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Reference Tables for the Pt-30 Percent Rh Versus Pt-6 Percent Rh Thermocouple

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Reference tables for the platinum-30 percent rhodium versus platinum-6 percent rhodium thermocouple have been established for the range 0 to 1820 °C based upon the calibrations of thermocouples furnished by three manufacturers in the United States and by one European manufacturer. The thermocouples were calibrated by comparison with standard instruments such as platinum resistance thermometers, platinum-10 percent rhodium versus platinum thermocouples and optical pyrometers. The test procedures and facilities used for the calibrations are described and the accuracy of the measurements is discussed. The platinum-rhodium elements of the thermocouples were examined by a general qualitative spectrochemical method and the results of the analyses are given. Tables of emf of the individual elements of the thermocouple versus Pt-27 for the range 0 to 1500 °C are also presented. In addition, the effect of variations in the alloying percentages of platinum and rhodium on the temperature-emf relationships of the elements are shown. The results of calibrations for other Pt-30 percent Rh versus Pt-6 percent Rh thermocouples, which were received for routine calibration at NBS during the period from May 1963 to March 1965, are also shown.

Key Words: Accuracy, calibration, emf, platinum-rhodium elements, platinum-30 percent rhodium versus platinum-6 percent rhodium, reference tables, spectrochemical analyses, thermocouple.

1. Introduction

Studies by Ehringer [1][1] and by Walker, Ewing, and Miller [2, 3], have demonstrated that thermocouples in which both legs are platinum-rhodium alloys are capable of reliable temperature measurements at high temperatures. Such thermocouples have been shown to offer the following distinct advantages over the more familiar platinum-10 percent rhodium versus platinum and platinum-13 percent rhodium versus platinum thermocouples at high temperatures: (1) improved stability, (2) increased mechanical strength, and (3) higher operating temperature. The three most common platinum-rhodium combinations in use today are the platinum-20 percent rhodium versus platinum-5 percent rhodium, or 20–5 thermocouple; the platinum-30 percent rhodium versus platinum-6 percent rhodium, or 30–6 thermocouple; and the platinum-40 percent rhodium versus platinum-20 percent rhodium, or 40–20 thermocouple. The temperature-emf curves for these thermocouples and the more familiar Pt-10 percent Rh versus Pt and Pt-13 percent Rh versus Pt thermocouples are shown in figure 1.

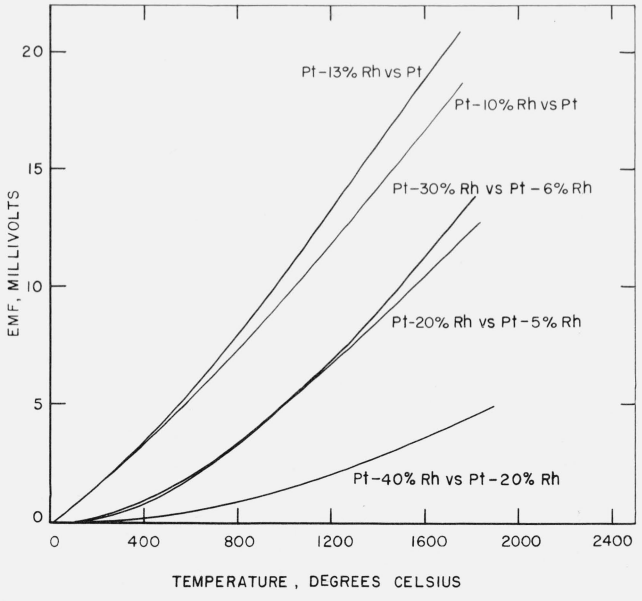

FIGURE 1. *Temperature-emf curves for platinum-rhodium thermocouples, reference junctions at 0 °C.*

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

Of the three platinum-rhodium combinations the 30–6 thermocouple offers the most favorable overall characteristics. Although the thermoelectric characteristics of the 30–6 thermocouple and the 20–5 thermocouple are similar, the 30–6 thermocouple does offer a slightly greater thermoelectric power at the higher temperatures and it also has a somewhat higher tensile strength than the 20–5 thermocouple. The 40–20 thermocouple is a special combination intended primarily for use in the 1700 to 1850 °C range [4]. Even though the 40–20 thermocouple may be used at slightly higher temperatures than the 30–6 thermocouple, its relatively low thermoelectric power limits its usefulness at lower temperatures.

Studies made with the 30–6 thermocouple have shown it can be used intermittently (for several hours) up to 1800 °C and continuously (for several hundred hours) at temperatures up to about 1750 °C with only small changes in calibration. The maximum temperature limit for the thermocouple is governed, primarily, by the liquidus of the Pt-6 percent Rh element which is estimated to be about 1820 °C [5]. The thermocouple is most reliable when used in a clean oxidizing atmosphere (air) but has also been used with some success in neutral atmospheres [2] and vacuum [3, 6]. The stability of the thermocouple at high temperatures has been shown [2] to depend, primarily, upon the quality of the materials used for protecting and insulating the thermocouple. High purity alumina with low iron-content appears to be the most suitable material available today for the purpose.

The 30–6 thermocouple was first introduced in Europe by Degussa, Hanau, Germany. Recently a reference curve for the thermocouple was published by Obrowski and Prinz [7] of the Degussa Laboratories. The curve, which is represented by a set of cubic equations, was developed by determining the emfs of numerous Degussa thermocouples at various thermometric fixed points. This curve is often referred to as the new Degussa curve since it replaces an older curve formerly used with the Degussa thermocouples. The emfs of the old and new Degussa reference curves [7] are given at 100 deg intervals in table 1 for the range 0 to 1800 °C.

Because of its favorable characteristics, the 30–6 thermocouple has rapidly gained acceptance and become more widely used in this country. Consequently, the National Bureau of Standards was requested by the American Society for Testing and Materials, Committee E–20, Subcommittee IV to prepare reference tables for the thermocouple to facilitate its use and calibration. A testing program was initiated by the Temperature Section at NBS for this purpose. In this program thermocouples were obtained from three manufacturers in the United States and from one European manufacturer and were calibrated by conventional methods of test. The methods included calibration by comparison with standard instruments, such as platinum-10 percent rhodium versus platinum thermocouples, platinum resistance thermometers, and optical pyrometers, and the determination of the emfs of the individual elements of the thermocouples against the platinum thermoelectric standard maintained at NBS known as Pt-27. These methods of test are discussed in NBS Circular 590. Reference tables for the 30–6 thermocouple were calculated from the results of the calibrations and the tables are presented in the appendix of this paper. The temperature-emf relationship given by the reference tables is believed to be representative of materials being produced by manufacturers in this country at the present time.

TABLE 1. *Emf of old and new Degussa reference curves for the 30–6 thermocouple*

Temperature	Emf	
(Int. 1948)	Old curve	New curve
°C	mV	mV
0	0.000	0.000
100	.056	.033
200	.162	.177
300	.419	.430
400	.790	.789
500	1.245	1.247
600	1.796	1.795
700	2.442	2.433
800	3.162	3.159
900	3.964	3.966
1000	4.839	4.847
1100	5.791	5.795
1200	6.811	6.806
1300	7.890	7.871
1400	9.000	8.977
1500	10.130	10.113
1600	11.260	11.267
1700	12.390	12.428
1800	13.520	13.583

Some of the preliminary work in the reference table program, concerned with the selection of thermocouple materials, was described in a previous paper [8]. The testing procedures and methods used in the program were also discussed in the previous paper but are described again in this paper in more detail.

2. Thermocouple Materials

2.1. Thermocouple Materials Used in the Preparation of the Reference Table

Thermocouple materials were supplied by three American manufacturers: (1) Engelhard Industries, Inc., (2) Sigmund Cohn Corporation, (3) J. Bishop and Company, and by one European manufacturer, Degussa, Hanau, Germany. A length of 0.020 in. (nominal) diameter wire, between 9 and 10 ft long, of both the Pt-6 percent Rh and the Pt-30 percent Rh alloy was furnished by each manufacturer. The alloy wires supplied by the American manufacturers were fabricated to have compositions of Pt-6.12 percent Rh and Pt-29.60 percent Rh [8]. The alloy wires submitted by Degussa were taken from stock and were reported to have nominal compositions of Pt-6.15 percent Rh and Pt-29.50 percent Rh.[2]

[2] For convenience in the ensuing discussion and presentation of the test results the platinum-rhodium wires submitted by Degussa will be referred to as Pt-6.12 percent Rh and Pt-29.60 percent Rh alloys.

Eleven thermocouples were prepared from the alloy wires supplied, three thermocouples from each of the American manufacturers and two thermocouples from Degussa. For purposes of this report, letter designations A, B, and C are assigned to the three American manufacturers (in an arbitrary way), and D is assigned to Degussa. The thermocouples of the various manufacturers are identified as shown in table 2.

TABLE 2. *Description of thermocouples used in preparation of reference table*

Manufacturer designation	Thermocouple identification	Material received
A	A1, A2, A3	Jan. 1963
B	B1, B2, B3	Dec. 1962
C	C1, C2, C3	Jan. 1963
D	D1, D2	Oct. 1962

Samples of the platinum-rhodium wires submitted by manufacturers A, B, C, and D were examined by a general qualitative spectrochemical method[3] and the results of the analyses are given in table 3. The results of an analysis for a thermocouple quality (reference grade) platinum wire are also shown for purposes of comparison.

groups of 0.020 in. diam platinum-rhodium wires were supplied by manufacturer B for study. The two groups consisted of one group of wires with rhodium percentages of 5.90, 5.95, 6.00, 6.05, and 6.10 and a second group of wires with rhodium percentages of 29.50, 29.75, 30.00, and 30.25. Also, during the period of test program, a number of 30–6 thermocouples were submitted by industrial users and thermocouple manufacturers for routine calibration. The results of the calibrations for some of the thermocouples submitted will be discussed in this paper. In most cases the manufacturers of these thermocouples were known. Some descriptive information about the thermocouples to be discussed is given in table 4.

TABLE 4. *Description of other thermocouples*

Manufacturer [a]	Approximate wire diameter	Thermocouple identification	Material received
	inches		
A	0.025	A11	Jan. 1964
A	.020	A22	Mar. 1965
B	.020	B11	Dec. 1963
B	.032	B22	May 1964
C	.020	C11	Oct. 1963
D	.020	D11	Oct. 1964
D	.020	D22	Oct. 1964
E [b]	.020	E11	May 1963
Unknown	.025	X11	Oct. 1963

[a] In cases where two thermocouples from the same manufacturer are listed, the thermocouples are from different lots.
[b] Manufacturer: Johnson Matthey and Company, London, England.

TABLE 3. *Results of spectrochemical analyses of platinum-rhodium thermoelements*

Elements detected	Manufacturer A		Manufacturer B		Manufacturer C		Manufacturer D		Reference grade platinum
	Pt-6.12%Rh element	Pt-29.60%Rh element	Pt-6.12%Rh element	Pt-29.60%Rh element	Pt-6.12%Rh element	Pt-29.60%Rh element	Pt-6.12%Rh element	Pt-29.60%Rh element	
Ag	−?	−?	−?	−?	−?	−?	−?	−?	−?
Al	−	−	−	W	−	−	−	−	−
Au	−?	VW	−?	−?	−?	−?	−?	VW	−?
B	−	FT	−	−	−	FT	−	−	−
Ca	−	T	−	−	−	T	−	FT	−
Cu	FT	T	FT	FT	FT	FT	FT	T	T
Fe	VW	W	FT	VW	T	VW	T	W	−
Ir	−	W	−	VW	−	VW	−	W	−
Mg	−?	T	−	−	T	−	VW	T	−
Ni	−	−	−	−?	−	−	−	−	−
Pd	W	W	VW	VW	W	VW	W	W	−
Pt	VS	VS	VS	VS	VS	VS	VS	VS	VS
Rh	S	VS	S	VS	S	VS	S	VS	−
Si	W	VW	−?	VW	VW	VW	−?	−	−
Tl	−?	−	−?	−	−?	−	−?	−	−?

