

Modified 1913 Reference Tables for Iron-Constantan Thermocouples

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An investigation was made of the characteristics of iron-constantan thermocouples typical of those being supplied to reproduce the standard temperature-electromotive force relationship that was established commercially in 1913. Using the calibration of the thermocouple that most nearly matched the 1913 reference table over the range to which iron-constantan thermocouples usually are limited (32° to $1,400^{\circ}$ F), a slightly different temperature-electromotive force relationship was derived which is more nearly realizable by commercially available materials. The new relationship is presented in four mutually consistent tables covering the range, -320° to $+1,600^{\circ}$ F (-196° to $+871^{\circ}$ C), in both Fahrenheit and Celsius units and with both temperature and electromotive force as arguments.

1. Introduction

The application of thermocouples to pyrometry has been accompanied by the development of indicating instruments (millivoltmeters, potentiometers) with scales calibrated so as to indicate temperature directly. Such scale calibration requires a knowledge of the temperature-emf relationship of the associated thermocouple. In general, the thermocouple is required to be readily replaceable, whereas the associated indicator is relatively long-lived. It is not practical to alter the scale of the indicator to allow for changes in the characteristics of the thermocouples used with it. Consequently, each manufacturer of a given type of thermoelectric pyrometer calibrates the scales of the indicator in accordance with a definite temperature-emf relationship (reference table) and undertakes to furnish replacement thermocouples that satisfy this relationship within certain narrow limits.

Several reference tables have existed in the past for each of the common thermocouples, each supplier adopting, for a given type of thermocouple, a table (or sometimes two) that was thought to represent closely the thermocouples supplied by that company. Thus, a partial survey in 1937 showed the existence of four reference tables for iron-constantan thermocouples, differing from each other by as much as 7 percent.

In the years 1933 to 1938, the National Bureau of Standards published reference tables for all of the common thermocouples [1, 2, 3].^{1,2} These tables were based on laboratory calibrations of numerous representative samples of these thermocouples. The tables in RP530 for platinum-platinum rhodium and those in RP1080 for copper-constantan were based on older tables and soon were widely accepted. The tables for chromel-alumel in RP767 likewise were widely accepted. Here, the situation was simplified by the fact that all chromel-P and alumel originates with one producer who prepares these alloys to a single set of specifications.

On the other hand, the tables for iron-constantan thermocouples published in RP1080 were the result of an investigation that began after another Government agency had noted that the NBS calibrations of iron-constantan thermocouples being purchased in the early 1930's did not match closely any existing reference table. The reference table in RP1080 represented an average of the commercially available thermocouples tested at that time and, hence, did not resemble closely any of the older tables for this type of thermocouple. RP1080 showed the manufacturers the necessity of either (1) altering the scales of new indicators, and of some existing ones, to conform to a temperature-emf relationship that was representative of the thermocouples actually being produced (RP1080), or (2) to develop new thermocouple materials that would have, within the desired tolerances, the temperature-emf relationship embodied in the scales of the existing indicators. Most of the manufacturers chose the latter course. Users with large investments in installed indicators were satisfied with this development, and the RP1080 table has not displaced the previous tables to any great extent, although it is the only table used for iron-constantan thermocouples in the field of military aircraft.

A further difference between the situations for iron-constantan and the other common thermocouples is related to the manner of procurement. Thermoelectric platinum and platinum-rhodium are prepared to specifications having the end use in view. Constantan and the purer grades of copper likewise are prepared with careful attention to the electrical properties of the product. On the other hand, such a small proportion of the total production of iron goes to thermocouples, that large producers of iron cannot be interested in controlling the properties of their product so as to suit it to this use. The manufacturer of pyrometers thus finds it more economical to select from the available production of commercial iron certain lots that happen to be suitable for thermoelectric use, rather than to have a suitable material prepared to specifications at a premium price by a producer of specialty metals. In classifying lots of iron, chemical tests are helpful, but the

¹ Figures in brackets indicate the literature references at the end of this paper.

² Most of the same tables are now available in expanded and revised form in NBS Circular 508, Reference Tables for Thermocouples, by Henry Shenker, John I. Lauritzen, Jr., and Robert J. Corruccini, issued May 7, 1951.

final test of the suitability of a lot must be a thermoelectric one.

In an effort to promote uniformity, steps were initiated in 1948 in the Recorder-Controller Section of the Scientific Apparatus Makers of America (SAMA), representing a number of pyrometer manufacturers, directed toward the adoption of the temperature-emf relationship known as the "1913" table³ as a tentative standard for iron-constantan thermocouples over the range, 32° to 1,400° F. This table was chosen because it is used more than any other. It is apparently based on a single calibration of a thermocouple (no longer in existence) that was typical of the iron-constantan of forty years ago. However, experience has shown that it is apparently not possible to produce a thermocouple, using present-day commercial iron, that will correspond precisely to the 1913 table. In addition, it was desired that the standard table should extend to subzero temperatures, whereas the original 1913 table did not extend below 32° F.

It appeared that experimental data on the characteristics of thermocouples of the type that reproduce the 1913 table were required in order to (1) judge the adequacy of the 1913 table as a permanent standard for SAMA, or, if it should prove desirable,

³ This table, sometimes called the Leeds and Northrup table, is identical with the tables given in International Critical Tables, 1, 59, (1926) and in Tech. Pap. BS 14, 306 (1920-21) T170, Table IV, Col. L.

to make adjustments in the table, and (2) to obtain data at low temperatures. Accordingly, a research project for this purpose was established at the NBS and was supported in part by a grant from SAMA and in part by funds of the Bureau. This paper presents the results of this investigation.

2. Experimental Procedure

Each member firm of the SAMA that supplies iron-constantan thermocouples was invited to submit samples for investigation at the Bureau. These thermocouples were to be of commercial materials that were selected to match closely the 1913 table over the range 32° to 1,400° F. Of the 8 eligible member concerns, 4 responded. Of these, 3 furnished 1 lot of wire each, while the fourth concern furnished 5 different lots of wire. The samples were designated by a letter representing the supplier, followed by a number representing the sample, e. g. A-1. The wire size was approximately No. 8 AWG. Information received from some of the suppliers indicated that the iron samples came from at least four different basic sources of ingot iron.

The thermoelectric measurements were made in two parts: (a) From 32° to 1,800° F the wires were calibrated in a tube-furnace which has already been described [4, 5]. For convenience, the iron wires

TABLE 1. Corresponding values of temperature and electromotive force for iron wires versus Pt-27
(Reference junctions at 32° F)

Temperature (Int. 1948)	Thermal electromotive force (absolute millivolts) for samples—							
	A-1	C-1	D-1	F-1	F-3	F-4	F-5	F-6
°F								
-319.5	-2.54	-2.64	-2.54	-2.65	-2.22	-2.43	-2.35	-2.29
-297.4	-2.50	-2.60	-2.50	-2.60	-2.19	-2.40	-2.32	-2.26
-147.1	-1.65	-1.72	-1.66	-1.70	-1.49	-1.61	-1.56	-1.52
-103.0	-1.28	-1.33	-1.28	-1.31	-1.17	-1.25	-1.21	-1.18
-61.8	-0.91	-0.95	-0.91	-0.93	-0.83	-0.89	-0.86	-0.84
-27.6	-0.58	-0.61	-0.59	-0.59	-0.54	-0.58	-0.55	-0.54
+32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	+0.68	+0.71	+0.68	+0.68	+0.64	+0.67	+0.65	+0.64
200	1.66	1.74	1.67	1.66	1.59	1.65	1.60	1.57
300	2.59	2.72	2.60	2.56	2.50	2.57	2.50	2.46
400	3.44	3.62	3.46	3.38	3.35	3.42	3.32	3.27
500	4.20	4.42	4.23	4.09	4.13	4.18	4.06	4.00
600	4.86	5.13	4.90	4.70	4.82	4.84	4.70	4.64
700	5.45	5.76	5.49	5.25	5.45	5.43	5.28	5.21
800	5.99	6.34	6.04	5.74	6.03	5.97	5.81	5.73
900	6.52	6.90	6.57	6.23	6.60	6.49	6.32	6.24
1,000	7.06	7.47	7.12	6.74	7.17	7.03	6.86	6.77
1,100	7.66	8.09	7.72	7.31	7.80	7.63	7.45	7.36
1,200	8.34	8.79	8.41	7.97	8.51	8.31	8.12	8.04
1,300	9.14	9.60	9.21	8.76	9.33	9.11	8.92	8.83
1,400	10.07	10.52	10.15	9.68	10.25	10.04	9.84	9.76
1,500	11.06	11.44	11.17	10.73	11.21	11.08	10.85	10.76
1,600	12.01	12.26	12.19	11.83	12.11	12.19	11.86	11.71
1,700	12.77	12.98	12.94	12.76	12.89	13.20	12.70	12.61
1,800	13.57	13.79	13.75	13.61	13.71	14.00	13.51	13.44

were calibrated against a standard iron wire, and the constantan wires against a standard constantan wire. The standard iron and the standard constantan wires had previously been calibrated against Pt 27, the platinum thermoelectric standard of the NBS, and they were rechecked at frequent intervals during each run against the platinum element of the platinum versus platinum-10 percent rhodium thermocouple used to measure the temperature. The test wires were calibrated three at a time. The measuring junctions of the test wires, the standard wire of the same material, and the platinum versus platinum-rhodium thermocouple used to measure the temperature were welded together. Because of the relative instability of the iron and constantan at temperatures above 1,400° F, measurements in this range were made against a platinum standard only. The average rate of rise of temperature in the region above 1,400° F was about 8 deg F per minute. All measurements were made at 100 deg F intervals on rising temperature. After each run, the heated section of the iron or constantan standard was cut off and discarded. The methods used were similar to those described in [4, p. 262-5, 277]. The measurements are considered to be accurate within the equivalent of 1 deg F. (b) From +32° to -319.5° F, the thermal emf of each wire against a copper reference wire was determined in stirred liquid baths. The copper reference wires were calibrated against

a platinum standard. Down to -147° F the cryostat described by Scott [6; 5, p. 206] was used. Observations at two lower temperatures were made by using baths of liquid oxygen and nitrogen stirred by a stream of the same gas. Temperatures in the baths were determined with a platinum resistance thermometer. Sections of wire that had not been previously heated were used for the low-temperature measurements. The limit of error in this range is considered to be the equivalent of ½ deg F.

In all the measurements, the reference junctions were kept at 32° F in a mixture of ice and water. An atmosphere of air surrounded the thermocouples at all times. The calibrations of the individual wires relative to Pt 27 at the various calibration temperatures were compiled and are given in tables 1 and 2. The data in table 3 for the complete thermocouples were obtained by combination of the data in tables 1 and 2.

