Au—*thermoelectric voltage,* E(T) , *Seebeck coefficient,* S(T), *and derivative of the Seebeck coefficient,* dS(T)

T K	E μV	S μV/K	dS/dT nV/K2	T K	E μV	S μV/K	dS/dT nV/K2	T K	E μV	S μV/K	dS/dT nV/K2
0	-1.39	0.222	-46.0	60	57.24	1.941	4.2	120	170.74	1.869	1.2
1	-1.19	0.178	-41.9	61	59.18	1.945	3.1	121	172.61	1.870	1.3
2	-1.03	0.138	-36.9	62	61.13	1.947	2.1	122	174.48	1.871	1.4
3	-0.91	0.104	-31.4	63	63.08	1.949	1.3	123	176.35	1.873	1.5
4	-0.82	0.076	-25.4	64	65.03	1.950	0.5	124	178.22	1.874	1.6
5	-0.76	0.054	-19.1	65	66.97	1.950	-0.3	125	180.10	1.876	1.7
6	-0.71	0.038	-12.6	66	68.92	1.949	-0.9	126	181.98	1.878	1.8
7	-0.68	0.028	-6.1	67	70.87	1.948	-1.5	127	183.85	1.879	1.9
8	-0.65	0.026	0.4	68	72.82	1.946	-2.0	128	185.73	1.881	2.0
9	-0.63	0.029	6.8	69	74.77	1.944	-2.4	129	187.62	1.883	2.1
10	-0.59	0.039	12.9	70	76.71	1.942	-2.8	130	189.50	1.885	2.2
11	-0.55	0.055	18.8	71	78.65	1.939	-3.1	131	191.39	1.888	2.3
12	-0.48	0.077	24.4	72	80.59	1.935	-3.3	132	193.28	1.890	2.5
13	-0.39	0.104	29.7	73	82.52	1.932	-3.5	133	195.17	1.893	2.6
14	-0.27	0.136	34.6	74	84.45	1.928	-3.7	134	197.06	1.895	2.7
15	-0.12	0.173	39.1	75	86.38	1.925	-3.8	135	198.96	1.898	2.9
16	0.07	0.214	43.2	76	88.30	1.921	-3.8	136	200.86	1.901	3.0
17	0.31	0.259	46.8	77	90.22	1.917	-3.9	137	202.76	1.904	3.1
18	0.59	0.307	50.1	78	92.13	1.913	-3.9	138	204.67	1.907	3.3
19	0.93	0.359	52.9	79	94.04	1.909	-3.8	139	206.57	1.911	3.4
20	1.31	0.413	55.3	80	95.95	1.906	-3.8	140	208.49	1.914	3.6
21	1.75	0.469	57.3	81	97.86	1.902	-3.7	141	210.40	1.918	3.7
22	2.25	0.528	58.9	82	99.76	1.898	-3.6	142	212.32	1.922	3.9
23	2.81	0.587	60.1	83	101.65	1.895	-3.4	143	214.25	1.926	4.1
24	3.43	0.648	61.0	84	103.55	1.891	-3.3	144	216.17	1.930	4.2
25	4.10	0.709	61.5	85	105.44	1.888	-3.1	145	218.11	1.934	4.4
26	4.84	0.771	61.7	86	107.32	1.885	-3.0	146	220.04	1.938	4.5
27	5.64	0.832	61.5	87	109.21	1.882	-2.8	147	221.98	1.943	4.7
28	6.51	0.894	61.1	88	111.09	1.880	-2.6	148	223.93	1.948	4.8
29	7.43	0.954	60.4	89	112.96	1.877	-2.4	149	225.88	1.953	4.9
30	8.42	1.014	59.5	90	114.84	1.875	-2.3	150	227.83	1.958	5.1
31	9.46	1.073	58.3	91	116.71	1.872	-2.1	151	229.79	1.963	5.2
32	10.56	1.131	57.0	92	118.59	1.870	-1.9	152	231.76	1.968	5.4
33	11.72	1.187	55.4	93	120.46	1.869	-1.7	153	233.73	1.974	5.5
34	12.94	1.242	53.7	94	122.32	1.867	-1.5	154	235.71	1.979	5.6
35	14.20	1.294	51.9	95	124.19	1.866	-1.4	155	237.69	1.985	5.7
36	15.52	1.345	49.9	96	126.05	1.864	-1.2	156	239.68	1.990	5.8
37	16.89	1.394	47.9	97	127.92	1.863	-1.0	157	241.67	1.996	5.9
38	18.31	1.441	45.8	98	129.78	1.862	-0.9	158	243.67	2.002	6.0
39	19.77	1.486	43.6	99	131.64	1.861	-0.7	159	245.67	2.008	6.1
40	21.28	1.528	41.4	100	133.50	1.861	-0.6	160	247.69	2.014	6.2
41	22.83	1.568	39.1	101	135.36	1.860	-0.5	161	249.70	2.021	6.2
42	24.42	1.606	36.8	102	137.22	1.860	-0.3	162	251.73	2.027	6.3
43	26.04	1.642	34.5	103	139.08	1.859	-0.2	163	253.76	2.033	6.4
44	27.70	1.675	32.3	104	140.94	1.859	-0.1	164	255.79	2.040	6.4
45	29.39	1.707	30.0	105	142.80	1.859	-0.0	165	257.84	2.046	6.5
46	31.11	1.736	27.8	106	144.66	1.859	0.1	166	259.89	2.053	6.5
47	32.86	1.762	25.7	107	146.52	1.859	0.2	167	261.94	2.059	6.5
48	34.64	1.787	23.6	108	148.38	1.860	0.3	168	264.00	2.066	6.5
49	36.44	1.809	21.5	109	150.24	1.860	0.4	169	266.07	2.072	6.6
50	38.26	1.830	19.5	110	152.10	1.860	0.5	170	268.15	2.079	6.6
51	40.10	1.848	17.6	111	153.96	1.861	0.5	171	270.23	2.085	6.6
52	41.95	1.865	15.8	112	155.82	1.861	0.6	172	272.32	2.092	6.6
53	43.82	1.880	14.0	113	157.68	1.862	0.7	173	274.41	2.098	6.6
54	45.71	1.893	12.3	114	159.55	1.863	0.8	174	276.52	2.105	6.6
55	47.61	1.905	10.7	115	161.41	1.864	0.8	175	278.62	2.112	6.5
56	49.52	1.915	9.2	116	163.27	1.864	0.9	176	280.74	2.118	6.5
57	51.44	1.923	7.8	117	165.14	1.865	1.0	177	282.86	2.125	6.5
58	53.37	1.930	6.5	118	167.00	1.866	1.1	178	284.99	2.131	6.5
59	55.30	1.936	5.3	119	168.87	1.867	1.1	179	287.12	2.138	6.5
60	57.24	1.941	4.2	120	170.74	1.869	1.2	180	289.26	2.144	6.5