NOTE: In general, VS, greater than 10%; S, 1–10%; W, 0.01–0.1%; VW, 0.001–0.01%; T, 0.0001–0.001%; FT, less than 0.0001%; −, not detected; −?, probably not detected.

2.2. Other Thermocouples and Thermocouple Materials

In addition to the materials supplied specifically for purposes of preparing the reference tables, other thermocouples and thermocouple materials were also obtained and various other tests performed. Two

[3] Spectrochemical analysis performed by the Spectrochemistry Section of the National Bureau of Standards.

3. Apparatus

Four stirred liquid baths were used for calibrations in the range 0 to 450 °C. Each of the baths employed a different liquid medium and each was used to cover a separate portion of the temperature range. Temperatures in the stirred liquid baths were determined with a calibrated platinum resistance thermometer. The baths are described in more detail in section 5.1c

of NBS Monograph 90. Also in the range 0 to 450 °C and for temperatures up to 1100 °C a horizontal tube type furnace was used. The furnace has a nickel (80)-chromium (20) tube which serves as a heating element. The tube has an inside diameter of 13/16 in., an outside diameter of 15/16 in. and is 24 in. long. The furnace is described in section 4.1 of NBS Circular 590. Temperatures in the tube furnace were determined with standard Pt-10 percent Rh versus Pt thermocouples. The Pt-10 percent Rh versus Pt thermocouples were calibrated by the fixed point method (see sections 3 and 5.1 of NBS Circular 590) and met the requirements of the International Practical Temperature Scale of 1948 for standard thermocouples (see NBS Monograph 37). The calibrations of the standard thermocouples above 1063 °C were extrapolated by the method described in section 5.1 of Circular 590.

Platinum reference wires were used in the calibrations performed in the stirred liquid baths and the tube furnace, and were also used in several other tests described in the paper. The emfs of the platinum reference wires were known relative to the platinum thermoelectic standard maintained at NBS, known as Standard Pt-27 (see section 7 of NBS Circ. 590).

The emf measurements for the calibrations in the stirred liquid baths in the 0 to 450 °C range were made with a six dial Rubicon thermal free potentiometer and the resistance measurements of the platinum resistance thermometer were made with a Leeds and Northrup Type G–2 resistance thermometer bridge. In all other tests, the emf measurements were made with Leeds and Northup Type K–3 potentiometers. The K–3 potentiometers were calibrated by comparison with a calibrated six dial precision potentiometer.

In the range 1063 to 1790 °C blackbodies were used for calibrations by direct comparison with an optical pyrometer. Two blackbodies were fabricated from 4 in. long, round, alumina rods, one with a diameter of 1 3/8 in. and one with a diameter of 1 1/2 in. In one end of each rod a 1/8 in. diam axial sight hole was drilled to a depth of 2 in. and a 1/4 in. diam axial hole was drilled in the opposite end of each rod to a depth of 1 15/16 in. The 1/8 in. diam axial sight holes approximate a blackbody very closely when the walls of the holes are at a uniform temperature. The spectral emissivity of the sight holes at a wavelength of 0.65 μ was assumed to be 1 for measurements described in this paper which involve temperature determinations with an optical pyrometer (see sec. 7 for a discussion of the errors associated with the use of the blackbodies). For convenience, the alumina rods will, henceforth, be referred to as the alumina "blackbodies." A cross section of the 1 1/2 in. diam alumina "blackbody" is shown in figure 2.

The 1 3/8 in. diam alumina "blackbody" was heated in a high temperature tube furnace. The heating element of the furnace was a silicon carbide tube with an inside diameter of about 1 3/8 in., and outside diameter of 2 3/8 in. and an overall length of 28 in. The alumina "blackbody" was located in the furnace at the center of the silicon carbide tube, and a series of alumina disks was positioned on either side of the rod. The disks served as radiation shields and reduced the power loses out the ends of the furnace. An alumina protecting tube with an o.d. of about 1/4 in. was inserted through central holes in the series of alumina disks and into the 1/4 in. hole in one end of the alumina "blackbody." A cross section of the furnace is shown in figure 3.

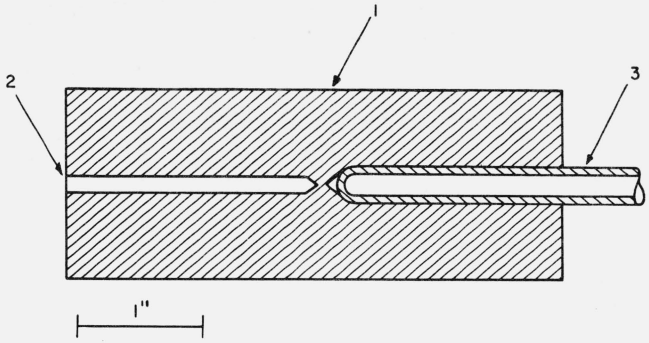

FIGURE 2. *Cross section of alumina "blackbody": (1) alumina rod; (2) blackbody cavity or sight hole; (3) alumina protecting tube.*

The 1 1/2-in. diam alumina "blackbody" was heated in a horizontal wire wound tube furnace. The furnace had three separate heater windings, two end windings, and a center winding of platinum-40 percent rhodium wire. The windings were wound on an alumina tube which had an inside diameter of about 1 1/2 in. and was 24 in. long. The inside of the alumina tube was lined with a Pt-10 percent Rh tube which was rolled from a piece of sheet stock 0.005 in. thick. The alumina "blackbody," alumina disks, and an alumina protecting tube were arranged in the furnace similar to the arrangement used in the silicon carbide tube furnace. A cross section of the wire wound tube furnace is shown in figure 4.

The temperatures of the alumina "blackbodies" were determined with a calibrated Leeds and Northrup Type 8636–C visual optical pyrometer. The optical pyrometer was calibrated by comparison with the NBS visual standard optical pyrometer[4] using a tungsten strip lamp as a transfer source. The calibration consisted of determining the relationship between the brightness or blackbody temperatures indicated by the instrument and the pyrometer lamp current. The calibration procedure is described in section 5.1 of NBS Monograph 41. In use the current through the pyrometer lamp was controlled with a rheostat and determined by measuring the voltage drop across a 1 Ω standard resistor in series with the lamp.

[4] This pyrometer is known as the Fairchild pyrometer and it is described in section 2.2 of NBS Monograph 41. The calibration and accuracy of the instrument are discussed in section 4 of the Monograph.

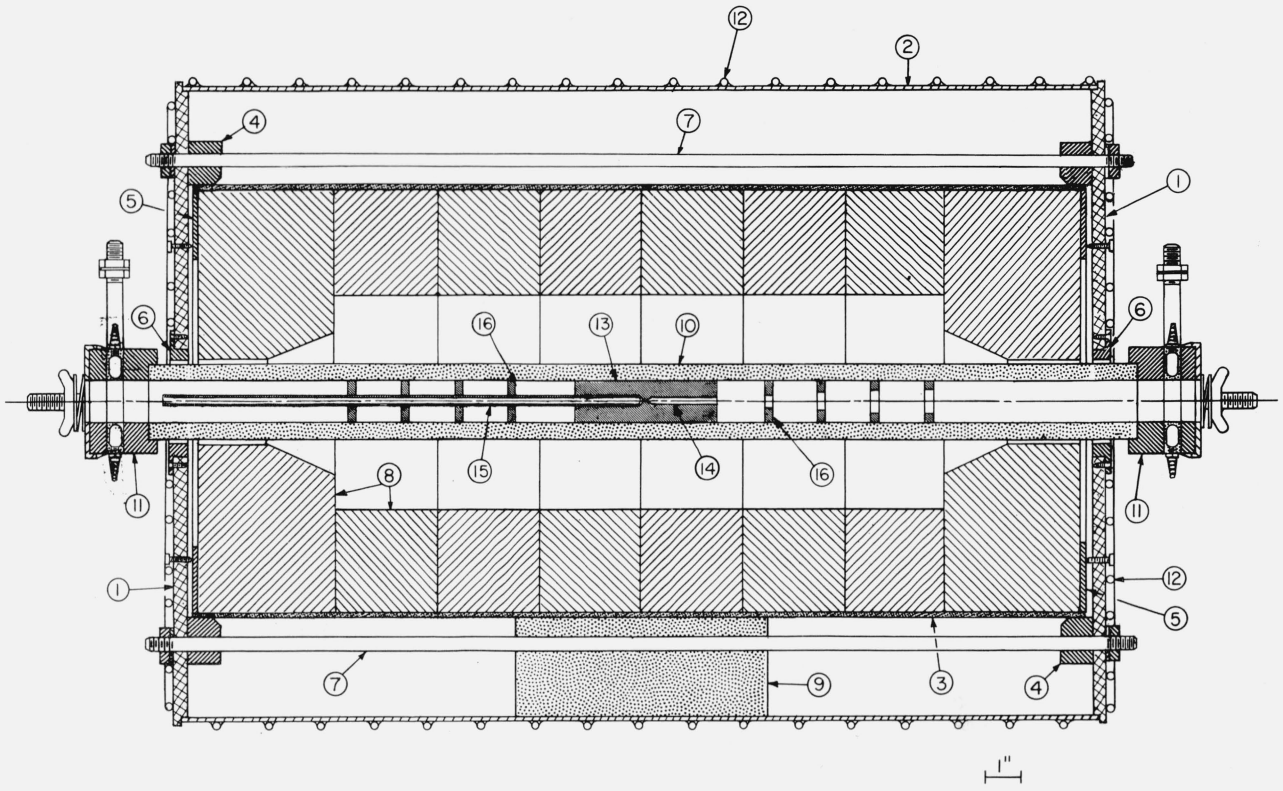

FIGURE 3. *Cross section of silicon carbide tube furnace: (1) brass end plate; (2) brass shell; (3) inconel liner; (4) stainless steel support ring; (5) stainless steel retaining disk; (6) transite insulator ring; (7) inconel tie rod; (8) refractory insulating liner; (9) refractory support; (10) silicon carbide heating tube; (11) terminal assembly; (12) copper tubing; (13) alumina "blackbody"; (14) blackbody cavity or sight hole; (15) alumina protecting tube; (16) alumina disk.*

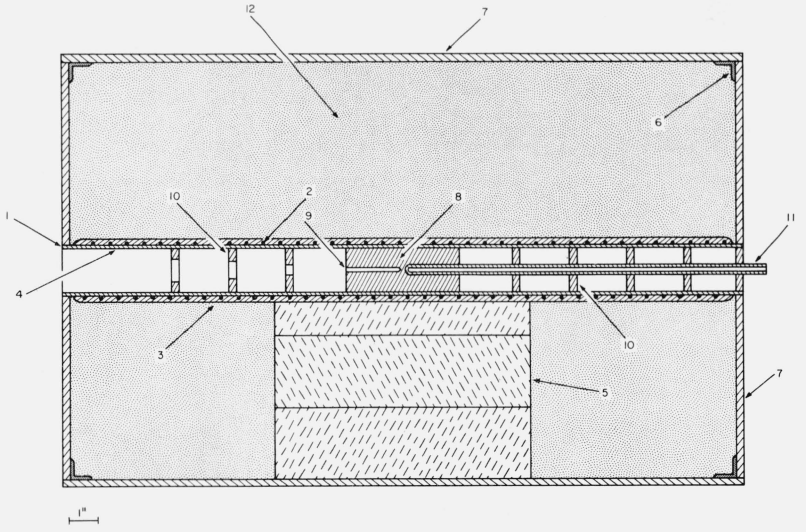

FIGURE 4. *Cross section of Pt-Rh wire wound tube furnace: (1) alumina tube; (2) Pt-40 percent Rh winding; (3) alumina cement; (4) 0.005 inch thick Pt-10 percent Rh liner; (5) refractory brick support; (6) steel angle frame; (7) transite shell; (8) alumina "blackbody"; (9) blackbody cavity or sight hole; (10) alumina disk; (11) alumina protecting tube; (12) bubbled alumina insulation.*

4. Experimental Procedure

4.1. Tests of Thermocouples in Table 2

The platinum-rhodium wires submitted by the four manufacturers were prepared for test by annealing them electrically in air for 1 hr at about 1450 °C. The annealing temperature of the wires was determined with an optical pyrometer, assuming the spectral emissivity of the wires was 0.3 at a wavelength of 0.65 μ. The wires were then cut and paired to form the 11 thermocouples listed in table 2. The measuring junctions of the thermocouples were welded with an oxygen-gas torch and the thermocouples were assembled in double bore alumina insulating tubes. The thermocouples were then tested as described in the following sections. The tests are described in the following sections in chronological order and are also summarized in table 5. All the tests were performed in air, and the reference junctions of the thermocouples and thermoelements were maintained at 0 °C in ice baths.