The deviations (expressed in deg F) of the various thermocouples from the 1913 table are shown in figure 1. The deviation of the RP1080 table is also shown. Because the A-1 thermocouple gave the nearest over-all match to the 1913 table in the range up to 1,400° F, the calibrations of the iron and constantan elements of this thermocouple were used as base lines for figures 2 and 3, respectively, in which are shown the differences among the various individual wires. The curves marked "RP1080" repre-

TABLE 2. Corresponding values of temperature and electromotive forces for constantan wires versus Pt-27

(Reference junctions at 32° F)

Temperature (Int. 1948)	Thermal electromotive force (absolute millivolts) for samples -						
	A-1	C-1	D-1	F-1, F-6	F-3	F-4	F-5
°F							
-319.5	+5.24	+5.14	+5.24	+5.31	+5.24	+5.30	+5.30
-297.4	4.99	4.89	4.99	5.05	4.98	5.04	5.04
-147.1	2.96	2.90	2.95	2.99	2.95	2.99	2.99
-103.0	2.28	2.33	2.28	2.31	2.28	2.31	2.31
-61.8	1.62	1.59	1.62	1.64	1.62	1.64	1.64
-27.6	1.05	1.03	1.05	1.06	1.05	1.06	1.06
+32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	-1.26	-1.24	-1.27	-1.28	-1.26	-1.28	-1.28
200	-3.24	-3.17	-3.25	-3.29	-3.24	-3.28	-3.28
300	-5.35	-5.26	-5.34	-5.43	-5.35	-5.42	-5.42
400	-7.58	-7.46	-7.60	-7.69	-7.58	-7.67	-7.67
500	-9.92	-9.75	-9.93	-10.04	-9.90	-10.01	-10.02
600	-12.32	-12.10	-12.33	-12.47	-12.30	-12.43	-12.45
700	-14.80	-14.54	-14.80	-14.97	-14.76	-14.92	-14.95
800	-17.33	-17.01	-17.31	-17.51	-17.25	-17.45	-17.48
900	-19.88	-19.51	-19.85	-20.08	-19.78	-20.01	-20.05
1,000	-22.46	-22.06	-22.42	-22.68	-22.34	-22.60	-22.64
1,100	-25.07	-24.61	-25.00	-25.29	-24.91	-25.20	-25.25
1,200	-27.67	-27.18	-27.59	-27.90	-27.49	-27.80	-27.86
1,300	-30.29	-29.76	-30.18	-30.52	-30.07	-30.41	-30.48
1,400	-32.89	-32.32	-32.77	-33.13	-32.64	-33.01	-33.08
1,500	-35.48	-34.86	-35.32	-35.71	-35.16	-35.59	-35.66
1,600	-38.04	-37.28	-37.86	-38.27	-37.72	-38.15	-38.22
1,700	-40.57	-39.87	-40.36	-40.79	-40.22	-40.67	-40.74
1,800	-43.06	-42.34	-42.84	-43.29	-42.68	-43.15	-43.23

TABLE 3. Corresponding values of temperature and electromotive force for iron-constantan thermocouples
(Reference junctions at 32° F)

Temperature (Int. 1948)	Thermal electromotive force (absolute millivolts) for samples—									
	A-1	C-1	D-1	F-1	F-3	F-4	F-5	F-6	1913 table	RP1080 table
° F										
-319.5	-7.79	-7.79	-7.78	-7.96	-7.45	-7.73	-7.66	-7.60	-----	-----
-297.4	-7.49	-7.49	-7.49	-7.65	-7.17	-7.44	-7.37	-7.31	-----	-7.83
-147.1	-4.61	-4.62	-4.61	-4.69	-4.44	-4.59	-4.55	-4.51	-----	-4.80
-103.0	-3.56	-3.57	-3.56	-3.62	-3.44	-3.55	-3.52	-3.49	-----	-3.71
-61.8	-2.53	-2.53	-2.53	-2.57	-2.45	-2.53	-2.50	-2.48	-----	-2.63
-27.6	-1.63	-1.63	-1.63	-1.65	-1.58	-1.63	-1.61	-1.60	-----	-1.69
+32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	+1.94	+1.94	+1.95	+1.96	+1.90	+1.95	+1.93	+1.92	+1.96	+2.00
200	4.91	4.91	4.92	4.95	4.83	4.93	4.88	4.86	4.92	5.03
300	7.94	7.97	7.97	7.99	7.85	7.99	7.91	7.88	7.95	8.13
400	11.03	11.07	11.07	11.06	10.93	11.09	11.00	10.96	11.02	11.25
500	14.12	14.17	14.16	14.13	14.03	14.19	14.08	14.04	14.10	14.35
600	17.18	17.23	17.23	17.17	17.12	17.27	17.15	17.10	17.17	17.43
700	20.26	20.30	20.30	20.22	20.21	20.35	20.23	20.18	20.24	20.49
800	23.32	23.35	23.35	23.25	23.29	23.42	23.29	23.24	23.32	23.54
900	26.40	26.41	26.42	26.31	26.38	26.50	26.37	26.32	26.42	26.60
1000	29.52	29.53	29.54	29.41	29.51	29.63	29.50	29.45	29.55	29.71
1100	32.72	32.70	32.72	32.60	32.72	32.82	32.70	32.65	32.75	32.89
1200	36.01	35.97	36.00	35.88	36.00	36.11	35.98	35.94	36.05	36.18
1300	39.43	39.36	39.40	39.28	39.40	39.52	39.40	39.36	39.46	39.58
1400	42.96	42.84	42.92	42.81	42.89	43.05	42.92	42.89	42.95	43.11
1500	46.53	46.30	46.49	46.44	46.37	46.67	46.51	46.48	46.47	46.73
1600	50.05	49.64	50.05	50.10	49.83	50.34	50.08	49.98	49.99	50.38
1700	53.34	52.86	53.31	53.55	53.10	53.87	53.44	53.40	53.52	53.86
1800	56.64	56.12	56.59	56.91	56.38	57.16	56.74	56.73	57.04	57.17

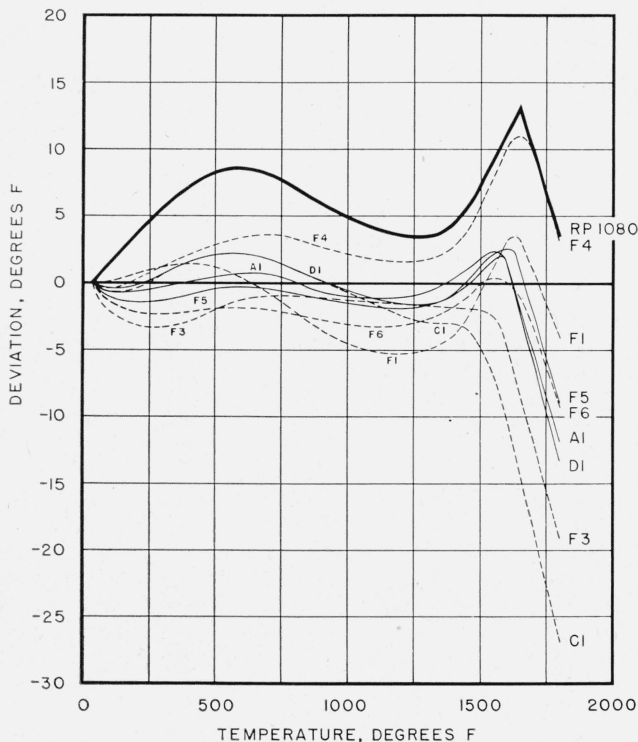


FIGURE 1. Deviation of SAMA iron-constantan thermocouples and RP1080 table from the 1913 table.

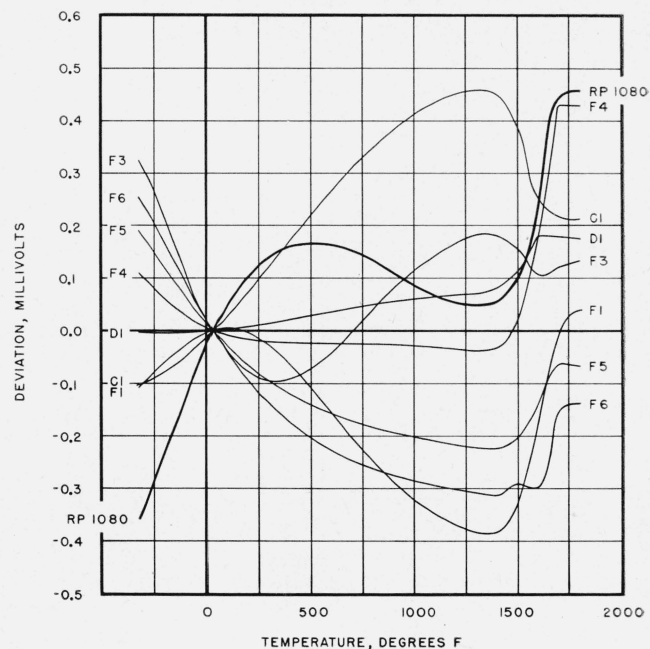


FIGURE 2. Deviation of SAMA iron samples and RP1080 iron from iron sample A-1.