TABLE 28. *Type TP versus* Ag–28 at% Au—*thermoelectric voltage,* E(T), *Seebeck coefficient,* S(T), *and derivative of the Seebeck coefficient,* dS(T)—Continued

T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²	T K	E μV	S μV/K	dS/dT nV/K²
180	289.26	2.144	6.5	240	431.13	2.608	6.8				
181	291.41	2.151	6.5	241	433.74	2.615	6.6				
182	293.56	2.157	6.4	242	436.36	2.621	6.5				
183	295.72	2.163	6.4	243	438.98	2.628	6.3				
184	297.89	2.170	6.4	244	441.61	2.634	6.3				
185	300.06	2.176	6.4	245	444.25	2.640	6.2				
186	302.24	2.183	6.4	246	446.89	2.647	6.2				
187	304.43	2.189	6.4	247	449.54	2.653	6.2				
188	306.62	2.196	6.4	248	452.20	2.659	6.2				
189	308.82	2.202	6.5	249	454.86	2.665	6.4				
190	311.03	2.209	6.5	250	457.53	2.672	6.5				
191	313.24	2.215	6.5	251	460.21	2.678	6.7				
192	315.46	2.222	6.6	252	462.89	2.685	7.0				
193	317.68	2.228	6.6	253	465.58	2.692	7.3				
194	319.91	2.235	6.7	254	468.27	2.700	7.7				
195	322.15	2.241	6.7	255	470.98	2.708	8.1				
196	324.39	2.248	6.8	256	473.69	2.716	8.6				
197	326.65	2.255	6.9	257	476.41	2.725	9.1				
198	328.90	2.262	7.0	258	479.14	2.734	9.7				
199	331.17	2.269	7.0	259	481.88	2.744	10.2				
200	333.44	2.276	7.1	260	484.63	2.755	10.8				
201	335.72	2.283	7.2	261	487.39	2.766	11.4				
202	338.01	2.291	7.4	262	490.16	2.777	11.9				
203	340.30	2.298	7.5	263	492.94	2.790	12.4				
204	342.61	2.306	7.6	264	495.74	2.802	12.9				
205	344.91	2.313	7.7	265	498.55	2.815	13.2				
206	347.23	2.321	7.8	266	501.37	2.829	13.3				
207	349.56	2.329	8.0	267	504.20	2.842	13.3				
208	351.89	2.337	8.1	268	507.05	2.855	12.9				
209	354.23	2.345	8.2	269	509.91	2.868	12.3				
210	356.58	2.353	8.3	270	512.79	2.879	11.2				
211	358.94	2.362	8.4	271	515.67	2.890	9.7				
212	361.30	2.370	8.6	272	518.57	2.899	7.7				
213	363.68	2.379	8.7	273	521.47	2.905	4.9				
214	366.06	2.387	8.8	274	524.37	2.908	1.4				
215	368.45	2.396	8.9	275	527.28	2.908	-3.1				
216	370.85	2.405	8.9	276	530.19	2.902	-8.6				
217	373.26	2.414	9.0	277	533.08	2.890	-15.3				
218	375.68	2.423	9.1	278	535.97	2.871	-23.4				
219	378.11	2.432	9.1	279	538.82	2.843	-33.1				
220	380.55	2.441	9.1	280	541.65	2.804	-44.6				
221	382.99	2.451	9.2								
222	385.45	2.460	9.2								
223	387.91	2.469	9.1								
224	390.39	2.478	9.1								
225	392.87	2.487	9.1								
226	395.36	2.496	9.0								
227	397.86	2.505	8.9								
228	400.37	2.514	8.8								
229	402.89	2.523	8.7								
230	405.42	2.531	8.6								
231	407.95	2.540	8.4								
232	410.50	2.548	8.2								
233	413.05	2.556	8.1								
234	415.61	2.564	7.9								
235	418.18	2.572	7.7								
236	420.75	2.580	7.5								
237	423.34	2.587	7.3								
238	425.93	2.594	7.1								
239	428.52	2.601	6.9								
240	431.13	2.608	6.8								

TABLE 29. *Type* Pt *versus* Ag–28 *at%* Au—*thermoelectric voltage*, E(T), *Seebeck coefficient*, S(T), *and derivative of the Seebeck coefficient*, dS(T)