TABLE 5. *Summary of tests on the thermocouples in table 2*

Section	Thermocouple tested	Description of test	Temperature reference
4.1a	A1, A2, A3, B1, B2, B3, C1, C2, C3, D1 and D2	Calibration of thermoelements by comparison with platinum reference wires in chromel tube furnace in 0 to 1100 °C range.	Pt versus Pt-10 percent Rh thermocouple.
4.1b	A1, B3 and C2	Calibration of thermoelements by comparison with platinum reference wires in stirred liquid baths in 0 to 450 °C range.	Platinum resistance thermometer.
4.1c	A1, A2, B2, B3, C1, C2, D1 and D2	Calibration of thermocouples by direct comparison with optical pyrometer in range 1050 to 1600 °C (thermocouples heated in SiC tube furnace).	Optical pyrometer.
4.1d	A1, B2, C1 and D2	Calibration of thermoelements by comparison with platinum reference wires in range 1063 to 1500 °C.	Thermocouple B3.
4.1e	A1, A2, B2, B3, C1, C2, D1 and D2	Calibration of thermocouples by comparison with Pt versus Pt-10 percent Rh thermocouple in range 1063 to 1450 °C.	Pt versus Pt-10 percent Rh thermocouple.
4.1f	A2, A3, B1, B3, C2, C3, D1 and D2	Calibration of thermocouples by direct comparison with optical pyrometer in range 1063 to 1750 °C [a] (thermocouples heated in Pt-Rh wire wound tube furnace).	Optical pyrometer.

[a] Thermocouples A3, B1, and C3 calibrated to 1790 °C.

a. Tests in Nickel-Chromium Tube Furnace in Range 0 to 1100 °C

In these tests the emf of both thermoelements of each of the eleven thermocouples was determined against platinum reference wires in the horizontal nickel-chromium tube furnace. Determinations were made with decreasing furnace temperature at 50 deg intervals in the range 1100 to 50 °C, as well as at 1063 °C, 630.5, and 419.5 °C. These measurements were followed by a second set of determinations made with increasing furnace temperature at 50 deg intervals from 425 to 1075 °C and the determinations at 400, 419.5, 630.5, and 1063 °C were repeated. For these tests the measuring junctions of several 30–6 thermocouples, a platinum-10 percent rhodium versus platinum thermocouple and a platinum reference wire were welded into a common junction. The thermocouples and reference wire were placed in a closed end alumina protecting tube and inserted into the tube furnace until the common measuring junction was at the center of the furnace. The temperature of the furnace was regulated by the manual control of the power with an adjustable transformer. The emf of the platinum-rhodium thermoelement against the platinum reference wire and the emf of the platinum-10 percent rhodium versus platinum thermocouple were determined simultaneously by the two-potentiometer method. The two-potentiometer method is described in section 4.1 of NBS Circular 590.

b. Tests in Stirred Liquid Baths in Range 0 to 450 °C

Thermocouples A1, B3, and C2 were selected for testing in the stirred liquid baths in the range 0 to 450 °C. For these tests the Pt-6.12 percent Rh elements of the three thermocouples and a platinum reference wire were assembled in a four bore alumina insulating tube and the measuring junction of the wires welded together. The Pt-29.60 percent Rh elements and a platinum reference wire were assembled in the same manner. Each of the alumina insulating tubes was inserted into a closed end Pyrex protecting tube.

The assemblies were immersed in the stirred liquid bath along with a platinum resistance thermometer. The temperature of the bath was regulated by manually controlling the power input to the bath with an adjustable transformer. With the temperature of the bath held nearly constant the emfs of the Pt-6.12 percent Rh and Pt-29.60 percent Rh wires against the platinum reference wires were measured. The measurements were preceded and followed by determinations of the bath temperature with the platinum resistance thermometer. In this manner, measurements were made at 25 deg intervals from 25 to 450 °C. Four different stirred liquid baths were required for this purpose.

c. Calibration of Thermocouples by Direct Comparison With Optical Pyrometer in Range 1050 to 1600 °C (Thermocouples Heated in SiC Tube Furnace)

Thermocouples A1, A2, B2, B3, C1, C2, D1, and D2 were calibrated one at a time in the range 1050 to 1600 °C in the SiC tube furnace (see fig. 3). The thermocouple to be calibrated was inserted into the alumina protecting tube so that the measuring junction was in contact with the closed end of the tube. The temperature of the alumina "blackbody" was controlled near a desired calibration point by manually regulating the input power to the SiC tube with an adjustable transformer. An optical pyrometer was optically alined with the axis of the 1/8 in. diam sight

hole in the alumina "blackbody" and focused on the hole near the surface. Brightness matches were made with the optical pyrometer by two experienced observers. With the temperature of the "alumina blackbody" held nearly constant (changing less than a few tenths of a deg per minute), a set of four independent brightness matches was made with the optical pyrometer by each observer. For every brightness match the pyrometer lamp current was determined and the emf of the thermocouple was measured simultaneously. A group of such readings was taken at about 1063 °C and then at approximately 50 deg intervals from 1050 to 1600 °C for each of the thermocouples. Some of the thermocouples were calibrated with increasing temperature, some with decreasing temperature, and others with both increasing and decreasing temperature. Approximately 6 to 8 hr was required to complete the calibration of each thermocouple in the range 1050 to 1600 °C.

Several problems were encountered with the measurements in the SiC tube furnace at the higher temperatures. Occasionally, the SiC tube would develop a "smoking condition" at the higher temperatures (usually above 1500 °C). When this occurred the furnace was cooled and the smoke was blown from the inside of the tube before attempting to make any further measurements with the optical pyrometer. Even so, a slight haze was sometimes noticeable inside the tube during the measurements. The effect of the haze on the optical pyrometer measurements was not known.

Also at temperatures above about 1500 °C a problem was experienced with the emf measurements which was attributed to electrical leakage between the thermocouple wires and the SiC heating element, through the alumina insulating parts and "blackbody." When the furnace power was turned off (briefly) at temperatures above about 1500 °C a difference in the emf of the thermocouple was usually observed. The magnitude and direction of the change in emf was unpredictable and would vary from thermocouple to thermocouple and from run to run. However, the change in emf was never observed to be more than 6 μV.

For measurements above 1500 °C the change in emf was determined after each set of readings and the appropriate correction was applied to the measured emfs. By this procedure it is estimated that the uncertainty in the emf measurements, because of the electrical leakage, was reduced to about 1μV or less.

Finally, a chemical reaction apparently occurred between the alumina "blackbody" and the SiC heating element at the higher temperatures. The electrical properties or characteristics of the SiC tube changed in the central region where the SiC tube and the alumina were in contact, and a "hot spot" developed in the tube. Consequently, the temperature distribution over the alumina "blackbody" became progressively less uniform and some additional uncertainty was introduced in the measurements. However, the temperature gradients were not severe and the error introduced by the nonuniform temperature probably did not exceed more than 1 or 2 deg at 1600 °C.

d. Calibration of Thermoelements by Comparison With Platinum Reference Wires in Range 1063 to 1500 °C

The emfs of the thermoelements of thermocouples A1, B2, C1, and D2 were determined against platinum reference wires at 1063 °C and then at 50 deg intervals with increasing temperature from 1100 to 1500 °C. The tests were made in the SiC tube furnace. For these tests another SiC heating tube was assembled in the furnace and a large diameter, closed end, alumina protecting tube (18 in. long with an inside diameter of 3/4 in.) was positioned inside the SiC heating tube. During the tests the thermocouples were located inside the alumina protecting tube and the tube was supported near the open end so as not to be in contact with the SiC heating tube. The test procedures were similar to those described in section 4.1a except that the temperature was determined with a 30–6 thermocouple (thermocouple B3), instead of a Pt-10 percent Rh versus Pt thermocouple.

e. Calibration of Thermocouples by Comparison With Pt-10 Percent Rh versus Pt Thermocouple in Range 1063 to 1450 °C

Thermocouples A1, A2, B2, B3, C1, C2, D1, and D2 were tested by comparing them directly with a Pt-10 percent Rh versus Pt thermocouple in the 1063 to 1450 °C range. The thermocouples were heated in the SiC tube furnace. The emf of each 30–6 thermocouple was determined at 1063 °C and then at 50 deg intervals with increasing temperature from 1100 to 1450 °C by using the two-potentiometer method.

f. Calibration of Thermocouples by Direct Comparison With Optical Pyrometer in Range 1063 to 1790 °C (Thermocouples Heated in Pt-Rh Wire Wound Tube Furnace)

Thermocouples A2, A3, B1, B3, C2, C3, D1, and D2 were calibrated by comparison with an optical pyrometer and the thermocouples were heated in the Pt-Rh wire wound tube furnace shown in figure 4. During these tests the Pt-Rh shield in the furnace was electrically grounded, and no difficulty was experienced with the emf measurements due to electrical leakage between the thermocouples and heater windings. The temperature control of the furnace was considerably more difficult than for the SiC tube furnace and rather tedious adjustments of the power to the various heater windings were required. The temperature profile in the region of the alumina "blackbody" was checked frequently with the 30–6 thermocouple being tested. The temperature was controlled and the temperature gradients minimized by manual regulation of the power to the various heater windings with variable transformers.

The calibration procedures for the thermocouples were similar to the procedures described in section 4.1c. Sets of brightness matches were taken by two different observers with the optical pyrometer and the emfs of the thermocouples were determined at about

1063 °C and then at approximately 50 deg intervals from 1100 to 1600 °C.

After completing the tests in the 1063 to 1600 °C range, each of the thermocouples was reassembled in double bore beryllium oxide insulating tube. The thermocouples were then calibrated at about 1600, 1650, 1700, and 1750 °C. Three of the thermocouples (A3, B1, C3) were also calibrated at about 1790 °C.