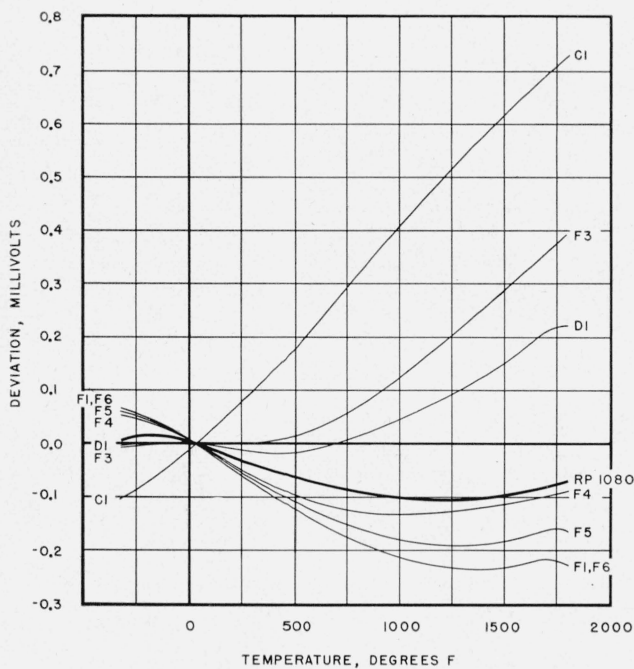


FIGURE 3. Deviation of SAMA constantan samples and RP1080 constantan from constantan sample A-1.

sent the data for iron versus platinum and constantan versus platinum given in [3]. The 1913 table was for iron versus constantan only and, consequently, the corresponding data for the individual elements versus platinum are not available for inclusion in figures 2 and 3. The constantan marked "F-1, F-6" was a single sample intended for use in combination with either the F-1 or F-6 iron sample. In figure 4 similar plots for the completed thermocouples are given. In preparing these figures, the 1913 and RP1080 tables were adjusted to the emf units and temperature scale used in this investigation and currently in use at this Bureau. These are the absolute system of electrical units [7] and the International Temperature Scale of 1948 [8]. One absolute volt is equal to 0.99967 international volt

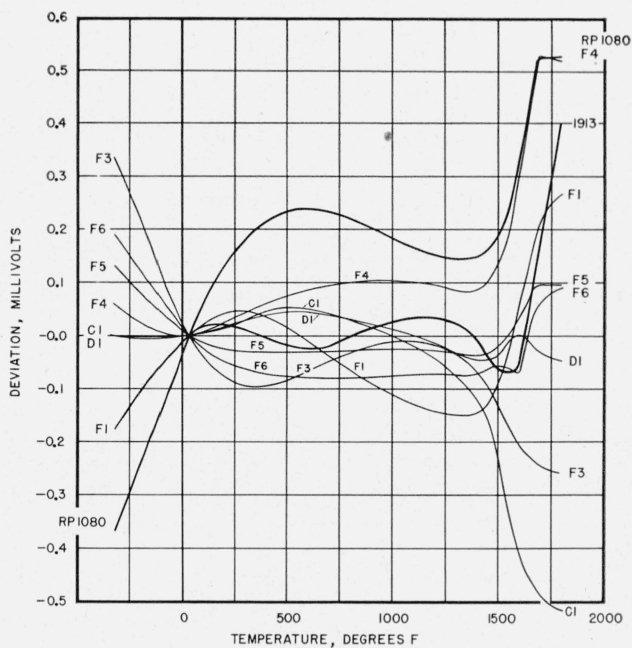


FIGURE 4. Deviations of SAMA iron-constantan thermocouples, the 1913 table, and the RP1080 table from thermocouple A-1.

(U. S.). The differences between the International Temperature Scales of 1948 and 1927 are not more than 0.8 deg F in the range of this investigation [9] and so are nearly negligible.

The differences in shape of the various curves in figure 4 are mainly due to the iron elements because the deviations of the constantan elements from each other are approximately linear. It is well known that thermal emf depends both on chemical composition and on the degree of strain. In hope of gaining some insight into the differences among the various thermocouples, the iron samples were analyzed chemically, and their hardnesses were determined. This work was done by the Chemistry and Metallurgy Divisions of the Bureau. The results are given in tables 4 and 5.

TABLE 4. Chemical and spectrographic analyses of iron samples

[Values are given in percent]

Sample	C	Mn	P	S	Cu	Si*	Ni*	Cr*	Sn*
A-1	0.07	0.25	0.015	0.031	0.12	< 0.01	0.044	0.015	< 0.01
C-1	.11	.38	.005	.031	.054	< .01	.030	.016	< .01
D-1	.04	.29	.009	.024	.14	< .01	.042	.016	< .01
F-1	.02	.03	.004	.029	.15	< .01	.039	.025	< .01
F-3	.08	.43	.080	.028	.018	.02	.011	< .01	< .01
F-4	.02	.23	.011	.016	.023	< .01	.014	< .01	< .01
F-5	.06	.21	.006	.020	.022	.01	.013	< .01	< .01
F-6	.05	.22	.006	.018	.022	< .01	.012	< .01	.01

*Spectrographic determination.

TABLE 5. Results of hardness measurements on samples of iron wire

Sample	Vickers number*	Equivalent Rockwell B number
A-1	99.8	55
C-1	106	59.5
D-1	138	76
F-1	127	71
F-3	210	94
F-4	83.6	39
F-5	138	76
F-6	131	73

*Determinations were made with a 10-kg load applied through a square-based diamond-pyramid indenter.

3. Discussion

The sharp changes in the slopes of the various curves in figure 1 at about 1,650° F are thought to be due to the 1913 table having been based in this region on an extrapolation that neglected the effect of the abrupt change in thermoelectric power of iron at the α - γ transition. At lower temperatures the various curves show a characteristic undulation. It is not known to what extent this is due to errors in the original 1913 calibration and to what extent to differences between the chemical compositions characteristic of iron used for thermocouples in 1913 and at present.

It was hardly to be expected that the curves of figure 2 would be fully interpretable, inasmuch as the research was designed to test these commercial materials in the "as received" condition, and did not provide for that control of the variables of chemical composition and heat treatment that would be necessary for a fundamental understanding of the results.

The quantum theory of metals leads to the correct predictions that iron is thermoelectrically positive to platinum and that the effect of small percentages of copper on the thermoelectric power is opposite in sign to the effect of manganese. However, a detailed explanation of the features shown in figure 2 is beyond the present scope of theory. Nevertheless, a few generalizations may be noted from the data.

Roeser and Dahl [3] showed that the 1913 table could be approximated by using iron wires having several tenths percent of Mn, whereas the samples of which RP1080 was characteristic contained less than 0.1 percent of Mn. The effects of small percentages of the minor elements that are common in commercial iron on the thermoelectric power of iron have been investigated by Finch [10], who described several compositions of iron that can be used in thermocouples. Finch showed that the thermoelectric power of iron at 500° C (932° F) is increased by additions of Cr, S, or Mn and decreased by Sn, Si, P, Ni, and (in percentages greater than 0.10) Cu, whereas the effect of carbon is negligible. It

will be noted that the curve for iron sample F-1 is similar in shape to that for RP1080 iron, and, indeed, its manganese content of only 0.03 percent marks it as an RP1080-type iron. In the other iron samples, manganese is the principal minor element, and the thermal emf at 932° F (see fig. 2), with minor exceptions, increases with the manganese concentration, as would be predicted from the work of Finch.

The bunching of the curves in the gamma region above 1,650° F may be the result of differences in electronic band-structure in alpha and gamma iron. However, the steep rise of F-1 and F-4 is exceptional. These samples were lowest in carbon (0.02 percent), whereas the samples showing the opposite behavior, C-1 and F-3, were highest and second highest, respectively, in carbon content (0.11 and 0.08 percent). The effect thus may be connected with the solution of carbon in the gamma-phase iron. A study of the phases present initially was not made, and so no positive statement may be made on this point.

Dahl has shown [11; 5, p. 1238] that thermocouple iron decreases in thermoelectric power on heating at temperatures above 1,200° F. However, the annealing of high-purity iron increases the thermoelectric power, so that it appears that the drift in the thermal emf of the iron elements of thermocouples at high temperatures is primarily due to phase changes and chemical changes, and that relief of strain is not an important factor in this drift.

The unique shape of curve F-3 may be related to any of the following factors: (1) Its manganese content was highest of all (0.43 percent); (2) Its phosphorus content was very much higher than that of the other samples; (3) Its hardness was unusually high.

The curves in figure 3 show the approximately linear deviation that is characteristic of constantan [3].

The maximum differences among the iron samples and also among the constantan samples amounted to about 0.8 mv at 1,400° F, which is equivalent to about 20 deg F in the indication of an iron-constantan thermocouple. In addition, there were marked differences in the curve shape for the iron samples. Nevertheless, the calibrations of the completed thermocouples fell within a satisfactorily narrow band up to 1,500° F. The width of this band on either side of the relation for thermocouple A-1 was approximately equivalent to commercial tolerances for the iron-constantan thermocouple, thus indicating the practicality of the A-1 relation for a commercial standard. However, the large differences among the wires of a given kind illustrate the impracticality of establishing standards for the emf of the individual elements (against platinum) as has been done for the elements of all the other common thermocouples.

The deviations of the thermocouples below 32° F are quite large in terms of temperature, which indicates the necessity for care in establishing the calibrations of thermocouples in this range. However, the deviations in emf are nearly linear, so that relatively few calibration temperatures need be used.

4. Reference Table for 1913-type Iron-Constantan Thermocouples

As a result of this investigation, the Thermocouple Calibration Curves Committee, Recorder-Controller Section, SAMA, has recommended adoption of the temperature electromotive force relationship of thermocouple A-1 as a tentative standard. Because of the known instability of iron-constantan thermocouples above 1,600° F, and also because of the large increase in deviation of the thermocouples from each other in this region, the upper limit of the standard has been set at 1,600° F. (Manufacturers of this thermocouple do not recommend its use above 1,400° to 1,500° F, except in special circumstances.) The differences between the A-1 relationship and the 1913 table, when both are expressed in consistent electrical units and temperature scale, are given in table 6.

TABLE 6. Differences between A-1 and 1913 tables for iron-constantan thermocouples

Temperature °F	Emf A-1 table minus emf 1913 table	
	Millivolts	Equivalent degrees F
32	0.00	0.0
100	-.02	-.7
200	-.01	-.3
300	-.01	-.3
400	+.01	+3
500	+.02	+7
600	+.01	+3
700	+.02	+7
800	.00	.0
900	-.02	-.7
1,000	-.03	-.9
1,100	-.03	-.9
1,200	-.04	-1.2
1,300	-.03	-0.9
1,400	+.01	+3
1,500	+.06	+1.7
1,600	+.06	+1.7

In December 1950, preliminary results of this investigation were summarized in a published article [12]. In this article it was pointed out that the temperature-emf relationship of sample A-1 was favored for the proposed new SAMA standard. In order to determine whether or not the A-1 relationship would be acceptable as an industry-wide standard, replacing not merely the 1913 table but also the RP1080 table, answers to the following questions were solicited: (1) Is industry-wide standardization on a single reference table for iron-constantan desirable? (2) Is the 1913 table, or a close approximation to it, acceptable for this purpose? (3) What degree of hardship will be occasioned by abandonment of the RP1080 table?

The replies received were uniformly favorable to a single industry-wide standard. Users and suppliers of 1913-type thermocouples were uniformly favorable to the proposed SAMA standard. However, most of the replies received from users and suppliers of solely

RP1080-type thermocouples indicated that it would not be practicable for them to change to the proposed SAMA standard. It is important to point out that the change from RP1080-type to A-1-type thermocouples would require alterations to most of the associated indicating equipment, whereas the difference between the 1913 and A-1 relationships is much smaller and is less than commercial tolerances for this thermocouple.