T K	E μV	S μV/K	dS/dT nV/K^2	T K	E μV	S μV/K	dS/dT nV/K^2	T K	E μV	S μV/K	dS/dT nV/K^2
0	0.00	-1.242	264.1	60	210.61	6.421	13.2	120	537.70	3.850	-60.3
1	-1.11	-0.989	242.6	61	217.04	6.432	9.3	121	541.52	3.790	-60.2
2	-1.99	-0.756	224.6	62	223.48	6.440	5.5	122	545.28	3.730	-60.2
3	-2.63	-0.539	209.7	63	229.92	6.443	1.8	123	548.98	3.670	-60.2
4	-3.07	-0.336	197.6	64	236.36	6.443	-1.8	124	552.62	3.609	-60.1
5	-3.31	-0.143	187.8	65	242.80	6.440	-5.2	125	556.20	3.549	-60.1
6	-3.36	0.041	180.0	66	249.24	6.433	-8.5	126	559.72	3.489	-60.0
7	-3.23	0.217	174.0	67	255.67	6.423	-11.6	127	563.18	3.429	-59.9
8	-2.92	0.389	169.4	68	262.08	6.410	-14.6	128	566.58	3.370	-59.8
9	-2.45	0.557	166.1	69	268.49	6.394	-17.5	129	569.92	3.310	-59.7
10	-1.81	0.721	163.7	70	274.87	6.375	-20.2	130	573.20	3.250	-59.6
11	-1.01	0.884	162.2	71	281.24	6.353	-22.8	131	576.42	3.191	-59.4
12	-0.04	1.046	161.3	72	287.58	6.329	-25.3	132	579.58	3.131	-59.3
13	1.08	1.207	160.9	73	293.89	6.303	-27.7	133	582.68	3.072	-59.1
14	2.37	1.368	160.8	74	300.18	6.274	-29.9	134	585.72	3.013	-59.0
15	3.82	1.529	161.0	75	306.44	6.243	-32.0	135	588.71	2.954	-58.8
16	5.43	1.690	161.3	76	312.67	6.210	-34.0	136	591.63	2.895	-58.6
17	7.20	1.851	161.6	77	318.86	6.175	-35.9	137	594.50	2.837	-58.4
18	9.13	2.013	161.9	78	325.02	6.138	-37.7	138	597.30	2.779	-58.2
19	11.23	2.175	162.2	79	331.13	6.100	-39.3	139	600.05	2.721	-58.0
20	13.48	2.337	162.2	80	337.21	6.060	-40.9	140	602.75	2.663	-57.8
21	15.90	2.500	162.1	81	343.25	6.018	-42.4	141	605.38	2.605	-57.6
22	18.48	2.662	161.8	82	349.25	5.975	-43.8	142	607.96	2.548	-57.3
23	21.22	2.823	161.2	83	355.20	5.930	-45.1	143	610.47	2.490	-57.1
24	24.13	2.984	160.3	84	361.11	5.885	-46.3	144	612.94	2.433	-56.8
25	27.19	3.144	159.1	85	366.97	5.838	-47.4	145	615.34	2.377	-56.6
26	30.41	3.302	157.7	86	372.79	5.790	-48.5	146	617.69	2.320	-56.3
27	33.79	3.459	155.9	87	378.55	5.741	-49.5	147	619.98	2.264	-56.1
28	37.33	3.614	153.9	88	384.27	5.691	-50.4	148	622.22	2.208	-55.8
29	41.02	3.767	151.5	89	389.93	5.640	-51.2	149	624.40	2.152	-55.5
30	44.86	3.917	148.8	90	395.55	5.588	-52.0	150	626.52	2.097	-55.2
31	48.85	4.064	145.9	91	401.11	5.536	-52.8	151	628.59	2.042	-55.0
32	52.99	4.208	142.7	92	406.62	5.483	-53.5	152	630.61	1.987	-54.7
33	57.27	4.349	139.2	93	412.07	5.429	-54.1	153	632.57	1.933	-54.4
34	61.69	4.487	135.6	94	417.48	5.375	-54.7	154	634.47	1.878	-54.1
35	66.24	4.620	131.6	95	422.82	5.320	-55.2	155	636.32	1.824	-53.8
36	70.93	4.750	127.5	96	428.12	5.264	-55.7	156	638.12	1.771	-53.5
37	75.74	4.875	123.2	97	433.35	5.208	-56.2	157	639.86	1.717	-53.3
38	80.68	4.996	118.7	98	438.53	5.152	-56.6	158	641.56	1.664	-53.0
39	85.73	5.113	114.1	99	443.66	5.095	-57.0	159	643.19	1.611	-52.7
40	90.90	5.225	109.4	100	448.72	5.038	-57.4	160	644.78	1.559	-52.4
41	96.18	5.332	104.5	101	453.73	4.980	-57.7	161	646.31	1.506	-52.2
42	101.56	5.434	99.6	102	458.68	4.923	-58.0	162	647.79	1.454	-51.9
43	107.04	5.531	94.6	103	463.58	4.864	-58.3	163	649.22	1.403	-51.6
44	112.62	5.623	89.5	104	468.41	4.806	-58.6	164	650.60	1.351	-51.4
45	118.29	5.710	84.4	105	473.19	4.747	-58.8	165	651.92	1.300	-51.1
46	124.04	5.792	79.3	106	477.91	4.688	-59.0	166	653.20	1.249	-50.8
47	129.87	5.868	74.2	107	482.57	4.629	-59.2	167	654.42	1.198	-50.6
48	135.77	5.940	69.1	108	487.17	4.570	-59.4	168	655.59	1.148	-50.3
49	141.75	6.007	64.0	109	491.71	4.511	-59.5	169	656.72	1.098	-50.1
50	147.79	6.068	59.0	110	496.19	4.451	-59.7	170	657.79	1.048	-49.9
51	153.88	6.125	54.0	111	500.61	4.391	-59.8	171	658.81	0.998	-49.6
52	160.03	6.176	49.1	112	504.97	4.331	-59.9	172	659.78	0.948	-49.4
53	166.23	6.223	44.3	113	509.27	4.272	-60.0	173	660.71	0.899	-49.2
54	172.48	6.265	39.5	114	513.51	4.211	-60.1	174	661.58	0.850	-49.0
55	178.76	6.302	34.9	115	517.69	4.151	-60.1	175	662.41	0.801	-48.7
56	185.08	6.334	30.3	116	521.82	4.091	-60.2	176	663.18	0.752	-48.5
57	191.43	6.363	25.9	117	525.88	4.031	-60.2	177	663.91	0.704	-48.3
58	197.80	6.386	21.5	118	529.88	3.971	-60.2	178	664.59	0.656	-48.1
59	204.20	6.406	17.3	119	533.82	3.911	-60.3	179	665.22	0.608	-47.9
60	210.61	6.421	13.2	120	537.70	3.850	-60.3	180	665.81	0.560	-47.7