The calibrations described in this section were made with increasing furnace temperature. The thermocouples were removed from the furnace after taking the measurements at each calibration point and then reinserted after the temperature of the furnace was increased to the next calibration point. In general, the time required for checking the temperature gradients in the central portion of the furnace, for allowing the temperature of the furnace to stabilize, and for the two observers to take a set of observations with the optical pyrometer seldom exceeded 20 min at a calibration point for each thermocouple.

Several of the thermocouples were recalibrated at 1063 °C by the procedures described in section 4.1a following completion of the test to 1600 °C and then again following the tests to 1750 and 1790 °C.

4.2. Tests of Platinum-Rhodium Wires With Various Percentages of Rhodium

The platinum-rhodium wires were prepared for test by annealing them electrically in air for 1 hr at about 1450 °C. The wires were then assembled in alumina insulating tubes. The emfs of the platinum-rhodium wires with rhodium percentages of 5.90, 5.95, 6.00, 6.05, and 6.10 were determined against a Pt-6.12 percent Rh wire (negative leg of thermocouple B2). Similarly, the emf of the platinum-rhodium wires with rhodium percentages of 29.50, 29.75, 30.00, and 30.25 were determined against a Pt-29.60 percent Rh wire (positive leg of thermocouple B2). In the first set of measurements the measuring junctions of the various Pt-6 percent Rh wires and a Pt-10 percent Rh versus Pt thermocouple were welded into a common junction and the wires and the thermocouple were inserted into the nickel-chromium tube furnace. The emf of the Pt-Rh wires against the Pt-6.12 percent Rh wire and the emf of the Pt-10 percent Rh versus Pt thermocouple were measured simultaneously by the two-potentiometer method. Measurements were made at 100 deg intervals with decreasing furnace temperature from 1100 to 100 °C. The Pt-10 percent Rh versus thermocouple was then replaced with a 30–6 thermocouple (thermocouple B3) and measurements were made by the same method at 100 deg intervals from 1100 to 1600 °C in the SiC tube furnace. Measurements were also made at 100 deg intervals with the various Pt-30 percent Rh wires from 0 to 1600 °C by the same procedure.

4.3. Tests of Thermocouples in Table 4

Each of the thermocouples in table 4 was electrically annealed in air for 1 hr at about 1450 °C and then assembled in a double bore alumina insulating tube before testing. The thermocouples were calibrated by direct comparison with calibrated thermocouples using the two-potentiometer method. The thermocouples were heated in the nickel-chromium tube furnace and a Pt-10 percent Rh versus Pt thermocouple was used to determine the temperature in the range up to 1063 °C. Above 1063 °C the thermocouples were heated in the SiC tube furnace and one of the 30–6 thermocouples in table 2 was used to determine the temperature.

5. Computations

From the results of the tests described in sections 4.1a and 4.1b corresponding values of temperature and emf were calculated at 25 deg C intervals from 0 to 1050 °C and at 419.5, 630.5, and 1063 °C for each thermocouple. Similarly, from the tests described in section 4.1f corresponding values of temperature and emf were calculated at 1063 °C and at 50 deg intervals from 1100 to 1750 °C for each thermocouple. In the latter calculations the four readings of each observer with the optical pyrometer were averaged to obtain a single emf value for each thermocouple at about 1063 °C and at about 50 deg intervals from 1100 to 1750 °C. These values were adjusted to obtain values at exactly 1063 °C and at the nearest integral multiples of 50 °C and then the values of each observer for each thermocouple were averaged to obtain a single value of emf at each temperature. Since the measured values were nearly always within the equivalent of 5 deg of integral multiples of 50 deg, the adjustment could be made without introducing any significant error by using an approximate value for the thermoelectric power $\left(\frac{dE}{dT}\right)$ of the thermocouple at each temperature.

With the use of an IBM 7094 digital computer cubic equations were fitted by the method of least squares to the sets of emf and temperature values obtained for each thermocouple. One of the cubic equations was selected arbitrarily to serve as a rough "standard curve" with which to compare all the individual thermocouples. The deviations of the measured emf values for each thermocouple from the "standard curve" were plotted graphically and an "average deviation curve" was drawn by visually estimating the best fit. From the "average deviation curve" corresponding values of emf and temperature were calculated at 25 deg C intervals from 0 to 1825 °C.

This set of values was taken as the "principal points" upon which the reference table would be based. Several methods were considered for constructing an expanded set of temperature and emf values (the reference table) at 1 deg intervals from the "principal points." Hand calculation of the reference table using graphical interpolation and smoothing was a possible, but tedious solution. This method was not seriously considered, since a primary requirement was to adopt a method for representing the table that could be

easily adapted to computer use. The method of second degree Lagrange interpolation applied to the "principal points" was given serious consideration, but was rejected in favor of using a single equation or several smoothly jointing equations.

The use of equations to represent the table instead of the Lagrange interpolation scheme seemed preferable for two reasons. First, equations require less storage space in the computer and their use is preferred by most people. Second, a set of "key values" can be generated from the equations and then the Lagrange interpolation scheme can be used for repsenting the table, if it is preferred. From preliminary curve fitting it was determined that a single polynomial equation of fairly low degree would not give an adequate representation of the temperature-emf relationship. Consequently, with the use of the IBM 7094 computer a series of polynomial equations was fitted to the "principal points" by the method of least squares. By trial, it was found that a good fit was obtained with a series of three quartic equations of the form: $E=a+bt+ct^2+dt^3+et^4$, where E is the emf in absolute millivolts and t is the temperature in degrees C (Int. 1948). The ranges of the three equations are 0 to 800 °C, 800 to 1175 °C, and 1175 to 1820 °C, and the coefficients of the equations were computed such that, at the crossover points of 800 and 1175 °C the emfs from each of the joining equations were equal and also the first derivatives $\left(\frac{dE}{dt}\right)$ of emf with respect to temperature were equal. The largest or maximum deviation of the equations from the "principal points" was 0.56 μV below 1175 °C and 0.88 μV in the region above 1175 °C, while the standard deviations for the fit of the three equations to the "principal points" were 0.31, 0.36, and 0.40 μV for the ranges 0 to 800, 800 to 1175, and 1175 to 1825, respectively.

By substituting for t in the equations the relationship 5/9 (t_f-32), where t_f is the temperature in degrees Fahrenheit, a set of three equations was calculated with the temperature expressed in degrees Fahrenheit. The coefficients and temperature ranges for the two sets of equations are given in table 6.

A method of successive approximations was developed for obtaining values of temperature from the equations at exact integral values of the emf. Sufficient accuracy was obtained with this inversion method by merely continuing the approximation until the required number of significant figures was achieved.

Using the results of the tests described in sections 4.1a, 4.1b, and 4.1d and curve fitting techniques similar to those described previously, smoothed emf values for Pt-6.12 percent Rh versus Pt-27 were determined at 50 °C intervals from 0 to 1500 °C. A set of emf values for Pt-29.60 percent Rh versus Pt-27 was then obtained by adding the set of emf values for Pt-6.12 percent Rh versus Pt-27 to the temperature-emf values given by the reference table for the thermocouple.

TABLE 6. *Coefficients and temperature ranges of equations for 30–6 thermocouple reference table*
Equations of the form $(E=a+bt+ct^2+dt^3+et^4)$* where E is given in abs. millivolts.

	*t expressed in degrees Celsius			*t expressed in degrees Fahrenheit		
Coefficients \ Ranges	0–800 °C	800–1175 °C	1175–1820 °C	32–1472 °F	1472–2147 °F	2147–3308 °F
a	0	−1.5120133	6.5238699	0.60419×10^{-2}	−1.6253233	6.8443222
b	-2.37021×10^{-4}	6.286779×10^{-3}	-0.17621535×10^{-1}	$-.24594442\times10^{-3}$	0.35904493×10^{-2}	-0.10239859×10^{-1}
c	0.5767866×10^{-5}	-0.4764704×10^{-5}	$.2258695\times10^{-4}$	$.17906004\times10^{-5}$	$-.15858965\times10^{-5}$	$.70950713\times10^{-5}$
d	$-.6332156\times10^{-9}$	$.6930475\times10^{-8}$	$-.7488765\times10^{-8}$	$-.10798282\times10^{-9}$	$.12139161\times10^{-8}$	$-.12948876\times10^{-8}$
e	$-.48653\times10^{-13}$	$-.209649\times10^{-11}$	$.8862174\times10^{-12}$	$-.46346781\times10^{-14}$	$-.19971135\times10^{-12}$	$.84420950\times10^{-13}$

6. Results

6.1. Results of Tests on Thermocouple Materials Used in the Preparation of the Reference Table

Reference tables (tables 1A and 3A) for the 30–6 thermocouple for a reference junction temperature of 0 °C (32 °F) were generated from the polynomial equations (see table 6 for coefficients of the polynomial equations). In reference table 1A values of emf are given in absolute millivolts at 1 deg C intervals for the range 0 to 1820 °C. Similarly, table 3A gives values of emf at 1 degree F intervals for the range 32 to 3308 °F. Reference tables 2A and 4A are an inversion of tables 1A and 3A, respectively, and were developed by the computer technique described in the computation section. Table 2A gives values of the temperature in degrees C at 0.01 mV intervals, while table 4A gives values of temperature in degrees F at 0.01 mV intervals.

The thermoelectric power $\left(\frac{dE}{dt}\right)$ of the thermocouple was calculated from the polynomial equations and is plotted against temperature in figure 5. The thermo-

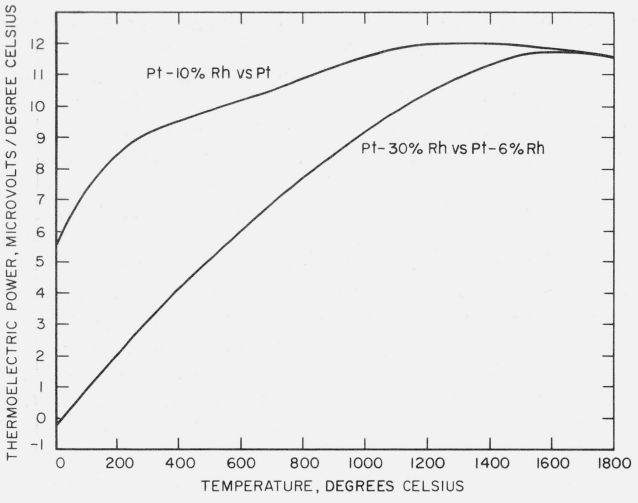

FIGURE 5. *Thermoelectric power* $\left(\frac{dE}{dt}\right)$ *of Pt-10 percent Rh versus Pt and Pt-30 percent Rh versus Pt-6 percent Rh thermocouples.*

electric power[5] of the more common Pt-10 percent Rh versus Pt thermocouple is also shown in figure 5 for purposes of comparison. The difference between the average calibration of the thermocouples from each manufacturer and the temperature-emf relationship given by the reference table are plotted in figure 6 for the range 0 to 1750 °C. The values shown in the figure in the range 0 to 1063 °C were calculated from the results of the tests described in sections 4.1a and 4.1b, and the values shown in the range 1063 to 1750 °C were calculated from tests described in section 4.1f. Since the elements of the thermocouples from each manufacturer were adjacent elements from the same wire lots, there was very little difference between the temperature-emf relationships of the thermocouples from the same manufacturer. For example, at 1063 °C the emf of each individual thermocouple from the same manufacturer (as determined in the

[5] Calculated from the Pt-10 percent Rh versus Pt thermocouple reference table given in NBS Circ. 561.