Thus it appears that at least two standards, the SAMA table (A-1) and the RP1080 table, will coexist in the immediate future. Most commercial production of iron-constantan will probably be based on the SAMA table, as it has been based on the 1913 table in the past. On the other hand, one of the principal fields in which the RP1080 standard is dominant—namely, in piston-engined military aircraft—is declining in importance.

In order to make the A-1 relationship useful, it has been expanded into four tables, numbers 7, 8, 9, and 10. Before doing this, additional samples of the A lot were calibrated as a check against gross errors. The differences between these and the calibration of A-1 were within the limit of error of the calibration process. In table 7, the desired function for the region from -320° to 0° F was obtained at intervals of 1 deg by the method of divided differences. For the range from 0° to +1600° F, the LaGrange polynomial was used. Linear interpolation, either direct or inverse, was then performed on this table to obtain the remaining tables. The preparation of tables 7 to 10 was carried out by the Applied Mathematics Division of the Bureau.

The thermoelectric measurements below 32° F were made in the Thermometry Laboratory by Ruth C. Gallman and Eugenia Thomas. It is a pleasure to acknowledge the advice given by Wm. F. Roeser and also the cooperation of the various members of the Thermocouple Calibration Curves Committee of SAMA and their chairman, Edward J. Albert.

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Table 7. Iron-Constantan Thermocouples

(Emf in Absolute Millivolts. Temperatures in Degrees F.* Reference Junctions at 32° F.)

°F	Millivolts											°F
	0	1	2	3	4	5	6	7	8	9	10	
-310	-7.66	-7.68	-7.69	-7.70	-7.71	-7.73	-7.74	-7.75	-7.76	-7.78	-7.79	-310
-300	-7.52	-7.54	-7.55	-7.57	-7.58	-7.59	-7.61	-7.62	-7.64	-7.65	-7.66	-300
-290	-7.38	-7.39	-7.40	-7.42	-7.44	-7.45	-7.46	-7.48	-7.49	-7.51	-7.52	-290
-280	-7.22	-7.24	-7.25	-7.27	-7.28	-7.30	-7.31	-7.33	-7.34	-7.36	-7.38	-280
-270	-7.06	-7.07	-7.09	-7.11	-7.12	-7.14	-7.15	-7.17	-7.19	-7.20	-7.22	-270
-260	-6.89	-6.90	-6.92	-6.94	-6.96	-6.97	-6.99	-7.01	-7.02	-7.04	-7.06	-260
-250	-6.71	-6.73	-6.75	-6.77	-6.78	-6.80	-6.82	-6.84	-6.85	-6.87	-6.89	-250
-240	-6.53	-6.55	-6.57	-6.59	-6.61	-6.62	-6.64	-6.66	-6.68	-6.70	-6.71	-240
-230	-6.35	-6.37	-6.38	-6.40	-6.42	-6.44	-6.46	-6.48	-6.50	-6.52	-6.53	-230
-220	-6.16	-6.18	-6.19	-6.21	-6.23	-6.25	-6.27	-6.29	-6.31	-6.33	-6.35	-220
-210	-5.96	-5.98	-6.00	-6.02	-6.04	-6.06	-6.08	-6.10	-6.12	-6.14	-6.16	-210
-200	-5.76	-5.78	-5.80	-5.82	-5.84	-5.86	-5.88	-5.90	-5.92	-5.94	-5.96	-200
-190	-5.55	-5.57	-5.59	-5.61	-5.63	-5.65	-5.67	-5.70	-5.72	-5.74	-5.76	-190
-180	-5.34	-5.36	-5.38	-5.40	-5.42	-5.44	-5.46	-5.49	-5.51	-5.53	-5.55	-180
-170	-5.12	-5.14	-5.16	-5.19	-5.21	-5.23	-5.25	-5.27	-5.30	-5.32	-5.34	-170
-160	-4.90	-4.92	-4.94	-4.97	-4.99	-5.01	-5.03	-5.06	-5.08	-5.10	-5.12	-160
-150	-4.68	-4.70	-4.72	-4.74	-4.76	-4.79	-4.81	-4.83	-4.86	-4.88	-4.90	-150
-140	-4.44	-4.47	-4.49	-4.51	-4.54	-4.56	-4.58	-4.61	-4.63	-4.65	-4.68	-140
-130	-4.21	-4.23	-4.26	-4.28	-4.30	-4.33	-4.35	-4.38	-4.40	-4.42	-4.44	-130
-120	-3.97	-4.00	-4.02	-4.04	-4.07	-4.09	-4.12	-4.14	-4.16	-4.19	-4.21	-120
-110	-3.73	-3.76	-3.78	-3.81	-3.83	-3.85	-3.88	-3.90	-3.93	-3.95	-3.97	-110
-100	-3.49	-3.51	-3.54	-3.56	-3.59	-3.61	-3.64	-3.66	-3.68	-3.71	-3.73	-100
-90	-3.24	-3.27	-3.29	-3.32	-3.34	-3.36	-3.39	-3.41	-3.44	-3.46	-3.49	-90
-80	-2.99	-3.02	-3.04	-3.07	-3.09	-3.12	-3.14	-3.17	-3.19	-3.22	-3.24	-80
-70	-2.74	-2.76	-2.79	-2.81	-2.84	-2.86	-2.89	-2.92	-2.94	-2.97	-2.99	-70
-60	-2.48	-2.51	-2.53	-2.56	-2.58	-2.61	-2.64	-2.66	-2.69	-2.71	-2.74	-60
-50	-2.22	-2.25	-2.27	-2.30	-2.33	-2.35	-2.38	-2.40	-2.43	-2.46	-2.48	-50
-40	-1.96	-1.99	-2.01	-2.04	-2.06	-2.09	-2.12	-2.14	-2.17	-2.20	-2.22	-40
-30	-1.70	-1.72	-1.75	-1.78	-1.80	-1.83	-1.86	-1.88	-1.91	-1.94	-1.96	-30
-20	-1.43	-1.46	-1.48	-1.51	-1.54	-1.56	-1.59	-1.62	-1.64	-1.67	-1.70	-20
-10	-1.16	-1.19	-1.21	-1.24	-1.27	-1.29	-1.32	-1.35	-1.38	-1.40	-1.43	-10
(-)0	-.89	-.91	-.94	-.97	-1.00	-1.02	-1.05	-1.08	-1.10	-1.13	-1.16	(-)0
(+)0	-.89	-.86	-.83	-.80	-.78	-.75	-.72	-.70	-.67	-.64	-.61	(+)0

*Based on the International Temperature Scale of 1948.

Table 7. Iron-Constantan Thermocouples—Continued

(Emf in Absolute Millivolts. Temperatures in Degrees F. * Reference Junctions at 32° F.)

°F	0	1	2	3	4	5	6	7	8	9	10	°F
	Millivolts											
(+)0	-.89	-.86	-.83	-.80	-.78	-.75	-.72	-.70	-.67	-.64	-.61	(+)0
10	-.61	-.58	-.56	-.53	-.50	-.48	-.45	-.42	-.39	-.36	-.34	10
20	-.34	-.31	-.28	-.25	-.22	-.20	-.17	-.14	-.11	-.09	-.06	20
30	-.06	-.03	-.00	.03	.05	.08	.11	.14	.17	.19	.22	30
40	.22	.25	.28	.31	.34	.36	.39	.42	.45	.48	.50	40
50	.50	.53	.56	.59	.62	.65	.67	.70	.73	.76	.79	50
60	.79	.82	.84	.87	.90	.93	.96	.99	1.02	1.04	1.07	60
70	1.07	1.10	1.13	1.16	1.19	1.22	1.25	1.28	1.30	1.33	1.36	70
80	1.36	1.39	1.42	1.45	1.48	1.51	1.54	1.56	1.59	1.62	1.65	80
90	1.65	1.68	1.71	1.74	1.77	1.80	1.83	1.85	1.88	1.91	1.94	90
100	1.94	1.97	2.00	2.03	2.06	2.09	2.12	2.14	2.17	2.20	2.23	100
110	2.23	2.26	2.29	2.32	2.35	2.38	2.41	2.44	2.47	2.50	2.52	110
120	2.52	2.55	2.58	2.61	2.64	2.67	2.70	2.73	2.76	2.79	2.82	120
130	2.82	2.85	2.88	2.91	2.94	2.97	3.00	3.03	3.06	3.08	3.11	130
140	3.11	3.14	3.17	3.20	3.23	3.26	3.29	3.32	3.35	3.38	3.41	140
150	3.41	3.44	3.47	3.50	3.53	3.56	3.59	3.62	3.65	3.68	3.71	150
160	3.71	3.74	3.77	3.80	3.83	3.86	3.89	3.92	3.95	3.98	4.01	160
170	4.01	4.04	4.07	4.10	4.13	4.16	4.19	4.22	4.25	4.28	4.31	170
180	4.31	4.34	4.37	4.40	4.43	4.46	4.49	4.52	4.55	4.58	4.61	180
190	4.61	4.64	4.67	4.70	4.73	4.76	4.79	4.82	4.85	4.88	4.91	190
200	4.91	4.94	4.97	5.00	5.03	5.06	5.09	5.12	5.15	5.18	5.21	200
210	5.21	5.24	5.27	5.30	5.33	5.36	5.39	5.42	5.45	5.48	5.51	210
220	5.51	5.54	5.57	5.60	5.63	5.66	5.69	5.72	5.75	5.78	5.81	220
230	5.81	5.84	5.87	5.90	5.93	5.96	5.99	6.02	6.05	6.08	6.11	230
240	6.11	6.14	6.17	6.20	6.24	6.27	6.30	6.33	6.36	6.39	6.42	240
250	6.42	6.45	6.48	6.51	6.54	6.57	6.60	6.63	6.66	6.69	6.72	250
260	6.72	6.75	6.78	6.81	6.84	6.87	6.90	6.93	6.96	7.00	7.03	260
270	7.03	7.06	7.09	7.12	7.15	7.18	7.21	7.24	7.27	7.30	7.33	270
280	7.33	7.36	7.39	7.42	7.45	7.48	7.51	7.54	7.58	7.61	7.64	280
290	7.64	7.67	7.70	7.73	7.76	7.79	7.82	7.85	7.88	7.91	7.94	290
300	7.94	7.97	8.00	8.04	8.07	8.10	8.13	8.16	8.19	8.22	8.25	300

*Based on the International Temperature Scale of 1948.

Table 7. Iron-Constantan Thermocouples—Continued

(Emf in Absolute Millivolts. Temperatures in Degrees F. * Reference Junctions at 32° F.)