TABLE 29. *Type* Pt *versus* Ag–28 *at%* Au—*thermoelectric voltage,* E(T), *Seebeck coefficient,* S(T), *and derivative of the Seebeck coefficient,* dS(T)—Continued

T K	E μV	S μV/K	dS/dT nV/K2	T K	E μV	S μV/K	dS/dT nV/K2	T K	E μV	S μV/K	dS/dT nV/K2
180	665.81	0.560	-47.7	240	621.33	-1.915	-36.2				
181	666.34	0.512	-47.5	241	619.39	-1.951	-36.1				
182	666.83	0.465	-47.3	242	617.43	-1.987	-36.1				
183	667.27	0.418	-47.1	243	615.42	-2.023	-36.0				
184	667.67	0.371	-46.9	244	613.38	-2.059	-35.9				
185	668.02	0.324	-46.7	245	611.30	-2.095	-35.8				
186	668.32	0.277	-46.5	246	609.19	-2.131	-35.7				
187	668.57	0.231	-46.3	247	607.04	-2.166	-35.5				
188	668.78	0.185	-46.1	248	604.86	-2.202	-35.4				
189	668.94	0.139	-45.9	249	602.64	-2.237	-35.2				
190	669.06	0.093	-45.7	250	600.38	-2.272	-35.0				
191	669.13	0.047	-45.5	251	598.09	-2.307	-34.7				
192	669.15	0.002	-45.3	252	595.77	-2.342	-34.5				
193	669.13	-0.043	-45.1	253	593.41	-2.376	-34.2				
194	669.07	-0.088	-44.9	254	591.02	-2.410	-33.8				
195	668.95	-0.133	-44.7	255	588.59	-2.444	-33.4				
196	668.80	-0.178	-44.4	256	586.13	-2.477	-33.0				
197	668.60	-0.222	-44.2	257	583.64	-2.510	-32.6				
198	668.36	-0.266	-44.0	258	581.11	-2.542	-32.2				
199	668.07	-0.310	-43.8	259	578.55	-2.574	-31.7				
200	667.74	-0.354	-43.5	260	575.96	-2.605	-31.2				
201	667.36	-0.397	-43.3	261	573.34	-2.636	-30.7				
202	666.94	-0.440	-43.0	262	570.69	-2.667	-30.2				
203	666.48	-0.483	-42.8	263	568.01	-2.697	-29.8				
204	665.98	-0.526	-42.6	264	565.30	-2.726	-29.4				
205	665.43	-0.568	-42.3	265	562.55	-2.756	-29.0				
206	664.84	-0.610	-42.0	266	559.78	-2.784	-28.8				
207	664.21	-0.652	-41.8	267	556.99	-2.813	-28.6				
208	663.54	-0.694	-41.5	268	554.16	-2.842	-28.6				
209	662.82	-0.735	-41.3	269	551.30	-2.871	-28.9				
210	662.07	-0.776	-41.0	270	548.42	-2.900	-29.3				
211	661.27	-0.817	-40.7	271	545.50	-2.929	-30.1				
212	660.43	-0.858	-40.5	272	542.56	-2.960	-31.2				
213	659.55	-0.898	-40.2	273	539.58	-2.992	-32.7				
214	658.63	-0.938	-40.0	274	536.57	-3.025	-34.7				
215	657.68	-0.978	-39.7	275	533.53	-3.061	-37.3				
216	656.68	-1.018	-39.5	276	530.45	-3.100	-40.6				
217	655.64	-1.057	-39.2	277	527.33	-3.143	-44.7				
218	654.56	-1.096	-39.0	278	524.16	-3.190	-49.6				
219	653.45	-1.135	-38.8	279	520.95	-3.242	-55.7				
220	652.29	-1.174	-38.5	280	517.68	-3.302	-62.9				
221	651.10	-1.212	-38.3								
222	649.87	-1.251	-38.1								
223	648.60	-1.289	-37.9								
224	647.29	-1.326	-37.8								
225	645.95	-1.364	-37.6								
226	644.56	-1.402	-37.4								
227	643.14	-1.439	-37.3								
228	641.69	-1.476	-37.1								
229	640.19	-1.513	-37.0								
230	638.66	-1.550	-36.9								
231	637.09	-1.587	-36.8								
232	635.49	-1.624	-36.7								
233	633.84	-1.660	-36.6								
234	632.16	-1.697	-36.5								
235	630.45	-1.733	-36.5								
236	628.70	-1.770	-36.4								
237	626.91	-1.806	-36.3								
238	625.09	-1.843	-36.3								
239	623.22	-1.879	-36.2								
240	621.33	-1.915	-36.2								

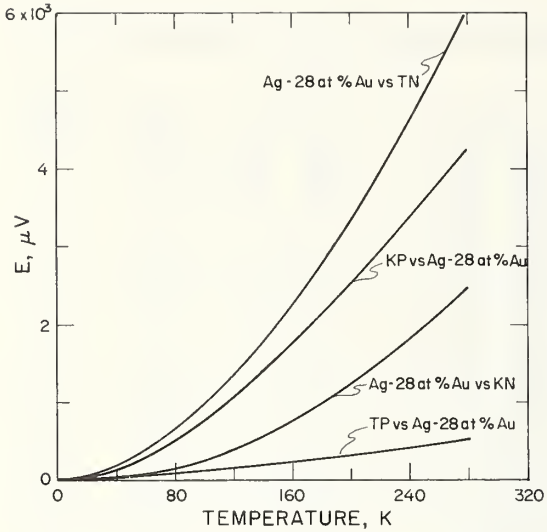

FIGURE 17. *Thermoelectric voltage for thermocouple materials versus Ag-28 at% Au.*