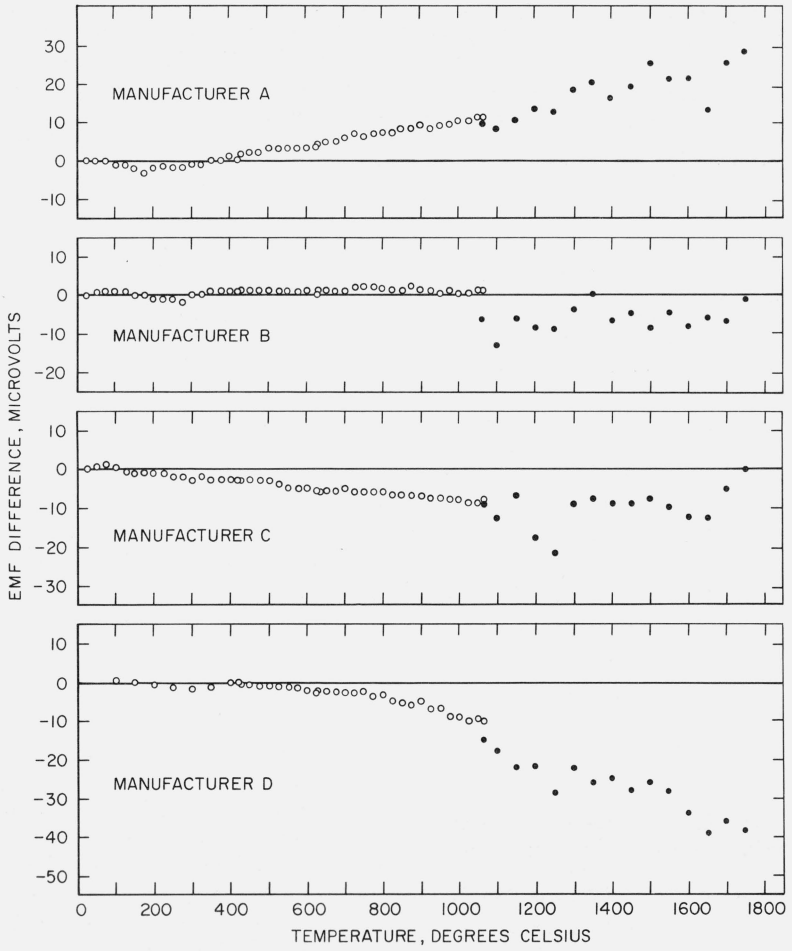

FIGURE 6. *Emf difference between average calibration of thermocouples from each manufacturer (see table 2) and the reference table (table 1A).*

Emf difference equals emf of thermocouple minus emf of reference table. Open symbols indicate temperature determined with standard thermocouples and resistance thermometers as described in sections 4.1a and 4.1b, respectively. Closed symbols indicate temperature determined with optical pyrometer as described in section 4.1f.

test described in section 4.1a), in no case differed by more than about 1 μV from the average emf of all the thermocouples from the manufacturer. For this reason, the individual calibrations of each of the thermocouples in table 2 are not shown but only the average calibration of the thermocouples of each manufacturer.

In table 7 the emf of the platinum-6.12 percent rhodium and the platinum 29.60 percent rhodium elements versus Pt-27 are given at 50 deg C intervals for the range 0 to 1500 °C. The difference between the temperature-emf values for the Pt-6.12 percent Rh elements of each manufacturer against Pt-27 and the temperature-emf values given in table 7 for the Pt-6.12 percent Rh versus Pt-27 are plotted in figure 7. Similarly, the difference between the temperature-emf values determined for the Pt-29.60 percent Rh elements against Pt-27 and the temperature-emf values given in table 7 for Pt-29.60 percent Rh versus Pt-27 are plotted in figure 8.

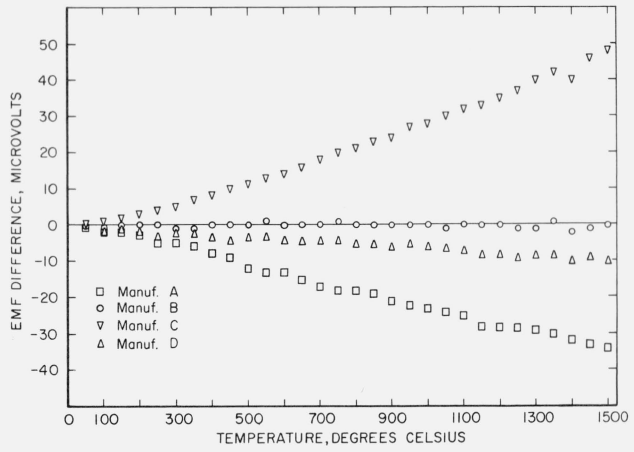

FIGURE 7. *Emf difference between Pt-6.12 percent Rh elements of each manufacturer and corresponding values in table 7 for emf of Pt-6.12 percent Rh versus Pt-27.*

Emf difference equals emf of element minus emf in table 7 at temperature indicated. Values shown determined in tests described in sections 4.1a, 4.1b, and 4.1d.

TABLE 7. *Emf of platinum-6.12 percent rhodium and platinum-29.60 percent rhodium versus Pt-27*

Temperature degrees C (Int. 1948)	Emf (abs. mV)	
	Pt-6.12% Rh	Pt-29.60% Rh
0	0.000	0.000
50	.276	.278
100	.586	.619
150	.920	1.012
200	1.272	1.450
250	1.636	1.927
300	2.007	2.438
350	2.384	2.980
400	2.765	3.551
450	3.148	4.150
500	3.534	4.775
550	3.922	5.427
600	4.313	6.104
650	4.708	6.808
700	5.106	7.537
750	5.508	8.292
800	5.914	9.072
850	6.323	9.874
900	6.737	10.700
950	7.154	11.549
1000	7.576	12.420
1050	8.003	13.314
1100	8.432	14.225
1150	8.863	15.153
1200	9.296	16.096
1250	9.732	17.058
1300	10.169	18.035
1350	10.608	19.026
1400	11.046	20.025
1450	11.480	21.029
1500	11.911	22.035

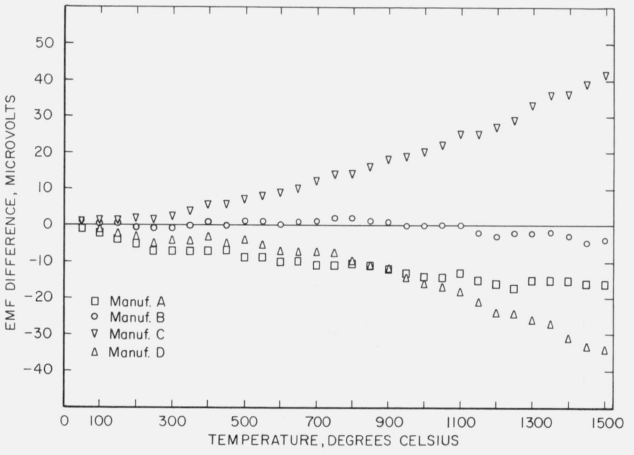

FIGURE 8. *Emf difference between Pt-29.60 percent Rh elements of each manufacturer and corresponding values in table 7 for emf of Pt-29.60 percent Rh versus Pt-27.*

Emf difference equals emf of element minus emf in table 7 at temperature indicated. Values shown determined in tests described in sections 4.1a, 4.1b, and 4.1d.

6.2. Results of Tests on Platinum-Rhodium Wires With Various Percentages of Rhodium

The emfs of the platinum-rhodium wires with compositions of Pt-5.90 percent Rh, Pt-5.95 percent Rh, Pt-6.00 percent Rh, Pt-6.05 percent Rh, Pt-6.10 percent Rh are shown versus a Pt-6.12 percent Rh wire (negative leg of thermocouple B2) in figure 9. In figure 10 the emfs of the platinum-rhodium wires with compositions of Pt-29.50 percent Rh, Pt-29.75 percent Rh, Pt-30.00 percent Rh, Pt-30.25 percent Rh are shown versus a Pt-29.60 percent Rh wire (positive leg of thermocouple B2) for the 0 to 1600 °C range.

6.3. Results of Testing for Other 30–6 Thermocouples

The deviations (expressed in microvolts) of the various thermocouples in table 4 from the reference table are shown in figure 11.

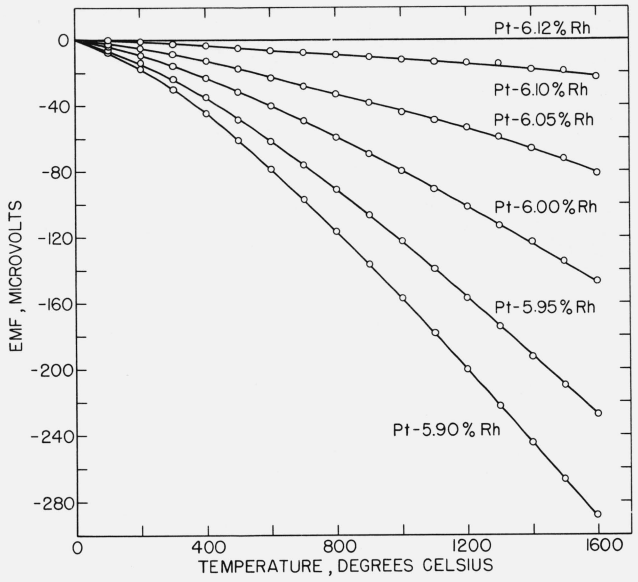

FIGURE 9. *Emf of platinum-rhodium wires with various percentages of rhodium versus a Pt-6.12 percent Rh wire (negative element of thermocouple B2).*

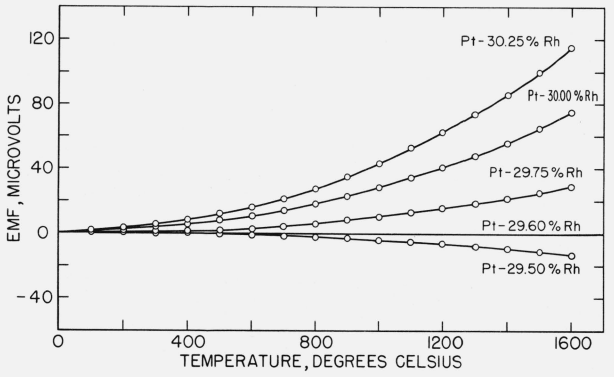

FIGURE 10. *Emf of platinum-rhodium wires with various percentages of rhodium versus a Pt-29.60 percent Rh wire (positive element of thermocouple B2).*

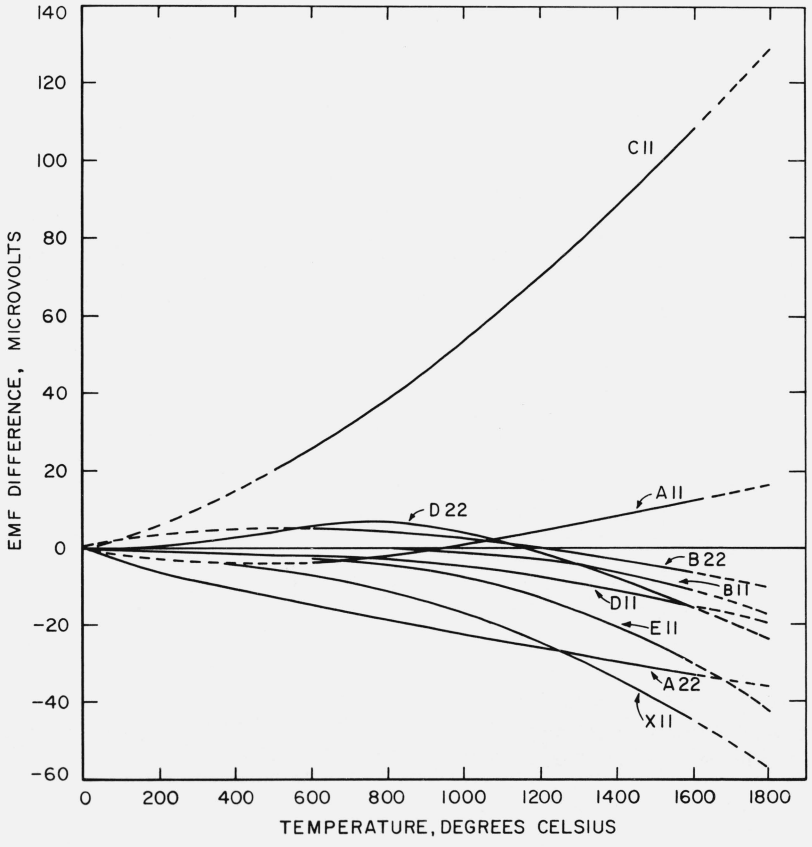

FIGURE 11. *Deviation of thermocouples in table 4 from reference table.*
Emf difference equals emf of thermocouple minus emf of reference table. Solid portion of curves indicate range of calibration data and dashed portions are extrapolated.