°F	0	1	2	3	4	5	6	7	8	9	10	°F
	Millivolts											
300	7.94	7.97	8.00	8.04	8.07	8.10	8.13	8.16	8.19	8.22	8.25	300
310	8.25	8.28	8.31	8.34	8.37	8.40	8.44	8.47	8.50	8.53	8.56	310
320	8.56	8.59	8.62	8.65	8.68	8.71	8.74	8.77	8.80	8.84	8.87	320
330	8.87	8.90	8.93	8.96	8.99	9.02	9.05	9.08	9.11	9.14	9.17	330
340	9.17	9.20	9.24	9.27	9.30	9.33	9.36	9.39	9.42	9.45	9.48	340
350	9.48	9.51	9.54	9.58	9.61	9.64	9.67	9.70	9.73	9.76	9.79	350
360	9.79	9.82	9.85	9.88	9.92	9.95	9.98	10.01	10.04	10.07	10.10	360
370	10.10	10.13	10.16	10.19	10.22	10.25	10.28	10.32	10.35	10.38	10.41	370
380	10.41	10.44	10.47	10.50	10.53	10.56	10.60	10.63	10.66	10.69	10.72	380
390	10.72	10.75	10.78	10.81	10.84	10.87	10.90	10.94	10.97	11.00	11.03	390
400	11.03	11.06	11.09	11.12	11.15	11.18	11.21	11.24	11.28	11.31	11.34	400
410	11.34	11.37	11.40	11.43	11.46	11.49	11.52	11.55	11.58	11.62	11.65	410
420	11.65	11.68	11.71	11.74	11.77	11.80	11.83	11.86	11.89	11.92	11.96	420
430	11.96	11.99	12.02	12.05	12.08	12.11	12.14	12.17	12.20	12.23	12.26	430
440	12.26	12.30	12.33	12.36	12.39	12.42	12.45	12.48	12.51	12.54	12.57	440
450	12.57	12.60	12.64	12.67	12.70	12.73	12.76	12.79	12.82	12.85	12.88	450
460	12.88	12.91	12.94	12.98	13.01	13.04	13.07	13.10	13.13	13.16	13.19	460
470	13.19	13.22	13.25	13.28	13.31	13.34	13.38	13.41	13.44	13.47	13.50	470
480	13.50	13.53	13.56	13.59	13.62	13.65	13.68	13.72	13.75	13.78	13.81	480
490	13.81	13.84	13.87	13.90	13.93	13.96	13.99	14.02	14.05	14.08	14.12	490
500	14.12	14.15	14.18	14.21	14.24	14.27	14.30	14.33	14.36	14.39	14.42	500
510	14.42	14.45	14.48	14.52	14.55	14.58	14.61	14.64	14.67	14.70	14.73	510
520	14.73	14.76	14.79	14.82	14.85	14.88	14.91	14.94	14.98	15.01	15.04	520
530	15.04	15.07	15.10	15.13	15.16	15.19	15.22	15.25	15.28	15.31	15.34	530
540	15.34	15.37	15.40	15.44	15.47	15.50	15.53	15.56	15.59	15.62	15.65	540
550	15.65	15.68	15.71	15.74	15.77	15.80	15.84	15.87	15.90	15.93	15.96	550
560	15.96	15.99	16.02	16.05	16.08	16.11	16.14	16.17	16.20	16.23	16.26	560
570	16.26	16.30	16.33	16.36	16.39	16.42	16.45	16.48	16.51	16.54	16.57	570
580	16.57	16.60	16.63	16.66	16.69	16.72	16.75	16.78	16.82	16.85	16.88	580
590	16.88	16.91	16.94	16.97	17.00	17.03	17.06	17.09	17.12	17.15	17.18	590
600	17.18	17.21	17.24	17.28	17.31	17.34	17.37	17.40	17.43	17.46	17.49	600

* Based on the International Temperature Scale of 1948.

Table 7. Iron-Constantan Thermocouples—Continued

(Emf in Absolute Millivolts. Temperatures in Degrees F.* Reference Junctions at 32° F.)

°F	0	1	2	3	4	5	6	7	8	9	10	°F
	Millivolts											
600	17.18	17.21	17.24	17.28	17.31	17.34	17.37	17.40	17.43	17.46	17.49	600
610	17.49	17.52	17.55	17.58	17.61	17.64	17.68	17.71	17.74	17.77	17.80	610
620	17.80	17.83	17.86	17.89	17.92	17.95	17.98	18.01	18.04	18.08	18.11	620
630	18.11	18.14	18.17	18.20	18.23	18.26	18.29	18.32	18.35	18.38	18.41	630
640	18.41	18.44	18.47	18.50	18.54	18.57	18.60	18.63	18.66	18.69	18.72	640
650	18.72	18.75	18.78	18.81	18.84	18.87	18.90	18.94	18.97	19.00	19.03	650
660	19.03	19.06	19.09	19.12	19.15	19.18	19.21	19.24	19.27	19.30	19.34	660
670	19.34	19.37	19.40	19.43	19.46	19.49	19.52	19.55	19.58	19.61	19.64	670
680	19.64	19.67	19.70	19.74	19.77	19.80	19.83	19.86	19.89	19.92	19.95	680
690	19.95	19.98	20.01	20.04	20.07	20.10	20.13	20.16	20.20	20.23	20.26	690
700	20.26	20.29	20.32	20.35	20.38	20.41	20.44	20.47	20.50	20.53	20.56	700
710	20.56	20.59	20.62	20.66	20.69	20.72	20.75	20.78	20.81	20.84	20.87	710
720	20.87	20.90	20.93	20.96	20.99	21.02	21.05	21.08	21.11	21.14	21.18	720
730	21.18	21.21	21.24	21.27	21.30	21.33	21.36	21.39	21.42	21.45	21.48	730
740	21.48	21.51	21.54	21.57	21.60	21.64	21.67	21.70	21.73	21.76	21.79	740
750	21.79	21.82	21.85	21.88	21.91	21.94	21.97	22.00	22.03	22.06	22.10	750
760	22.10	22.13	22.16	22.19	22.22	22.25	22.28	22.31	22.34	22.37	22.40	760
770	22.40	22.43	22.46	22.49	22.52	22.55	22.58	22.62	22.65	22.68	22.71	770
780	22.71	22.74	22.77	22.80	22.83	22.86	22.89	22.92	22.95	22.98	23.01	780
790	23.01	23.04	23.08	23.11	23.14	23.17	23.20	23.23	23.26	23.29	23.32	790
800	23.32	23.35	23.38	23.41	23.44	23.47	23.50	23.53	23.56	23.60	23.63	800
810	23.63	23.66	23.69	23.72	23.75	23.78	23.81	23.84	23.87	23.90	23.93	810
820	23.93	23.96	23.99	24.02	24.06	24.09	24.12	24.15	24.18	24.21	24.24	820
830	24.24	24.27	24.30	24.33	24.36	24.39	24.42	24.45	24.48	24.52	24.55	830
840	24.55	24.58	24.61	24.64	24.67	24.70	24.73	24.76	24.79	24.82	24.85	840
850	24.85	24.88	24.91	24.94	24.98	25.01	25.04	25.07	25.10	25.13	25.16	850
860	25.16	25.19	25.22	25.25	25.28	25.32	25.35	25.38	25.41	25.44	25.47	860
870	25.47	25.50	25.53	25.56	25.59	25.62	25.65	25.68	25.72	25.75	25.78	870
880	25.78	25.81	25.84	25.87	25.90	25.93	25.96	25.99	26.02	26.06	26.09	880
890	26.09	26.12	26.15	26.18	26.21	26.24	26.27	26.30	26.33	26.36	26.40	890
900	26.40	26.43	26.46	26.49	26.52	26.55	26.58	26.61	26.64	26.67	26.70	900

* Based on the International Temperature Scale of 1948.

Table 7. Iron-Constantan Thermocouples—Continued

(Emf in Absolute Millivolts Temperatures in Degrees F. * Reference Junctions at 32° F.)

°F	0	1	2	3	4	5	6	7	8	9	10	°F
	Millivolts											
900	26.40	26.43	26.46	26.49	26.52	26.55	26.58	26.61	26.64	26.67	26.70	900
910	26.70	26.74	26.77	26.80	26.83	26.86	26.89	26.92	26.95	26.98	27.02	910
920	27.02	27.05	27.08	27.11	27.14	27.17	27.20	27.23	27.26	27.30	27.33	920
930	27.33	27.36	27.39	27.42	27.45	27.48	27.51	27.54	27.58	27.61	27.64	930
940	27.64	27.67	27.70	27.73	27.76	27.80	27.83	27.86	27.89	27.92	27.95	940
950	27.95	27.98	28.02	28.05	28.08	28.11	28.14	28.17	28.20	28.23	28.26	950
960	28.26	28.30	28.33	28.36	28.39	28.42	28.45	28.48	28.52	28.55	28.58	960
970	28.58	28.61	28.64	28.67	28.70	28.74	28.77	28.80	28.83	28.86	28.89	970
980	28.89	28.92	28.96	28.99	29.02	29.05	29.08	29.11	29.14	29.18	29.21	980
990	29.21	29.24	29.27	29.30	29.33	29.37	29.40	29.43	29.46	29.49	29.52	990
1000	29.52	29.56	29.59	29.62	29.65	29.68	29.71	29.75	29.78	29.81	29.84	1000
1010	29.84	29.87	29.90	29.94	29.97	30.00	30.03	30.06	30.10	30.13	30.16	1010
1020	30.16	30.19	30.22	30.25	30.28	30.32	30.35	30.38	30.41	30.44	30.48	1020
1030	30.48	30.51	30.54	30.57	30.60	30.64	30.67	30.70	30.73	30.76	30.80	1030
1040	30.80	30.83	30.86	30.89	30.92	30.96	30.99	31.02	31.05	31.08	31.12	1040
1050	31.12	31.15	31.18	31.21	31.24	31.28	31.31	31.34	31.37	31.40	31.44	1050
1060	31.44	31.47	31.50	31.53	31.56	31.60	31.63	31.66	31.69	31.72	31.76	1060
1070	31.76	31.79	31.82	31.85	31.88	31.92	31.95	31.98	32.01	32.05	32.08	1070
1080	32.08	32.11	32.14	32.18	32.21	32.24	32.27	32.30	32.34	32.37	32.40	1080
1090	32.40	32.43	32.47	32.50	32.53	32.56	32.60	32.63	32.66	32.69	32.72	1090
1100	32.72	32.76	32.79	32.82	32.86	32.89	32.92	32.95	32.98	33.02	33.05	1100
1110	33.05	33.08	33.11	33.15	33.18	33.21	33.24	33.28	33.31	33.34	33.37	1110
1120	33.37	33.41	33.44	33.47	33.50	33.54	33.57	33.60	33.64	33.67	33.70	1120
1130	33.70	33.73	33.76	33.80	33.83	33.86	33.90	33.93	33.96	33.99	34.03	1130
1140	34.03	34.06	34.09	34.12	34.16	34.19	34.22	34.26	34.29	34.32	34.36	1140
1150	34.36	34.39	34.42	34.45	34.49	34.52	34.55	34.58	34.62	34.65	34.68	1150
1160	34.68	34.72	34.75	34.78	34.82	34.85	34.88	34.92	34.95	34.98	35.01	1160
1170	35.01	35.05	35.08	35.11	35.15	35.18	35.21	35.25	35.28	35.31	35.35	1170
1180	35.35	35.38	35.41	35.45	35.48	35.51	35.54	35.58	35.61	35.64	35.68	1180
1190	35.68	35.71	35.74	35.78	35.81	35.84	35.88	35.91	35.94	35.98	36.01	1190
1200	36.01	36.05	36.08	36.11	36.15	36.18	36.21	36.25	36.28	36.31	36.35	1200

*Based on the International Temperature Scale of 1948.