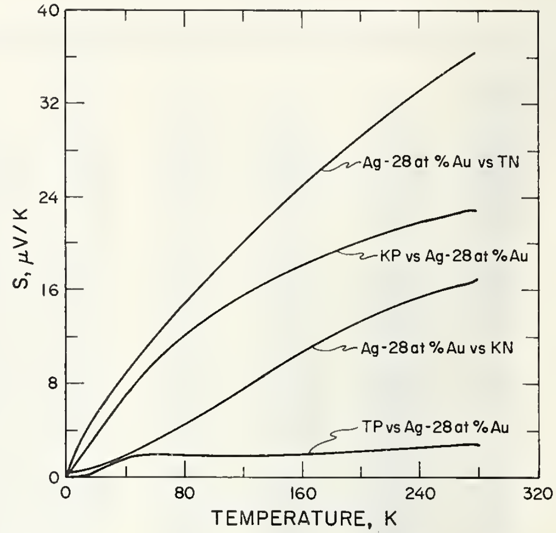

FIGURE 18. *Seebeck coefficient for thermocouple materials* versus *Ag-28 at% Au.*

TABLE 30. *Orthonormal polynomials,* $F_n(T)$

$$F(1) = 2.62695799729*10^{-3}\ T$$

$$F(2) = [3.21644559388*10^{-5}\ T - 1.11692313742*10^{-2}]\ T$$

$$F(3) = [(3.58994672085*10^{-7}\ T - 1.55668898366*10^{-4})\ T + 1.81141779139*10^{-2}]\ T$$

$$F(4) = [([5.34771916750*10^{-9}\ T - 3.05001967653*10^{-6}]\ T + 5.54667177985*10^{-4})\ T - 3.34658422520*10^{-2}]\ T$$

$$F(5) = [([(6.07172355876*10^{-11}\ T - 4.27432761250*10^{-8})\ T + 1.07134115475*10^{-5}]\ T - 1.13778202262*10^{-3})\ T + 4.64639951890*10^{-2}]\ T$$

$$F(6) = [([([8.82401710220*10^{-13}\ T - 7.28215534531*10^{-10}]\ T + 2.24773793974*10^{-7})\ T - 3.18955000427*10^{-5}]\ T + 2.05440454443*10^{-3})\ T - 5.17932580803*10^{-2}]\ T$$

$$F(7) = [([([(1.33824606626*10^{-14}\ T - 1.32028601056*10^{-11})\ T + 5.13259305511*10^{-9}]\ T - 9.93311925650*10^{-7})\ T + 9.91984763183*10^{-5}]\ T - 4.75613476303*10^{-3})\ T + 8.88013836676*10^{-2}]\ T$$

$$F(8) = [([([([1.91132074699*10^{-16}\ T - 2.16764477633*10^{-13}]\ T + 1.00343183849*10^{-10})\ T - 2.43627536044*10^{-8}]\ T + 3.31511839310*10^{-6})\ T - 2.49812576663*10^{-4}]\ T + 9.57751308277*10^{-3})\ T - 1.50632954813*10^{-1}]\ T$$

$$F(9) = [([([([(2.92699640234*10^{-18}\ T - 3.70260683908*10^{-15})\ T + 1.95728888009*10^{-12}]\ T - 5.60626859326*10^{-10})\ T + 9.43455906591*10^{-8}]\ T - 9.46059087662*10^{-6})\ T + 5.47509430874*10^{-4}]\ T - 1.67843839799*10^{-2})\ T + 2.24865631061*10^{-1}]\ T$$

$$F(10) = [([([([([3.95878009884*10^{-20}\ T - 5.60672761438*10^{-17}]\ T + 3.38846529678*10^{-14})\ T - 1.14017603261*10^{-11}]\ T + 2.33739535638*10^{-9})\ T - 3.00235955099*10^{-7}]\ T + 2.39472835021*10^{-5})\ T - 1.13608914666*10^{-3}]\ T + 2.93503055072*10^{-2})\ T - 3.46577248522*10^{-1}]\ T$$

$$F(11) = [([([([([(5.38594950415*10^{-22}\ T - 8.32449251443*10^{-19})\ T + 5.56752245363*10^{-16}]\ T - 2.11081095546*10^{-13})\ T + 4.99305085248*10^{-11}]\ T - 7.64533953636*10^{-9})\ T + 7.61388315316*10^{-7}]\ T - 4.83235619795*10^{-5})\ T + 1.86364817796*10^{-3}]\ T - 4.00502423767*10^{-2})\ T + 4.09600033130*10^{-1}]\ T$$

$$F(12) = [([([([([([8.26258016537*10^{-24}\ T - 1.39945594083*10^{-20}]\ T + 1.03888019552*10^{-17})\ T - 4.44103690669*10^{-15}]\ T + 1.20799873313*10^{-12})\ T - 2.18091879863*10^{-10}]\ T + 2.64614938335*10^{-8})\ T - 2.13892665858*10^{-6}]\ T + 1.11908345512*10^{-4})\ T - 3.59445386267*10^{-3}]\ T + 6.49375809159*10^{-2})\ T - 5.70520840814*10^{-1}]\ T$$

$$F(13) = [([([([([([(1.25468717991*10^{-25}\ T - 2.30116953479*10^{-22})\ T + 1.87050454270*10^{-19}]\ T - 8.87619885518*10^{-17})\ T + 2.72633781444*10^{-14}]\ T - 5.67992988009*10^{-12})\ T + 8.17885879975*10^{-10}]\ T - 8.14236157658*10^{-8})\ T + 5.51694463147*10^{-6}]\ T - 2.46137502017*10^{-4})\ T + 6.83930829183*10^{-3}]\ T - 1.08276043179*10^{-1})\ T + 8.45979503380*10^{-1}]\ T$$

$$F(14) = [([([([([([([1.85361805469*10^{-27}\ T - 3.66118430728*10^{-24}]\ T + 3.23511219579*10^{-21})\ T - 1.68774968707*10^{-18}]\ T + 5.77794561728*10^{-16})\ T - 1.36468119697*10^{-13}]\ T + 2.27608365626*10^{-11})\ T - 2.69817191322*10^{-9}]\ T + 2.25821878327*10^{-7})\ T - 1.30846653820*10^{-5}]\ T + 5.06904044529*10^{-4})\ T - 1.24174854893*10^{-2}]\ T + 1.76141425155*10^{-1})\ T - 1.25341332333]\ T$$