7. Discussion

As shown in figure 6 the differences between the average calibrations of the thermocouples from the different manufacturers and the temperature-emf relationship given by the reference table are quite small. The largest deviation for thermocouples from an American manufacturer occurs at 1750 °C for the thermocouples from manufacturer A and is only about 28 μV (about 2.4 °C). The differences between the temperature-emf relationships of the individual thermoelements of the thermocouples are somewhat larger than the difference between the temperature-emf relationships of the thermocouples themselves, as shown in figures 7 and 8. The spread between the temperature-emf relationships of the Pt-6.12 percent Rh thermoelements (fig. 7) is about the same as for the Pt-29.60 percent Rh thermoelements (fig. 8). The maximum spreads occur at the highest temperature measured, 1500 °C, and are about 80 μV and 75 μV for the Pt-6.12 percent Rh and Pt-29.60 percent Rh thermoelements, respectively.

It is interesting to note that the temperature-emf relationships of thermocouples from different manufacturers may agree quite closely, even though the temperature-emf relationship for the corresponding thermoelements of the thermocouples differ considerably. This is the case for the thermocouples from manufacturers B and C. It is also interesting that the spread between the temperature-emf relationships of the Pt-29.60 percent Rh elements from different manufacturers is about as large as the spread between the temperature-emf relationships of the Pt-6.12 percent Rh elements. This is a little surprising, since a small variation in rhodium content has a more pronounced effect on the temperature-emf relationship of the dilute alloy (Pt-6.12 % Rh).

The differences between the temperature-emf relationships of the various thermocouples and platinum-rhodium thermoelements are attributed to slight variations in the chemical compositions of the wires. In general, two platinum-rhodium wires of the same nominal type will differ slightly in chemical composition because of a variation in purity combined with a slight variation in the rhodium content.

It can be seen from the results of the spectrochemical analyses (table 3) that some significant differences in the purity of the platinum-rhodium thermoelements from the various manufacturers do exist. Appreciable amounts of Fe, Ir, Au, Pd, Si, and Al were detected in some of the platinum-rhodium wires as well as small traces of Ca, Mg, B, and Cu. A fairly large amount of aluminum was detected in the Pt-29.60 percent Rh wire submitted by manufacturer B, while none was detected in any of the other wires. However, the aluminum is probably present in oxide form and would be expected to have little or no effect on the thermoelectric characteristics of the wire. Of more importance is that the concentrations of Fe, Ir, Au, and Pd detected in the wires of manufacturers A and D were, in general, somewhat higher than the concentrations detected in the wires of manufacturers B and C. Another interesting point is that the wires of manufacturer D (Degussa) contained less Si than the wires submitted by the American manufacturers (A, B, and C). Also, the results of the analysis on the reference grade platinum wire shows that commercially available thermocouple platinum is considerably more pure than platinum-rhodium alloys. Consequently, the relative impurity of the platinum-rhodium alloys is attributed for the most part to impurities in the rhodium constituent.

The curves in figures 9 and 10 show the effect on the temperature-emf relationship of Pt-6 percent Rh and Pt-30 percent Rh thermoelements, respectively, caused by small variations in rhodium content. The differences between the curves are assumed to a first approximation to be entirely due to differences in rhodium. This assumption seems reasonable since the wires in each group were prepared by the same manufacturer from the same batch of platinum and rhodium. For example, the Pt-30.25 percent Rh wire should contain the same inpurities as the Pt-29.50 percent Rh wire and the concentrations would be expected to differ by a factor of only about $\frac{30.25}{29.50}$ (ratio of the rhodium percentages). It can be calculated from the curves that a 0.1 percent change in the rhodium content of a Pt-29.60 percent Rh wire will produce a corresponding change in the emf of about 15 μV at 1500 °C, while a change in the rhodium content of only about 0.01 percent will produce the same change in the emf of a Pt-6.12 percent Rh wire.

Efforts to determine the percentage of rhodium in the Pt-Rh elements from the different manufacturers to a few hundredths of a percent by chemical analysis were unsuccessful. Consequently, it is difficult, if not impossible, to establish whether the differences between the temperature-emf relationships of the thermoelements from different manufacturers are caused primarily by variation in purity or by variation in rhodium content. However, the variations of the impurities and their concentrations between thermoelements undoubtedly are large enough to be responsible for at least part of the differences. Also, slight variations in the rhodium content of thermoelements from different manufacturers are unavoidable and these variations combined with the variations in purity can easily account for the differences in emf shown in figures 7 and 8.

It has been suggested that slight differences in the alloying percentage of platinum and rhodium, and variations in purity can explain differences in the temperature-emf relationships of thermoelements and thermocouples from different manufacturers. For these same reasons differences between the temperature-emf relationships of thermocouples from the same manufacturer, but from different lots, will also occur. Comparison of the deviation curves in figure 11 with the deviation curves in figure 6, shows that the differences between the temperature-emf relationships of thermocouples from the same manufacturer do exist and can be rather large. For example, the difference between the average calibration of thermocouples C1, C2, and

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C3 (shown by curve for manufacturer C in fig. 6) and the calibration of thermocouple C11 (see fig. 11) is about 130 μV at 1600 °C. The difference is larger than the differences between the temperature-emf relationships of any of the other thermocouples and probably represents a rather extreme case. For thermocouples tested from the other manufacturers differences in emf at 1600 °C ranging from a few microvolts up to about 60 μV were typical for lot to lot differences.

If thermocouple C11 is disregarded, the variations among the temperature-emf relationships of all the other thermocouples in tables 2 and 4 are surprisingly small considering that five different manufacturers and about 12 different lots of wire are represented. The maximum difference between the temperature-emf relationships of the various thermocouples at 1600 °C is about 70 μV (about 6 deg C), and the largest deviation of any thermocouple from the reference table is only about 45 μV (about 3.8 deg C). Consequently, it is estimated that nearly all the 30–6 thermocouples produced by manufacturers in this country will have temperature-emf relationships that agree with the temperature-emf relationship given by the reference table to within the equivalent of ± 0.5 percent of the temperature in the range 500 to 1800 °C and to within ± 15 μV for temperatures below 500 °C.

These values do not represent a standard manufacturing tolerance for the 30–6 thermocouple, nor are they a recommendation for one. The values are merely estimates, based upon the calibrations of a rather small sampling of thermocouples which have been tested at NBS. The values are intended to serve as a guide for prospective users of the thermocouple, since no standard manufacturing tolerances exist for the thermocouple at present. If the 30–6 thermocouple comes into common use in this country, technical societies and manufacturers will most likely agree upon and adopt standard manufacturing tolerances.

The difference between the Degussa reference curves (old and new) and the reference table presented with this paper are shown in figure 12. It can be seen that the differences between the new Degussa reference curve, established by Obrowski and Prinz [7], and the temperature-emf relationship given by the NBS table are less than the spread between the temperature-emf relationships of the thermocouples tested in this investigation. The difference at 1600 °C is 19 μV or about 1.6 deg C while the maximum difference occurs at 1800 °C and is only 33 μV or about 2.9 deg C. This indicates that the thermocouples used by Obrowski and Prinz in establishing the new Degussa reference curve had essentially the same characteristics as the Pt-29.60 percent Rh versus Pt-6.12 percent Rh thermocouples produced by American manufacturers.

The fact that the emf developed by the 30–6 thermocouple is relatively small (about two-thirds the emf of the Pt-10 percent Rh versus Pt thermocouple at 1700 °C as shown in fig. 1) imposes no particular restrictions on the use of the thermocouple at high temperatures. The thermoelectric power or sensitivity of the

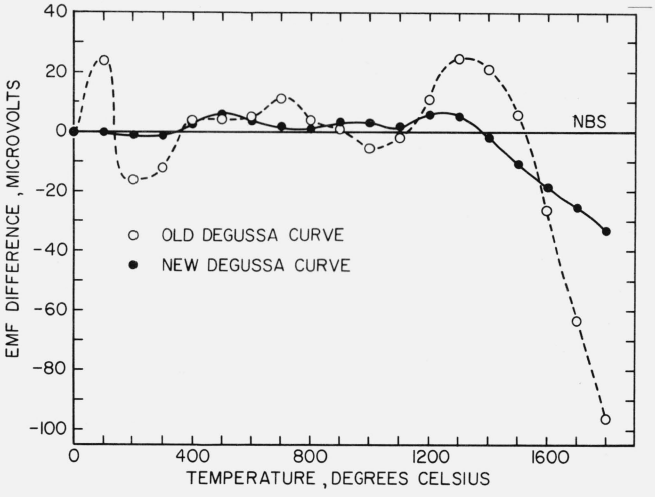

FIGURE 12. *Emf difference between Degussa reference curves (old and new) and NBS reference table for 30–6 thermocouple.*
Emf difference equals emf of Degussa curves minus emf of NBS reference table.

thermocouple above 1100 °C, which is most important, is fairly high (> 9 μV/°C) and compares favorably with the thermoelectric power of the Pt-10 percent Rh versus Pt thermocouple as shown in figure 5. One advantage of the 30–6 thermocouple over most other types of thermocouples, is that the thermoelectric power and emf of the thermocouple are almost negligible in the normal room temperature range. Consequently, in most applications the reference junction temperature of the thermocouple does not need to be controlled or even known as long as it is between 0 and 50 °C. For example, as shown by the reference tables the emf developed by the thermocouple with the reference junctions at 0 °C undergoes a reversal in sign at about 41 °C, and between 0 and 50 °C varies from a minimum of about -2 μV at about 20 °C to a maximum of about $+3$ μV at 50 °C. Therefore, in use, if the reference junctions of the thermocouple are both at the same temperature and within the range 0 to 50 °C, then a 0 °C reference junction temperature can be assumed and the error introduced will not exceed 3 μV. At high temperatures (above 1100 °C) an additional error of 3 μV (about 0.3 deg) in the measurements would be insignificant in most instances.

The arbitrary nature of the reference tables reported in this paper should be emphasized. The tables are intended only to accurately represent the general shape of the temperature-emf curve for the 30–6 thermocouple, and should not be expected to represent the actual emf, even for a thermocouple having exactly the composition given (Pt-29.60 % Rh versus Pt-6.12 % Rh).