Table 7. Iron-Constantan Thermocouples—Continued

(Emf in Absolute Millivolts. Temperatures in Degrees F.* Reference Junctions at 32° F.)

°F	0	1	2	3	4	5	6	7	8	9	10	°F
Millivolts												
1200	36.01	36.05	36.08	36.11	36.15	36.18	36.21	36.25	36.28	36.31	36.35	1200
1210	36.35	36.38	36.42	36.45	36.48	36.52	36.55	36.58	36.62	36.65	36.69	1210
1220	36.69	36.72	36.75	36.79	36.82	36.86	36.89	36.92	36.96	36.99	37.02	1220
1230	37.02	37.06	37.09	37.13	37.16	37.20	37.23	37.26	37.30	37.33	37.36	1230
1240	37.36	37.40	37.43	37.47	37.50	37.54	37.57	37.60	37.64	37.67	37.71	1240
1250	37.71	37.74	37.78	37.81	37.84	37.88	37.91	37.95	37.98	38.02	38.05	1250
1260	38.05	38.08	38.12	38.15	38.19	38.22	38.26	38.29	38.32	38.36	38.39	1260
1270	38.39	38.43	38.46	38.50	38.53	38.57	38.60	38.64	38.67	38.70	38.74	1270
1280	38.74	38.77	38.81	38.84	38.88	38.91	38.95	38.98	39.02	39.05	39.08	1280
1290	39.08	39.12	39.15	39.19	39.22	39.26	39.29	39.33	39.36	39.40	39.43	1290
1300	39.43	39.47	39.50	39.54	39.57	39.61	39.64	39.68	39.71	39.75	39.78	1300
1310	39.78	39.82	39.85	39.89	39.92	39.96	39.99	40.03	40.06	40.10	40.13	1310
1320	40.13	40.17	40.20	40.24	40.27	40.31	40.34	40.38	40.41	40.45	40.48	1320
1330	40.48	40.52	40.55	40.59	40.62	40.66	40.69	40.73	40.76	40.80	40.83	1330
1340	40.83	40.87	40.90	40.94	40.98	41.01	41.05	41.08	41.12	41.15	41.19	1340
1350	41.19	41.22	41.26	41.29	41.33	41.36	41.40	41.43	41.47	41.50	41.54	1350
1360	41.54	41.58	41.61	41.65	41.68	41.72	41.75	41.79	41.82	41.86	41.90	1360
1370	41.90	41.93	41.97	42.00	42.04	42.07	42.11	42.14	42.18	42.22	42.25	1370
1380	42.25	42.29	42.32	42.36	42.39	42.43	42.46	42.50	42.53	42.57	42.61	1380
1390	42.61	42.64	42.68	42.71	42.75	42.78	42.82	42.85	42.89	42.92	42.96	1390
1400	42.96	43.00	43.03	43.07	43.10	43.14	43.18	43.21	43.25	43.28	43.32	1400
1410	43.32	43.35	43.39	43.43	43.46	43.50	43.53	43.57	43.60	43.64	43.68	1410
1420	43.68	43.71	43.75	43.78	43.82	43.85	43.89	43.92	43.96	44.00	44.03	1420
1430	44.03	44.07	44.10	44.14	44.18	44.21	44.25	44.28	44.32	44.35	44.39	1430
1440	44.39	44.42	44.46	44.50	44.53	44.57	44.60	44.64	44.68	44.71	44.75	1440
1450	44.75	44.78	44.82	44.85	44.89	44.93	44.96	45.00	45.03	45.07	45.10	1450
1460	45.10	45.14	45.18	45.21	45.25	45.28	45.32	45.35	45.39	45.42	45.46	1460
1470	45.46	45.50	45.53	45.57	45.60	45.64	45.68	45.71	45.75	45.78	45.82	1470
1480	45.82	45.85	45.89	45.92	45.96	46.00	46.03	46.07	46.10	46.14	46.18	1480
1490	46.18	46.21	46.25	46.28	46.32	46.35	46.39	46.42	46.46	46.50	46.53	1490
1500	46.53	46.57	46.60	46.64	46.67	46.71	46.74	46.78	46.82	46.85	46.89	1500
1510	46.89	46.92	46.96	47.00	47.03	47.07	47.10	47.14	47.17	47.21	47.24	1510
1520	47.24	47.28	47.32	47.35	47.39	47.42	47.46	47.49	47.53	47.56	47.60	1520
1530	47.60	47.63	47.67	47.70	47.74	47.78	47.81	47.85	47.88	47.92	47.95	1530
1540	47.95	47.99	48.02	48.06	48.09	48.13	48.16	48.20	48.24	48.27	48.31	1540
1550	48.31	48.34	48.38	48.41	48.45	48.48	48.52	48.55	48.59	48.62	48.66	1550
1560	48.66	48.69	48.73	48.76	48.80	48.83	48.87	48.90	48.94	48.97	49.01	1560
1570	49.01	49.04	49.08	49.11	49.15	49.18	49.22	49.25	49.29	49.32	49.36	1570
1580	49.36	49.39	49.43	49.46	49.50	49.53	49.56	49.60	49.63	49.67	49.70	1580
1590	49.70	49.74	49.77	49.81	49.84	49.88	49.91	49.94	49.98	50.01	50.05	1590
1600	50.05											1600

*Based on the International Temperature Scale of 1948.

Table 8. Iron-Constantan Thermocouples

(Emf in Absolute Millivolts. Temperatures in Degrees F*. Reference Junctions at 32° F)

Millivolts	.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00	Millivolts
Degrees F												
-7.00	-267	-273	-279	-285	-292	-298	-305	-313	-320			-7.00
-6.00	-212	-217	-222	-228	-233	-238	-244	-249	-255	-261	-267	-6.00
-5.00	-165	-169	-174	-178	-183	-188	-192	-197	-202	-207	-212	-5.00
-4.00	-121	-125	-130	-134	-138	-142	-147	-151	-156	-160	-165	-4.00
-3.00	-80	-84	-88	-92	-96	-100	-105	-109	-113	-117	-121	-3.00
-2.00	-42	-45	-49	-53	-57	-61	-65	-69	-72	-76	-80	-2.00
-1.00	-4	-8	-12	-15	-19	-23	-26	-30	-34	-38	-42	-1.00
(-)0.00	32	29	25	21	18	14	10	7	3	0	-4	(-)0.00
(+)0.00	32	36	39	43	46	50	53	57	60	64	67	(+)0.00
1.00	67	71	74	78	81	85	88	92	95	99	102	1.00
2.00	102	105	109	112	116	119	123	126	129	133	136	2.00
3.00	136	140	143	146	150	153	156	160	163	166	170	3.00
4.00	170	173	177	180	183	187	190	193	196	200	203	4.00
5.00	203	206	210	213	216	220	223	226	230	233	236	5.00
6.00	236	240	243	246	249	253	256	259	263	266	269	6.00
7.00	269	272	276	279	282	286	289	292	295	299	302	7.00
8.00	302	305	308	312	315	318	321	325	328	331	334	8.00
9.00	334	338	341	344	347	351	354	357	360	364	367	9.00
10.00	367	370	373	376	380	383	386	389	393	396	399	10.00
11.00	399	402	406	409	412	415	419	422	425	428	431	11.00
12.00	431	435	438	441	444	448	451	454	457	461	464	12.00
13.00	464	467	470	474	477	480	483	487	490	493	496	13.00
14.00	496	499	503	506	509	513	516	519	522	526	529	14.00
15.00	529	532	535	539	542	545	548	552	555	558	561	15.00
16.00	561	565	568	571	574	578	581	584	587	591	594	16.00
17.00	594	597	601	604	607	610	614	617	620	623	627	17.00
18.00	627	630	633	636	640	643	646	649	653	656	659	18.00
19.00	659	662	666	669	672	675	679	682	685	688	692	19.00
20.00	692	695	698	701	705	708	711	714	718	721	724	20.00

*Based on the International Temperature Scale of 1948.