TABLE 31. *Orthonormal polynomial coefficients for thermocouple types T, E, K,* Pt *versus TP, KP (or EP) versus* Pt, *and* Pt *versus KN*; E = f(T)

Orthogonal polynomial coefficients	Thermocouple Type					
	T	E	K	Pt versus TP	KP versus Pt	Pt versus KN
A_0	0.0	0.0	0.0	1.39	0.79	−0.22
A(1)	10,673.449	16,803.073	11,244.719	−442.405	6572.181	4672.551
A(2)	1,947.339	2,969.618	2,174.984	−695.540	1717.903	457.074
A(3)	−158.363	−404.812	−297.765	−123.572	−122.875	−174.884
A(4)	44.549	65.116	5.348	107.723	−87.182	92.560
A(5)	−34.604	−22.801	−4.536	−45.512	57.285	−61.819
A(6)	11.028	3.257	−0.486	3.506	−11.373	10.886
A(7)	−0.281	1.746	2.117	5.395	−3.425	5.557
A(8)	−2.977	−1.931	−1.922	−4.032	5.110	−7.052
A(9)	2.087	0.340	0.780	0.601	−2.236	3.026
A(10)	−1.098	.107	−0.288	1.034	0.262	−0.555
A(11)	−0.055	−.720		−1.055	.445	−.587
A(12)	.558	.581		0.635	−.609	.822
A(13)	−.641	−.348				
A(14)	.430					

TABLE 32. *Orthonormal polynomial coefficients for thermocouple types* Pt *versus TN (or EN), KP (or EP) versus* Ag-28 *at%* Au, Ag-28 *at%* Au *versus KN, TP versus* Ag-28 *at%* Au, Ag-28 *at%* Au *versus TN (or EN), and* Pt *versus* Ag-28 *at%* Au; E = f(T)

Orthogonal polynomial coefficients	Thermocouple Type					
	Pt versus TN	KP versus Ag-28 Au	Ag-28 Au versus KN	TP versus Ag-28 Au	Ag-28 Au versus TN	Pt versus Ag-28 Au
A_0	0.0	0.79	−0.22	−1.39	0.0	0.0
A(1)	10,230.996	6,956.840	4,287.892	827.064	9,846.336	384.659
A(2)	1,251.750	1,107.199	1,067.778	84.835	1,862.454	−610.705
A(3)	−281.919	−246.253	−51.506	0.194	−158.541	−123.378
A(4)	152.320	47.181	−41.803	26.640	17.957	134.363
A(5)	−80.096	−12.833	8.299	−24.606	−9.978	−70.118
A(6)	14.588	−0.096	−0.391	7.771	3.310	11.277
A(7)	5.157	2.649	−.517	0.679	−0.917	6.074
A(8)	−7.032	−2.283	.342	−3.361	.361	−7.393
A(9)	2.637	1.069	−.279	2.704	−.668	3.305
A(10)	−0.111	−0.365	.072	−1.661	.516	−0.627
A(11)	−1.147	−.216	.074	0.394	−.486	−.661
A(12)	1.178	.111	.102	.085	.458	.720
A(13)	−0.681	−.511	.511	−.511	−.170	−.511
A(14)						

Table 33. *Standard deviations* (μV) *of reduced order fits for thermocouple types T, E, K,* Pt *versus TP, KP (or EP) versus* Pt, *and* Pt *versus KN*; E=f(T)

Number of coefficients	Approximate Standard Deviation					
	T	E	K	Pt versus TP	KP versus Pt	Pt versus KN
4	5	3	1	6	8	9
5	1.6	0.6	0.5	1.1	1.7	2
6	0.7	.5	.4	1.0	0.9	1.2
7	.6	.4	.3	0.6	.8	1.0
8	.4	.2	.13	.3	.4	0.4
9	.3	.19	.09	.2	.16	.18
10	.2	.18	.08	.19	.15	.17
11	.15	.15		.13	.13	.15
12	.13	.13		.10	.11	.10
13	.09	.12				
14	.07					

Table 34. *Standard deviations* (μV) *of reduced order fits for thermocouple types* Pt *versus TN (or EN), KP (or EP) versus* Ag-28 *at%* Au, Ag-28 *at%* Au *versus KN, TP versus* Ag-28 *at%* Au, Ag-28 *at%* Au *versus TN (or EN), and* Pt *versus* Ag-28 *at%* Au; E=f(T)

Number of coefficients	Approximate Standard Deviation					
	Pt versus TN	KP versus Ag-28 Au	Ag-28 Au versus KN	TP versus Ag-28 Au	Ag-28 Au versus TN	Pt versus Ag-28 Au
4	11	13	14	12	15	10
5	3	3	3	3	4	2
6	1.3	1.7	1.9	1.8	2	1.4
7	1.1	1.4	1.5	1.3	1.6	1.1
8	0.6	0.7	0.7	0.6	0.8	0.5
9	0.5	0.4	0.5	0.4	0.6	0.18
10	0.4	0.3	0.4	0.3	0.5	0.16
11	0.3	0.2	0.3	0.2	0.4	0.14
12	0.15	0.15	0.14	0.14	0.18	0.09
13	0.12	0.08	0.08	0.08	0.15	0.08
14		0.07	0.07	0.07	0.07	0.07
15		0.06	0.06	0.06	0.06	0.06
16		0.05	0.05	0.05	0.05	0.05