In general, the temperature-emf relationship of a particular 30–6 thermocouple will deviate somewhat from the relationship given by the reference table. The deviation can be expected to be rather small and vary smoothly as shown by the curves in figures 6 and 11. Consequently, a deviation curve from the refer-

ence table can be constructed that will yield a calibration sufficiently accurate for most purposes, by calibrating a particular thermocouple at relatively few temperatures. The uncertainties in interpolated emf values calculated for the thermocouple from the deviation curve will then depend upon the number and spacing of the calibration points used in constructing the deviation curve, the uncertainty in the calibration points, and the quality or "accuracy" of the reference table. Obviously, the quality or "accuracy" of the reference table will depend to a certain extent on the accuracy of the measurements upon which the table is based and upon the method employed for constructing the table from the measured data.

The inaccuracies introduced in the reference table for the 30–6 thermocouple by the method employed for interpolating between the measured data are not believed to be significant. Almost any interpolation scheme will give an adequate representation of the data since there is an abundance of data and the temperature intervals between the data points are small. Therefore, any inaccuracy in the shape of the temperature-emf relationship given by the table is attributed for the most part to uncertainties in the measurements.

At temperatures below 450 °C the thermoelectric power of the 30–6 thermocouple becomes quite small. Hence, the accuracy of the measurements is limited in this range by inhomogeneities in the thermocouple materials and by limitations in the testing facilities and measuring equipment, rather than by uncertainties in the calibration of the standard instrument (platinum resistance thermometer) used for measuring the temperature. In the range 450 to 1063 °C the accuracy is limited primarily by uncertainties in the calibration of the platinum-10 percent rhodium versus platinum thermocouples used in the measurements for determining the temperature. Similarly the accuracy of the measurements above 1063 °C is limited by uncertainties in the calibration of the optical pyrometer. In addition, factors such as electrical leakage through the insulating parts and changes in the chemical composition of the wires may contribute to the uncertainty in the measurements above 1063 °C. Changes in the chemical composition of the wires may result from chemical contamination, preferential loss of platinum or rhodium by oxidation and volatilization, and rhodium migration. Considering the thermocouple wire sizes used, the quality and sizes of the alumina insulating tubes used, and the rather short exposure times involved, none of the factors are believed to introduce any significant uncertainty in the measurements for temperature up to about 1600 °C. However, above about 1600 °C the factors become more serious.

In preliminary experiments, beryllia (BeO) insulating tubes were found to have higher electrical resistance in the 1600 to 1790 °C range than alumina tubes by a factor of two or more. Consequently, the thermocouples were insulated with BeO insulating tubes for measurements in the range above 1600 °C. Even so, electrical conduction through the BeO insulating tubes is believed to have produced a small error in the measurements. From determinations made on the insulation resistance of the BeO tubes, by measuring the resistance between the wires of thermocouples with their measuring junctions open, the magnitude of the error is estimated not to exceed 0.5 deg C for temperatures up to 1790 °C.

Some significant shifts in the thermoelectric characteristics of the thermocouples occurred as a result of testing in the 1600 to 1790 °C range. The shifts were detected by measuring the emf of the thermocouples at a lower temperature (1063 °C) before and after the measurements in the 1600 to 1790 °C range and were attributed to changes in the chemical composition of the thermocouple wires. Chemical contamination by impurities transferred from the insulating and protecting parts was believed to have been the principal cause of the compositional changes. The error introduced in the measurements above 1600 °C because of the compositional changes in the thermocouple wires is estimated to be not more than about 1 deg C.

Another source of error in the measurements above 1063 °C is introduced by the alumina "blackbodies." In all the measurements with the optical pyrometer the spectral emissivities of the alumina "blackbodies" at a wavelength of 0.65 μ were taken as 1. Consequently, any departure in the spectral emissivities from 1 will produce an error in the measurements. The spectral emissivity or quality of a blackbody depends upon the internal dimensions of the blackbody cavity, the nature of the internal reflections (diffuse or specular), the values of the reflection factor, and the temperature distribution over the cavity walls [9]. Assuming uniform temperature of the cavity walls and using the calculations described by DeVos [9] with an experimentally determined value for the partial reflectivity of alumina, the spectral emissivities at a wavelength of 0.65 μ of the alumina "blackbodies" are estimated to be about 0.999. A departure of 0.001 in the spectral emissivities of the alumina "blackbodies" from the assumed value of 1 produces an uncertainty of less than 0.2 °C in the measurements in the range 1063 to 1790 °C. However, the temperature distributions along the walls of the blackbody cavities or sight holes were not uniform during the measurements. The temperature gradient along the alumina "blackbody" which was heated in the Pt-Rh wire wound tube furnace seldom exceeded more than 1 deg per inch. This would have a negligible effect upon the spectral emissivity of the blackbody cavity, but would introduce an additional error in the measurements. When there was a temperature gradient along the alumina "blackbody" the measuring junction of the thermocouple being tested would not have been at the temperature of the back wall of the blackbody cavity, since it was located approximately 1/8 in. from the cavity wall. Errors introduced by temperature gradients in the alumina "blackbody" are estimated not to exceed more than 0.2 or 0.3 deg for measurements in the Pt-Rh wire wound tube furnace.

The quality of the alumina "blackbodies" is verified experimentally by the good agreement (about 0.5 deg) achieved at 1063 °C between the calibrations of the

various 30–6 thermocouples determined by comparison with the standard thermocouple (sec. 4.1a and 4.1e) and by comparison with the optical pyrometer (sec. 4.1f). The agreement achieved between the two methods of calibration really reflects the accuracy of the entire system since the quality of the furnace, thermocouples, optical pyrometer calibration and blackbody influence the agreement.

The results of other tests described in this paper also give some experimental verification to the accuracy of the measurements above 1063 °C. The calibrations of thermocouples by direct comparison with the optical pyrometer which were performed in both the silicon carbide tube furnace (sec. 4.1c) and the Pt-Rh wire wound tube furnace (sec. 4.1f) were in agreement to within about 0.5 deg C at 1063 °C and to within about 2 deg C at temperatures up to 1600 °C. In general, the calibrations in the Pt-Rh wire wound tube furnace yielded slightly higher emfs for the thermocouples than the calibrations performed in the SiC tube furnace. The calibrations in the Pt-Rh wire wound tube furnace were considered more reliable since problems with electrical leakage, hazing and nonuniformity of temperature were experienced in the SiC tube furnace. For this reason, the data obtained in the calibrations performed in the SiC tube furnace were not used in the calculation of the reference table. Even though the measurements made in the SiC tube furnace may be questionable, the agreement between the calibrations made in the two different furnaces does give added confidence in the measurements. Further confidence in the measurements above 1063 °C is gained by the agreement achieved between calibrations of thermocouples determined by direct comparison with standard Pt-10 percent Rh versus Pt thermocouples (sec. 4.1e) and by direct comparison with the optical pyrometer (sec. 4.1f). Calibrations of the same thermocouples by the two different methods agree to within 1 deg C in the range 1063 to 1350 °C and to within about 2 deg C up to 1450 °C. This agreement is quite satisfactory, since the calibrations of the standard Pt-10 percent Rh versus Pt thermocouples were obtained by extrapolation above 1063 °C and are estimated to be uncertain by 2 deg C at 1450 °C.

Since the 30–6 thermocouple is primarily intended for use in the range above 1063 °C, particular emphasis is placed upon the accuracy of the measurements in this range. Other tests, which are not described in this paper, were performed in hope of gaining more insight into the accuracy of the measurements. For example several 30–6 thermocouples were calibrated at the melting points of palladium (1552 °C) and platinum (1769 °C) by the wire method [10], and these calibrations differed from calibrations based upon comparison with an optical pyrometer by no more than about 1 deg C at the melting point of palladium and by no more than 2 deg C at the melting point of platinum. These differences were not considered unreasonable since the measurements by the wire method were estimated to be uncertain by about 1.5 deg C at the melting point of palladium and 2 or 3 deg C at the melting point of platinum. Several 30–6 thermocouples were also calibrated in a vertical "blackbody" furnace [11] at temperatures up to 1600 °C in an helium atmosphere and a different calibrated optical pyrometer was used to determine the temperature. These calibrations were in agreement with calibrations of the thermocouples performed in air in the Pt-Rh wire wound tube furnace to within about 2 deg C up to 1600 °C. In another test, a 30–6 thermocouple was calibrated by direct comparison with a calibrated Leeds and Northrup type 8640 photoelectric pyrometer in the range 1063 to 1555 °C. The thermocouple was heated in the Pt-Rh wire wound furnace. The difference between this calibration and a calibration of the thermocouple in the same furnace, but using the visual optical pyrometer to determine the temperature, varied from about 0.5 deg C at 1063 °C to about 1.5 deg C at 1555 °C.

After considering the capabilities of the standard instruments and test facilities used, the quality and stability of the thermocouples tested, and the results of the various tests performed, the uncertainties in the measurements that were used in calculating the reference table are estimated not to exceed ± 2 μV in the range 0 to 450 °C and about ± 3 μV in the range 450 to 1063 °C. The uncertainties in the measurements increased above 1063 °C and are estimated not to exceed the equivalent of about ± 2 deg C at 1400 °C, and about ± 3 or 4 deg C at 1750 °C. Furthermore, it is estimated that determinations of the emf of a particular 30–6 thermocouple at about 600, 1063, and 1300 °C by comparison with a standard Pt-10 percent Rh versus Pt thermocouple and at the melting point of palladium (1552 °C) by the melting wire method will be sufficient to construct a deviation curve from the reference table such that the resulting calibration will be accurate to within ± 6 μV up to 1063 °C, the equivalent of about ± 3 deg C up to 1550 °C, and the equivalent of about ± 5 deg C above.

Calibration of other 30–6 thermocouples can then be determined rather easily by directly comparing them with a calibrated 30–6 thermocouple. In any event, calibration of 30–6 thermocouples by direct comparison with an optical pyrometer will generally prove undesirable, since the method is tedious, time consuming, and requires rather elaborate facilities and techniques. Also, actual calibration of the thermocouples above about 1600 °C seems undesirable in most instances, since it is likely to introduce some instability in the thermocouple and render it less reliable in use. Calibration values above 1600 °C can be obtained accurately by extrapolating the deviation curve.

Based upon the experience gained at NBS with the 30–6 thermocouple during the present studies, the following information is summarized for the thermocouple.

(1) Nearly all 30–6 thermocouples produced by manufacturers in this country will have temperature-emf relationships that agree with the temperature-emf relationship given by the reference table to within the equivalent of ± 0.5 percent of the temperature in the range 500 to 1800 °C and to within ± 15 μV for temperatures below 500 °C.

(2) Calibration of a particular 30–6 thermocouple at four points (about 600, 1063, 1300, and 1552 °C) will be sufficient to construct a deviation curve from the reference table such that the resulting calibration will be accurate to within ± 6 μV up to 1063 °C, the equivalent of about ± 3 °C up to 1552 °C, and the equivalent of about ± 5 °C above.

(3) Actual calibration of the thermocouple above about 1600 °C is not recommended, since some instability may result in the thermocouple. Values above 1600 °C may be accurately determined by extrapolation.

(4) High purity alumina is recommended for insulation and protection of the thermocouple but caution should be exercised at temperatures above about 1600 °C for errors introduced by the electrical conductance of the insulators.

(5) The use of large diameter wires (at least 0.020 in.) and larger size insulating tubes is recommended for operating temperatures above 1500 or 1600 °C, so as to give the thermocouple added strength and to minimize errors due to electrical leakage.

(6) In most instances the reference junction temperature need not be controlled since the emf and thermoelectric power of the thermocouple at normal room temperatures are very small.