Table 8. Iron-Constantan Thermocouples—Continued

(Emf in Absolute Millivolts. Temperatures in Degrees F*. Reference Junctions at 32° F)

Millivolts	Degrees F											Millivolts
	.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00	
20.00	692	695	698	701	705	708	711	714	718	721	724	20.00
21.00	724	727	731	734	737	741	744	747	750	754	757	21.00
22.00	757	760	763	767	770	773	777	780	783	786	790	22.00
23.00	790	793	796	799	803	806	809	812	816	819	822	23.00
24.00	822	825	829	832	835	839	842	845	848	852	855	24.00
25.00	855	858	861	865	868	871	874	878	881	884	887	25.00
26.00	887	890	894	897	900	903	907	910	913	916	919	26.00
27.00	919	923	926	929	932	936	939	942	945	948	952	27.00
28.00	952	955	958	961	964	967	971	974	977	980	983	28.00
29.00	983	987	990	993	996	999	1002	1006	1009	1012	1015	29.00
30.00	1015	1018	1021	1024	1028	1031	1034	1037	1040	1043	1046	30.00
31.00	1046	1050	1053	1056	1059	1062	1065	1068	1071	1074	1078	31.00
32.00	1078	1081	1084	1087	1090	1093	1096	1099	1102	1105	1108	32.00
33.00	1108	1112	1115	1118	1121	1124	1127	1130	1133	1136	1139	33.00
34.00	1139	1142	1145	1148	1151	1154	1157	1160	1164	1167	1170	34.00
35.00	1170	1173	1176	1179	1182	1185	1188	1191	1194	1197	1200	35.00
36.00	1200	1203	1206	1209	1212	1215	1217	1220	1223	1226	1229	36.00
37.00	1229	1232	1235	1238	1241	1244	1247	1250	1253	1256	1259	37.00
38.00	1259	1261	1264	1267	1270	1273	1276	1279	1282	1285	1288	38.00
39.00	1288	1290	1293	1296	1299	1302	1305	1308	1311	1313	1316	39.00
40.00	1316	1319	1322	1325	1328	1331	1333	1336	1339	1342	1345	40.00
41.00	1345	1348	1350	1353	1356	1359	1362	1365	1367	1370	1373	41.00
42.00	1373	1376	1379	1381	1384	1387	1390	1393	1395	1398	1401	42.00
43.00	1401	1404	1407	1410	1412	1415	1418	1421	1424	1426	1429	43.00
44.00	1429	1432	1435	1438	1440	1443	1446	1449	1451	1454	1457	44.00
45.00	1457	1460	1463	1465	1468	1471	1474	1477	1480	1482	1485	45.00
46.00	1485	1488	1491	1494	1496	1499	1502	1505	1508	1510	1513	46.00
47.00	1513	1516	1519	1522	1524	1527	1530	1533	1536	1539	1541	47.00
48.00	1541	1544	1547	1550	1553	1556	1558	1561	1564	1567	1570	48.00
49.00	1570	1573	1576	1578	1581	1584	1587	1590	1593	1596	1599	49.00
50.00	1599	1602										50.00

*Based on the International Temperature Scale of 1948.

Table 9. Iron-Constantan Thermocouples

(Emf in Absolute Millivolts. Temperatures in Degrees C(Int.1948) Reference Junctions at 0° C)

°C	0	1	2	3	4	5	6	7	8	9	10	°C
	Millivolts											
-190	-7.66	-7.69	-7.71	-7.73	-7.76	-7.78						-190
-180	-7.40	-7.43	-7.46	-7.49	-7.51	-7.54	-7.56	-7.59	-7.61	-7.64	-7.66	-180
-170	-7.12	-7.15	-7.18	-7.21	-7.24	-7.27	-7.30	-7.32	-7.35	-7.38	-7.40	-170
-160	-6.82	-6.85	-6.88	-6.91	-6.94	-6.97	-7.00	-7.03	-7.06	-7.09	-7.12	-160
-150	-6.50	-6.53	-6.56	-6.60	-6.63	-6.66	-6.69	-6.72	-6.76	-6.79	-6.82	-150
-140	-6.16	-6.19	-6.22	-6.26	-6.29	-6.33	-6.36	-6.40	-6.43	-6.46	-6.50	-140
-130	-5.80	-5.84	-5.87	-5.91	-5.94	-5.98	-6.01	-6.05	-6.08	-6.12	-6.16	-130
-120	-5.42	-5.46	-5.50	-5.54	-5.58	-5.61	-5.65	-5.69	-5.72	-5.76	-5.80	-120
-110	-5.03	-5.07	-5.11	-5.15	-5.19	-5.23	-5.27	-5.31	-5.35	-5.38	-5.42	-110
-100	-4.63	-4.67	-4.71	-4.75	-4.79	-4.83	-4.87	-4.91	-4.95	-4.99	-5.03	-100
-90	-4.21	-4.25	-4.30	-4.34	-4.38	-4.42	-4.46	-4.50	-4.55	-4.59	-4.63	-90
-80	-3.78	-3.82	-3.87	-3.91	-3.96	-4.00	-4.04	-4.08	-4.13	-4.17	-4.21	-80
-70	-3.34	-3.38	-3.43	-3.47	-3.52	-3.56	-3.60	-3.65	-3.69	-3.74	-3.78	-70
-60	-2.89	-2.94	-2.98	-3.03	-3.07	-3.12	-3.16	-3.21	-3.25	-3.30	-3.34	-60
-50	-2.43	-2.48	-2.52	-2.57	-2.62	-2.66	-2.71	-2.75	-2.80	-2.84	-2.89	-50
-40	-1.96	-2.01	-2.06	-2.10	-2.15	-2.20	-2.24	-2.29	-2.34	-2.38	-2.43	-40
-30	-1.48	-1.53	-1.58	-1.63	-1.67	-1.72	-1.77	-1.82	-1.87	-1.91	-1.96	-30
-20	-1.00	-1.04	-1.09	-1.14	-1.19	-1.24	-1.29	-1.34	-1.39	-1.43	-1.48	-20
-10	-0.50	-0.55	-0.60	-0.65	-0.70	-0.75	-0.80	-0.85	-0.90	-0.95	-1.00	-10
(-)0	0.00	-0.05	-0.10	-0.15	-0.20	-0.25	-0.30	-0.35	-0.40	-0.45	-0.50	(-)0
(+)0	0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	(+)0
10	0.50	0.56	0.61	0.66	0.71	0.76	0.81	0.86	0.91	0.97	1.02	10
20	1.02	1.07	1.12	1.17	1.22	1.28	1.33	1.38	1.43	1.48	1.54	20
30	1.54	1.59	1.64	1.69	1.74	1.80	1.85	1.90	1.95	2.00	2.06	30
40	2.06	2.11	2.16	2.22	2.27	2.32	2.37	2.42	2.48	2.53	2.58	40
50	2.58	2.64	2.69	2.74	2.80	2.85	2.90	2.96	3.01	3.06	3.11	50
60	3.11	3.17	3.22	3.27	3.33	3.38	3.43	3.49	3.54	3.60	3.65	60
70	3.65	3.70	3.76	3.81	3.86	3.92	3.97	4.02	4.08	4.13	4.19	70
80	4.19	4.24	4.29	4.35	4.40	4.46	4.51	4.56	4.62	4.67	4.73	80
90	4.73	4.78	4.83	4.89	4.94	5.00	5.05	5.10	5.16	5.21	5.27	90
100	5.27	5.32	5.38	5.43	5.48	5.54	5.59	5.65	5.70	5.76	5.81	100

Table 9. Iron-Constantan Thermocouples—Continued

(Emf in Absolute Millivolts. Temperatures in Degrees C (Int.1948) Reference Junctions at 0° C)

°C	0	1	2	3	4	5	6	7	8	9	10	°C
Millivolts												
100	5.27	5.32	5.38	5.43	5.48	5.54	5.59	5.65	5.70	5.76	5.81	100
110	5.81	5.86	5.92	5.97	6.03	6.08	6.14	6.19	6.25	6.30	6.36	110
120	6.36	6.41	6.47	6.52	6.58	6.63	6.68	6.74	6.79	6.85	6.90	120
130	6.90	6.96	7.01	7.07	7.12	7.18	7.23	7.29	7.34	7.40	7.45	130
140	7.45	7.51	7.56	7.62	7.67	7.73	7.78	7.84	7.89	7.95	8.00	140
150	8.00	8.06	8.12	8.17	8.23	8.28	8.34	8.39	8.45	8.50	8.56	150
160	8.56	8.61	8.67	8.72	8.78	8.84	8.89	8.95	9.00	9.06	9.11	160
170	9.11	9.17	9.22	9.28	9.33	9.39	9.44	9.50	9.56	9.61	9.67	170
180	9.67	9.72	9.78	9.83	9.89	9.95	10.00	10.06	10.11	10.17	10.22	180
190	10.22	10.28	10.34	10.39	10.45	10.50	10.56	10.61	10.67	10.72	10.78	190
200	10.78	10.84	10.89	10.95	11.00	11.06	11.12	11.17	11.23	11.28	11.34	200
210	11.34	11.39	11.45	11.50	11.56	11.62	11.67	11.73	11.78	11.84	11.89	210
220	11.89	11.95	12.00	12.06	12.12	12.17	12.23	12.28	12.34	12.39	12.45	220
230	12.45	12.50	12.56	12.62	12.67	12.73	12.78	12.84	12.89	12.95	13.01	230
240	13.01	13.06	13.12	13.17	13.23	13.28	13.34	13.40	13.45	13.51	13.56	240
250	13.56	13.62	13.67	13.73	13.78	13.84	13.89	13.95	14.00	14.06	14.12	250
260	14.12	14.17	14.23	14.28	14.34	14.39	14.45	14.50	14.56	14.61	14.67	260
270	14.67	14.72	14.78	14.83	14.89	14.94	15.00	15.06	15.11	15.17	15.22	270
280	15.22	15.28	15.33	15.39	15.44	15.50	15.55	15.61	15.66	15.72	15.77	280
290	15.77	15.83	15.88	15.94	16.00	16.05	16.11	16.16	16.22	16.27	16.33	290
300	16.33	16.38	16.44	16.49	16.55	16.60	16.66	16.71	16.77	16.82	16.88	300
310	16.88	16.93	16.99	17.04	17.10	17.15	17.21	17.26	17.32	17.37	17.43	310
320	17.43	17.48	17.54	17.60	17.65	17.71	17.76	17.82	17.87	17.93	17.98	320
330	17.98	18.04	18.09	18.15	18.20	18.26	18.32	18.37	18.43	18.48	18.54	330
340	18.54	18.59	18.65	18.70	18.76	18.81	18.87	18.92	18.98	19.03	19.09	340
350	19.09	19.14	19.20	19.26	19.31	19.37	19.42	19.48	19.53	19.59	19.64	350
360	19.64	19.70	19.75	19.81	19.86	19.92	19.97	20.03	20.08	20.14	20.20	360
370	20.20	20.25	20.31	20.36	20.42	20.47	20.53	20.58	20.64	20.69	20.75	370
380	20.75	20.80	20.86	20.91	20.97	21.02	21.08	21.13	21.19	21.24	21.30	380
390	21.30	21.35	21.41	21.46	21.52	21.57	21.63	21.68	21.74	21.79	21.85	390
400	21.85	21.90	21.96	22.02	22.07	22.13	22.18	22.24	22.29	22.35	22.40	400

Table 9. Iron-Constantan Thermocouples—Continued
(Emf in Absolute Millivolts. Temperatures in Degrees C(Int.1948) Reference Junctions at 0° C)