Table 35. *Number of digits necessary in computations to reduce round-off errors below certain limits for thermocouple types E, K, and T*

Error criteria (microvolts)	Number of digits necessary for thermocouple					
	Type E		Type K		Type T	
	binary	decimal	binary	decimal	binary	decimal
0.01	33	10	26	8	38	12
0.1	29	9	24	8	35	11
1	24	8	24	8	32	10
50					24	8

TABLE 36. *Power series coefficients for thermocouple types T, E, K,* Pt *versus TP, KP (or EP) versus* Pt, *and* Pt *versus KN;* E=f(T)

Power Series Coefficients	THERMOCOUPLE TYPE T	E	K	Pt vs TP	KP vs Pt	Pt vs KN
B_0	0.0	0.0	0.0	1.39	0.79	-0.22
B(1)	$-3.9974007864 \times 10^{-1}$	$-2.0344697205 \times 10^{-1}$	$2.4061140104 \times 10^{-1}$	-1.4640952167	$8.8156405460 \times 10^{-1}$	$-8.1278243433 \times 10^{-1}$
B(2)	$2.6329515981 \times 10^{-1}$	$3.0220985715 \times 10^{-1}$	$7.3438313272 \times 10^{-2}$	$1.5504530215 \times 10^{-1}$	$-9.3936984428 \times 10^{-3}$	$1.0177014774 \times 10^{-1}$
B(3)	$-9.6491216443 \times 10^{-3}$	$-5.7844373965 \times 10^{-3}$	$1.2873437647 \times 10^{-3}$	$-4.5229974840 \times 10^{-3}$	$1.0764263734 \times 10^{-3}$	$-8.0117882598 \times 10^{-4}$
B(4)	$3.8973308068 \times 10^{-4}$	$1.7879650162 \times 10^{-4}$	$-2.2622572598 \times 10^{-6}$	$1.2567399648 \times 10^{-4}$	$-4.7301010528 \times 10^{-6}$	$5.5069534221 \times 10^{-6}$
B(5)	$-9.8186150331 \times 10^{-6}$	$-3.6597667313 \times 10^{-6}$	$2.1765238991 \times 10^{-7}$	$-2.2941953771 \times 10^{-6}$	$1.2205104205 \times 10^{-6}$	$-1.5634107516 \times 10^{-6}$
B(6)	$1.6059280063 \times 10^{-7}$	$4.9073685405 \times 10^{-8}$	$-1.3304091711 \times 10^{-9}$	$2.6472001924 \times 10^{-8}$	$-1.7091960951 \times 10^{-8}$	$2.2462807756 \times 10^{-8}$
B(7)	$-1.7932074012 \times 10^{-9}$	$-4.4751468891 \times 10^{-10}$	$5.2493539029 \times 10^{-12}$	$-2.0080565850 \times 10^{-10}$	$1.4643113188 \times 10^{-10}$	$-1.9463792863 \times 10^{-10}$
B(8)	$1.4080710479 \times 10^{-11}$	$2.8331235582 \times 10^{-12}$	$-1.2997123230 \times 10^{-14}$	$1.0216975122 \times 10^{-12}$	$-8.1100019449 \times 10^{-13}$	$1.0850459226 \times 10^{-12}$
B(9)	$-7.8671373053 \times 10^{-14}$	$-1.2476596612 \times 10^{-14}$	$1.8403309812 \times 10^{-17}$	$-3.4633267717 \times 10^{-16}$	$2.9294552976 \times 10^{-16}$	$-3.9356803254 \times 10^{-16}$
B(10)	$3.1144995156 \times 10^{-16}$	$3.7536769066 \times 10^{-17}$	$-1.1382797374 \times 10^{-20}$	$7.5154929578 \times 10^{-18}$	$-6.6830987502 \times 10^{-18}$	$9.0024388333 \times 10^{-18}$
B(11)	$-8.5433550766 \times 10^{-19}$	$-7.3627479508 \times 10^{-20}$		$-9.4542089558 \times 10^{-21}$	$8.7574467586 \times 10^{-21}$	$-1.1814675379 \times 10^{-20}$
B(12)	$1.5448411036 \times 10^{-21}$	$8.4898427718 \times 10^{-23}$		$5.2465132898 \times 10^{-24}$	$-5.0290738536 \times 10^{-24}$	$6.7889721524 \times 10^{-24}$
B(13)	$-1.6565456476 \times 10^{-24}$	$-4.3671808488 \times 10^{-26}$				
B(14)	$7.9795893156 \times 10^{-28}$					

TABLE 37. *Power series coefficients for thermocouple types* Pt *versus TN, KP (or EP) versus* Ag–28 *at%* Au, Ag–28 *at%* Au *versus KN, TP versus* Ag–28 *at%* Au, Ag–28 *at%* Au *versus TN (or EN), and* Pt *versus* Ag–28 *at%* Au; E=f(T)

Power Series Coefficients	THERMOCOUPLE TYPE Pt vs TN	KP vs Ag-28 Au	Ag-28 Au vs KN	TP vs Ag-28 Au	Ag-28 Au vs TN	Pt vs Ag-28 Au
B_0	0.0	0.79	-0.22	-1.39	0.0	0.0
B(1)	-1.3554899994	$-3.6076071398 \times 10^{-1}$	$4.2954233425 \times 10^{-1}$	$2.2177044812 \times 10^{-1}$	$-1.1316523082 \times 10^{-1}$	-1.2423247686
B(2)	$3.4652834771 \times 10^{-1}$	$1.2265257221 \times 10^{-1}$	$-3.0276122916 \times 10^{-2}$	$-2.2999031492 \times 10^{-2}$	$2.1448207706 \times 10^{-1}$	$1.3204627066 \times 10^{-1}$
B(3)	$-9.0819255844 \times 10^{-3}$	$-2.8340569492 \times 10^{-3}$	$3.1093044966 \times 10^{-3}$	$6.1251416150 \times 10^{-4}$	$-5.1714422619 \times 10^{-3}$	$-3.9104833225 \times 10^{-3}$
B(4)	$3.0641502305 \times 10^{-4}$	$1.2050049774 \times 10^{-4}$	$-1.1273197404 \times 10^{-4}$	$4.2127511783 \times 10^{-6}$	$1.3861351479 \times 10^{-4}$	$1.6780150826 \times 10^{-4}$
B(5)	$-6.6872307885 \times 10^{-6}$	$-2.9451112757 \times 10^{-6}$	$2.6022109446 \times 10^{-6}$	$-1.8714263191 \times 10^{-6}$	$-2.5216090923 \times 10^{-6}$	$-4.1656216962 \times 10^{-6}$
B(6)	$9.2918751551 \times 10^{-8}$	$4.4522461939 \times 10^{-8}$	$-3.9151615135 \times 10^{-8}$	$3.5142420967 \times 10^{-8}$	$3.1304328660 \times 10^{-8}$	$6.1614422891 \times 10^{-8}$
B(7)	$-8.6343935330 \times 10^{-10}$	$-4.4656334954 \times 10^{-10}$	$3.9835655279 \times 10^{-10}$	$-3.9218882292 \times 10^{-10}$	$-2.7044487188 \times 10^{-10}$	$-5.9299448143 \times 10^{-10}$
B(8)	$5.5205042407 \times 10^{-12}$	$3.0681256239 \times 10^{-12}$	$-2.7940798957 \times 10^{-12}$	$2.8574283062 \times 10^{-12}$	$1.6413784223 \times 10^{-12}$	$3.8791258184 \times 10^{-12}$
B(9)	$-2.4433756717 \times 10^{-14}$	$-1.4533910778 \times 10^{-14}$	$1.3527685750 \times 10^{-14}$	$-1.4000039304 \times 10^{-14}$	$-6.9703906420 \times 10^{-16}$	$-1.7463366075 \times 10^{-14}$
B(10)	$7.3673482545 \times 10^{-17}$	$4.6715512210 \times 10^{-17}$	$-4.4396172127 \times 10^{-17}$	$4.5883118002 \times 10^{-17}$	$2.0274871585 \times 10^{-17}$	$5.3398610960 \times 10^{-17}$
B(11)	$-1.4456806816 \times 10^{-19}$	$-9.7332490028 \times 10^{-20}$	$9.4275261408 \times 10^{-20}$	$-9.6635727831 \times 10^{-20}$	$-3.8478131369 \times 10^{-20}$	$-1.0608993679 \times 10^{-19}$
B(12)	$1.6654864402 \times 10^{-22}$	$1.1860116875 \times 10^{-22}$	$-1.1684127045 \times 10^{-22}$	$1.1838372931 \times 10^{-22}$	$4.2918401418 \times 10^{-23}$	$1.2363024260 \times 10^{-22}$
B(13)	$-8.5503285099 \times 10^{-26}$	$-6.4163759372 \times 10^{-26}$	$6.4163759372 \times 10^{-26}$	$-6.4163759372 \times 10^{-26}$	$-2.1339525727 \times 10^{-26}$	$-6.4163759372 \times 10^{-26}$
B(14)						

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Appendix A. Standard designations for thermocouples

ANSI, ASTM, and ISA (American National Standards Institute, American Society for Testing and Materials, and Instrument Society of America, respectively) have adopted the following letter designations for thermocouples described in this monograph:

THERMOCOUPLE COMBINATIONS:

The positive thermoelectric material is conventionally written first.

Type E	Nickel-chromium alloy versus copper-nickel alloy.
Type K	Nickel-chromium alloy versus nickel-aluminum alloy.
Type T	Copper versus copper-nickel alloy.

SINGLE-LEG WIRES:

——N	The negative wire in a combination.
——P	The positive wire in a combination.
EN or TN	A copper-nickel alloy, often referred to as Adams' constantan; Advance[1], Cupron[4], nominally 55 wt% Cu, 45% Ni.

EP or KP — A nickel-chromium alloy, often referred to as Chromel[2]; *T*−1[1], ThermoKanthal *KP*[3], Tophel[4]; nominally 90% Ni, 10% Cr.

KN — A nickel-aluminum alloy, often referred to as Alumel[2]; *T*−2[1], ThermoKanthal *KN*[3], Nial[4]; nominally 95% Ni, 2% Al, 2% Mn, 1% Si.

TP — Copper, usually Electrolytic Tough Pitch.

Registered Trademarks:

[1] Trademark—Driver-Harris Co.
[2] Trademark—Hoskins Manufacturing Co.
[3] Trademark—Kanthal Corp.
[4] Trademark—Wilbur B. Driver Co.

The use of trade names does not constitute an endorsement of any manufacturer's products. All materials manufactured in compliance with the established thermoelectric voltage standards are equally acceptable.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

The experimental program to establish low-temperature reference tables for the commonly used thermocouples has been completed. Details of the experimental system, instrumentation, data analysis, error analysis, and materials tested are given in order to allow the user to better evaluate and apply the results. The results presented here include:

(1) Reference tables for thermocouple types E, K, and T, both as $E = f(T)$ and $T = f(E)$. The shorter $f(E)$ tables have a 0°C (273.15 K) reference temperature while all other tables have a 0 K reference temperature.

(2) Reference tables for Pt and Ag - 28 at % Au vs the materials used in thermocouple types E, K, and T. These data are presented as $E = f(T)$ only.

(3) Orthogonal polynomials and the associated coefficients necessary to generate the data with reduced order approximations.

(4) Power series coefficients for full precision reproduction of the reference data.

The data presented in the $E = f(T)$ tables cover the temperature range from 0 to 280 K. The $T = f(E)$ tables cover the temperature ranges from 273.15 K down to the lowest temperatures allowed by table resolution.

17. KEY WORDS (Alphabetical order, separated by semicolons) Cryogenics; homogeneity tests; liquid helium; liquid hydrogen; liquid nitrogen; thermocouples.

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