°C	0	1	2	3	4	5	6	7	8	9	10	°C
Millivolts												
400	21.85	21.90	21.96	22.02	22.07	22.13	22.18	22.24	22.29	22.35	22.40	400
410	22.40	22.46	22.51	22.57	22.62	22.68	22.73	22.79	22.84	22.90	22.95	410
420	22.95	23.01	23.06	23.12	23.17	23.23	23.28	23.34	23.39	23.45	23.50	420
430	23.50	23.56	23.61	23.67	23.72	23.78	23.83	23.89	23.94	24.00	24.06	430
440	24.06	24.11	24.17	24.22	24.28	24.33	24.39	24.44	24.50	24.55	24.61	440
450	24.61	24.66	24.72	24.77	24.83	24.88	24.94	25.00	25.05	25.11	25.16	450
460	25.16	25.22	25.27	25.33	25.38	25.44	25.49	25.55	25.60	25.66	25.72	460
470	25.72	25.77	25.83	25.88	25.94	25.99	26.05	26.10	26.16	26.22	26.27	470
480	26.27	26.33	26.38	26.44	26.49	26.55	26.61	26.66	26.72	26.77	26.83	480
490	26.83	26.89	26.94	27.00	27.05	27.11	27.17	27.22	27.28	27.33	27.39	490
500	27.39	27.45	27.50	27.56	27.61	27.67	27.73	27.78	27.84	27.90	27.95	500
510	27.95	28.01	28.07	28.12	28.18	28.23	28.29	28.35	28.40	28.46	28.52	510
520	28.52	28.57	28.63	28.69	28.74	28.80	28.86	28.91	28.97	29.02	29.08	520
530	29.08	29.14	29.20	29.25	29.31	29.37	29.42	29.48	29.54	29.59	29.65	530
540	29.65	29.71	29.76	29.82	29.88	29.94	29.99	30.05	30.11	30.16	30.22	540
550	30.22	30.28	30.34	30.39	30.45	30.51	30.57	30.62	30.68	30.74	30.80	550
560	30.80	30.85	30.91	30.97	31.02	31.08	31.14	31.20	31.26	31.31	31.37	560
570	31.37	31.43	31.49	31.54	31.60	31.66	31.72	31.78	31.83	31.89	31.95	570
580	31.95	32.01	32.06	32.12	32.18	32.24	32.30	32.36	32.41	32.47	32.53	580
590	32.53	32.59	32.65	32.71	32.76	32.82	32.88	32.94	33.00	33.06	33.11	590
600	33.11	33.17	33.23	33.29	33.35	33.41	33.46	33.52	33.58	33.64	33.70	600
610	33.70	33.76	33.82	33.88	33.94	33.99	34.05	34.11	34.17	34.23	34.29	610
620	34.29	34.35	34.41	34.47	34.53	34.58	34.64	34.70	34.76	34.82	34.88	620
630	34.88	34.94	35.00	35.06	35.12	35.18	35.24	35.30	35.36	35.42	35.48	630
640	35.48	35.54	35.60	35.66	35.72	35.78	35.84	35.90	35.96	36.02	36.08	640
650	36.08	36.14	36.20	36.26	36.32	36.38	36.44	36.50	36.56	36.62	36.69	650
660	36.69	36.75	36.81	36.87	36.93	36.99	37.05	37.11	37.18	37.24	37.30	660
670	37.30	37.36	37.42	37.48	37.54	37.60	37.66	37.73	37.79	37.85	37.91	670
680	37.91	37.97	38.04	38.10	38.16	38.22	38.28	38.34	38.41	38.47	38.53	680
690	38.53	38.59	38.66	38.72	38.78	38.84	38.90	38.97	39.03	39.09	39.15	690
700	39.15	39.22	39.28	39.34	39.40	39.47	39.53	39.59	39.65	39.72	39.78	700
710	39.78	39.84	39.91	39.97	40.03	40.10	40.16	40.22	40.28	40.35	40.41	710
720	40.41	40.48	40.54	40.60	40.66	40.73	40.79	40.86	40.92	40.98	41.05	720
730	41.05	41.11	41.17	41.24	41.30	41.36	41.43	41.49	41.56	41.62	41.68	730
740	41.68	41.75	41.81	41.87	41.94	42.00	42.07	42.13	42.19	42.26	42.32	740
750	42.32	42.38	42.45	42.51	42.58	42.64	42.70	42.77	42.83	42.90	42.96	750
760	42.96	43.02	43.09	43.15	43.22	43.28	43.35	43.41	43.48	43.54	43.60	760
770	43.60	43.67	43.73	43.80	43.86	43.92	43.99	44.05	44.12	44.18	44.25	770
780	44.25	44.31	44.38	44.44	44.50	44.57	44.63	44.70	44.76	44.82	44.89	780
790	44.89	44.95	45.02	45.08	45.15	45.21	45.28	45.34	45.40	45.47	45.53	790
800	45.53	45.60	45.66	45.72	45.79	45.85	45.92	45.98	46.05	46.11	46.18	800
810	46.18	46.24	46.30	46.37	46.43	46.50	46.56	46.62	46.69	46.75	46.82	810
820	46.82	46.88	46.94	47.01	47.07	47.14	47.20	47.27	47.33	47.39	47.46	820
830	47.46	47.52	47.58	47.65	47.71	47.78	47.84	47.90	47.97	48.03	48.09	830
840	48.09	48.16	48.22	48.28	48.35	48.41	48.48	48.54	48.60	48.66	48.73	840
850	48.73	48.79	48.85	48.92	48.98	49.04	49.10	49.17	49.23	49.29	49.36	850
860	49.36	49.42	49.48	49.54	49.61	49.67	49.73	49.79	49.86	49.92	49.98	860
870	49.98	50.04										870

Table 10. Iron-Constantan Thermocouples

(Emf in Absolute Millivolts. Temperatures in Degrees C(Int.1948) Reference Junctions at 0° C)

Millivolts	.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00	Millivolts
Degrees C												
-7.00	-166	-169	-173	-176	-180	-184	-188	-192	-196			-7.00
-6.00	-136	-138	-141	-144	-147	-150	-153	-156	-159	-163	-166	-6.00
-5.00	-109	-112	-114	-117	-119	-122	-125	-127	-130	-133	-136	-5.00
-4.00	-85	-87	-90	-92	-94	-97	-99	-102	-104	-107	-109	-4.00
-3.00	-62	-65	-67	-69	-71	-74	-76	-78	-80	-83	-85	-3.00
-2.00	-41	-43	-45	-47	-49	-52	-54	-56	-58	-60	-62	-2.00
-1.00	-20	-22	-24	-26	-28	-30	-32	-35	-37	-39	-41	-1.00
(-)0.00	0	-2	-4	-6	-8	-10	-12	-14	-16	-18	-20	(-)0.00
(+)0.00	0	2	4	6	8	10	12	14	16	18	20	(+)0.00
1.00	20	22	24	25	27	29	31	33	35	37	39	1.00
2.00	39	41	43	45	47	48	50	52	54	56	58	2.00
3.00	58	60	62	63	65	67	69	71	73	75	77	3.00
4.00	77	78	80	82	84	86	88	90	91	93	95	4.00
5.00	95	97	99	101	102	104	106	108	110	112	113	5.00
6.00	113	115	117	119	121	123	124	126	128	130	132	6.00
7.00	132	134	135	137	139	141	143	144	146	148	150	7.00
8.00	150	152	154	155	157	159	161	163	164	166	168	8.00
9.00	168	170	172	173	175	177	179	181	182	184	186	9.00
10.00	186	188	190	191	193	195	197	199	200	202	204	10.00
11.00	204	206	208	209	211	213	215	217	218	220	222	11.00
12.00	222	224	226	227	229	231	233	235	236	238	240	12.00
13.00	240	242	244	245	247	249	251	253	254	256	258	13.00
14.00	258	260	262	263	265	267	269	271	272	274	276	14.00
15.00	276	278	280	281	283	285	287	289	290	292	294	15.00
16.00	294	296	298	300	301	303	305	307	309	310	312	16.00
17.00	312	314	316	318	319	321	323	325	327	329	330	17.00
18.00	330	332	334	336	338	339	341	343	345	347	348	18.00
19.00	348	350	352	354	356	357	359	361	363	365	366	19.00
20.00	366	368	370	372	374	376	377	379	381	383	385	20.00

Table 10. Iron-Constantan Thermocouples—Continued

(Emf in Absolute Millivolts. Temperatures in Degrees C(Int.1948) Reference Junctions at 0° C)

Millivolts	Degrees C											Millivolts
	.00	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.00	
20.00	366	368	370	372	374	376	377	379	381	383	385	20.00
21.00	385	386	388	390	392	394	395	397	399	401	403	21.00
22.00	403	405	406	408	410	412	414	416	417	419	421	22.00
23.00	421	423	424	426	428	430	432	434	435	437	439	23.00
24.00	439	441	443	444	446	448	450	452	453	455	457	24.00
25.00	457	459	461	463	464	466	468	470	472	473	475	25.00
26.00	475	477	479	481	482	484	486	488	489	491	493	26.00
27.00	493	495	497	499	500	502	504	506	507	509	511	27.00
28.00	511	513	514	516	518	520	522	523	525	527	529	28.00
29.00	529	530	532	534	536	537	539	541	543	544	546	29.00
30.00	546	548	550	551	553	555	557	558	560	562	564	30.00
31.00	564	565	567	569	571	572	574	576	577	579	581	31.00
32.00	581	583	584	586	588	589	591	593	595	596	598	32.00
33.00	598	600	601	603	605	607	608	610	612	613	615	33.00
34.00	615	617	618	620	622	624	625	627	629	630	632	34.00
35.00	632	634	635	637	639	640	642	644	645	647	649	35.00
36.00	649	650	652	654	655	657	659	660	662	664	665	36.00
37.00	665	667	668	670	672	673	675	677	678	680	681	37.00
38.00	681	683	685	686	688	690	691	693	694	696	698	38.00
39.00	698	699	701	702	704	706	707	709	710	712	713	39.00
40.00	713	715	717	718	720	721	723	725	726	728	729	40.00
41.00	729	731	732	734	736	737	739	740	742	743	745	41.00
42.00	745	747	748	750	751	753	754	756	757	759	761	42.00
43.00	761	762	764	765	767	768	770	772	773	775	776	43.00
44.00	776	778	779	781	782	784	785	787	789	790	792	44.00
45.00	792	793	795	796	798	799	801	803	804	806	807	45.00
46.00	807	809	810	812	814	815	817	818	820	821	823	46.00
47.00	823	824	826	828	829	831	832	834	835	837	839	47.00
48.00	839	840	842	843	845	846	848	850	851	853	854	48.00
49.00	854	856	858	859	861	862	864	866	867	869	870	49.00
50.00	870	872										50.00

WASHINGTON, March 11, 1953.