8. Appendix

TABLE 1A. *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*
(Temperatures in Degrees C(Int. 1948). Electromotive Force in Absolute Millivolts. Reference Junctions at 0 °C.)

°C	0	1	2	3	4	5	6	7	8	9
	Millivolts									
0	− 0.	− 0.000	− 0.000	− 0.001	− 0.001	− 0.001	− 0.001	− 0.001	− 0.002	− 0.002
10	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002
20	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002
30	− 0.002	− 0.002	− 0.002	− 0.002	− 0.001	− 0.001	− 0.001	− 0.001	− 0.001	− 0.001
40	− 0.000	− 0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.002
50	0.002	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.006	0.006
60	0.006	0.007	0.007	0.008	0.008	0.009	0.009	0.010	0.010	0.011
70	0.011	0.012	0.013	0.013	0.014	0.014	0.015	0.016	0.016	0.017
80	0.018	0.018	0.019	0.020	0.020	0.021	0.022	0.023	0.023	0.024
90	0.025	0.026	0.027	0.027	0.028	0.029	0.030	0.031	0.032	0.032
100	0.033	0.034	0.035	0.036	0.037	0.038	0.039	0.040	0.041	0.042
110	0.043	0.044	0.045	0.046	0.047	0.048	0.049	0.050	0.051	0.052
120	0.054	0.055	0.056	0.057	0.058	0.059	0.060	0.062	0.063	0.064
130	0.065	0.066	0.068	0.069	0.070	0.072	0.073	0.074	0.075	0.077
140	0.078	0.079	0.081	0.082	0.084	0.085	0.086	0.088	0.089	0.091
150	0.092	0.094	0.095	0.096	0.098	0.099	0.101	0.102	0.104	0.106
160	0.107	0.109	0.110	0.112	0.113	0.115	0.117	0.118	0.120	0.122
170	0.123	0.125	0.127	0.128	0.130	0.132	0.133	0.135	0.137	0.139
180	0.140	0.142	0.144	0.146	0.148	0.149	0.151	0.153	0.155	0.157
190	0.159	0.161	0.163	0.164	0.166	0.168	0.170	0.172	0.174	0.176
200	0.178	0.180	0.182	0.184	0.186	0.188	0.190	0.192	0.194	0.197
210	0.199	0.201	0.203	0.205	0.207	0.209	0.211	0.214	0.216	0.218
220	0.220	0.222	0.225	0.227	0.229	0.231	0.234	0.236	0.238	0.240
230	0.243	0.245	0.247	0.250	0.252	0.254	0.257	0.259	0.262	0.264
240	0.266	0.269	0.271	0.274	0.276	0.279	0.281	0.284	0.286	0.289
250	0.291	0.294	0.296	0.299	0.301	0.304	0.306	0.309	0.312	0.314
260	0.317	0.320	0.322	0.325	0.328	0.330	0.333	0.336	0.338	0.341
270	0.344	0.347	0.349	0.352	0.355	0.358	0.360	0.363	0.366	0.369
280	0.372	0.374	0.377	0.380	0.383	0.386	0.389	0.392	0.395	0.398
290	0.401	0.404	0.406	0.409	0.412	0.415	0.418	0.421	0.424	0.427

TABLE 1A. *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*—Continued

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

°C	0	1	2	3	4	5	6	7	8	9
	Millivolts									
300	0.431	0.434	0.437	0.440	0.443	0.446	0.449	0.452	0.455	0.458
310	0.462	0.465	0.468	0.471	0.474	0.477	0.481	0.484	0.487	0.490
320	0.494	0.497	0.500	0.503	0.507	0.510	0.513	0.517	0.520	0.523
330	0.527	0.530	0.533	0.537	0.540	0.543	0.547	0.550	0.554	0.557
340	0.561	0.564	0.568	0.571	0.575	0.578	0.582	0.585	0.589	0.592
350	0.596	0.599	0.603	0.606	0.610	0.614	0.617	0.621	0.625	0.628
360	0.632	0.635	0.639	0.643	0.647	0.650	0.654	0.658	0.661	0.665
370	0.669	0.673	0.676	0.680	0.684	0.688	0.692	0.696	0.699	0.703
380	0.707	0.711	0.715	0.719	0.723	0.726	0.730	0.734	0.738	0.742
390	0.746	0.750	0.754	0.758	0.762	0.766	0.770	0.774	0.778	0.782
400	0.786	0.790	0.794	0.799	0.803	0.807	0.811	0.815	0.819	0.823
410	0.827	0.832	0.836	0.840	0.844	0.848	0.853	0.857	0.861	0.865
420	0.869	0.874	0.878	0.882	0.887	0.891	0.895	0.900	0.904	0.908
430	0.913	0.917	0.921	0.926	0.930	0.934	0.939	0.943	0.948	0.952
440	0.957	0.961	0.966	0.970	0.975	0.979	0.984	0.988	0.993	0.997
450	1.002	1.006	1.011	1.015	1.020	1.025	1.029	1.034	1.038	1.043
460	1.048	1.052	1.057	1.062	1.066	1.071	1.076	1.080	1.085	1.090
470	1.095	1.099	1.104	1.109	1.114	1.118	1.123	1.128	1.133	1.138
480	1.143	1.147	1.152	1.157	1.162	1.167	1.172	1.177	1.182	1.186
490	1.191	1.196	1.201	1.206	1.211	1.216	1.221	1.226	1.231	1.236
500	1.241	1.246	1.251	1.256	1.261	1.267	1.272	1.277	1.282	1.287
510	1.292	1.297	1.302	1.307	1.313	1.318	1.323	1.328	1.333	1.339
520	1.344	1.349	1.354	1.359	1.365	1.370	1.375	1.381	1.386	1.391
530	1.396	1.402	1.407	1.412	1.418	1.423	1.429	1.434	1.439	1.445
540	1.450	1.455	1.461	1.466	1.472	1.477	1.483	1.488	1.494	1.499
550	1.505	1.510	1.516	1.521	1.527	1.532	1.538	1.543	1.549	1.554
560	1.560	1.566	1.571	1.577	1.583	1.588	1.594	1.599	1.605	1.611
570	1.616	1.622	1.628	1.634	1.639	1.645	1.651	1.656	1.662	1.668
580	1.674	1.680	1.685	1.691	1.697	1.703	1.709	1.714	1.720	1.726
590	1.732	1.738	1.744	1.750	1.756	1.761	1.767	1.773	1.779	1.785
600	1.791	1.797	1.803	1.809	1.815	1.821	1.827	1.833	1.839	1.845
610	1.851	1.857	1.863	1.869	1.875	1.882	1.888	1.894	1.900	1.906
620	1.912	1.918	1.924	1.931	1.937	1.943	1.949	1.955	1.962	1.968
630	1.974	1.980	1.986	1.993	1.999	2.005	2.011	2.018	2.024	2.030
640	2.037	2.043	2.049	2.056	2.062	2.068	2.075	2.081	2.087	2.094
650	2.100	2.107	2.113	2.120	2.126	2.132	2.139	2.145	2.152	2.158
660	2.165	2.171	2.178	2.184	2.191	2.197	2.204	2.210	2.217	2.224
670	2.230	2.237	2.243	2.250	2.257	2.263	2.270	2.276	2.283	2.290
680	2.296	2.303	2.310	2.316	2.323	2.330	2.337	2.343	2.350	2.357
690	2.363	2.370	2.377	2.384	2.391	2.397	2.404	2.411	2.418	2.425

TABLE 1A. *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*—Continued

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

°C	0	1	2	3	4	5	6	7	8	9
	Millivolts									
700	2.431	2.438	2.445	2.452	2.459	2.466	2.473	2.480	2.486	2.493
710	2.500	2.507	2.514	2.521	2.528	2.535	2.542	2.549	2.556	2.563
720	2.570	2.577	2.584	2.591	2.598	2.605	2.612	2.619	2.626	2.633
730	2.641	2.648	2.655	2.662	2.669	2.676	2.683	2.690	2.698	2.705
740	2.712	2.719	2.726	2.733	2.741	2.748	2.755	2.762	2.770	2.777
750	2.784	2.791	2.799	2.806	2.813	2.821	2.828	2.835	2.843	2.850
760	2.857	2.865	2.872	2.879	2.887	2.894	2.901	2.909	2.916	2.924
770	2.931	2.939	2.946	2.953	2.961	2.968	2.976	2.983	2.991	2.998
780	3.006	3.013	3.021	3.028	3.036	3.043	3.051	3.059	3.066	3.074
790	3.081	3.089	3.097	3.104	3.112	3.119	3.127	3.135	3.142	3.150
800	3.158	3.165	3.173	3.181	3.188	3.196	3.204	3.212	3.219	3.227
810	3.235	3.243	3.250	3.258	3.266	3.274	3.281	3.289	3.297	3.305
820	3.313	3.321	3.328	3.336	3.344	3.352	3.360	3.368	3.376	3.384
830	3.391	3.399	3.407	3.415	3.423	3.431	3.439	3.447	3.455	3.463
840	3.471	3.479	3.487	3.495	3.503	3.511	3.519	3.527	3.535	3.543
850	3.551	3.559	3.567	3.575	3.583	3.591	3.600	3.608	3.616	3.624
860	3.632	3.640	3.648	3.656	3.665	3.673	3.681	3.689	3.697	3.706
870	3.714	3.722	3.730	3.738	3.747	3.755	3.763	3.771	3.780	3.788
880	3.796	3.805	3.813	3.821	3.829	3.838	3.846	3.854	3.863	3.871
890	3.879	3.888	3.896	3.905	3.913	3.921	3.930	3.938	3.947	3.955
900	3.963	3.972	3.980	3.989	3.997	4.006	4.014	4.023	4.031	4.040
910	4.048	4.057	4.065	4.074	4.082	4.091	4.099	4.108	4.117	4.125
920	4.134	4.142	4.151	4.160	4.168	4.177	4.185	4.194	4.203	4.211
930	4.220	4.229	4.237	4.246	4.255	4.263	4.272	4.281	4.290	4.298
940	4.307	4.316	4.324	4.333	4.342	4.351	4.360	4.368	4.377	4.386
950	4.395	4.404	4.412	4.421	4.430	4.439	4.448	4.457	4.465	4.474
960	4.483	4.492	4.501	4.510	4.519	4.528	4.537	4.545	4.554	4.563
970	4.572	4.581	4.590	4.599	4.608	4.617	4.626	4.635	4.644	4.653
980	4.662	4.671	4.680	4.689	4.698	4.707	4.716	4.726	4.735	4.744
990	4.753	4.762	4.771	4.780	4.789	4.798	4.807	4.817	4.826	4.835
1000	4.844	4.853	4.862	4.872	4.881	4.890	4.899	4.908	4.918	4.927
1010	4.936	4.945	4.954	4.964	4.973	4.982	4.992	5.001	5.010	5.019
1020	5.029	5.038	5.047	5.057	5.066	5.075	5.085	5.094	5.103	5.113
1030	5.122	5.131	5.141	5.150	5.160	5.169	5.178	5.188	5.197	5.207
1040	5.216	5.225	5.235	5.244	5.254	5.263	5.273	5.282	5.292	5.301
1050	5.311	5.320	5.330	5.339	5.349	5.358	5.368	5.377	5.387	5.396
1060	5.406	5.415	5.425	5.435	5.444	5.454	5.463	5.473	5.483	5.492
1070	5.502	5.511	5.521	5.531	5.540	5.550	5.560	5.569	5.579	5.589
1080	5.598	5.608	5.618	5.627	5.637	5.647	5.657	5.666	5-676	5.686
1090	5.695	5.705	5.715	5.725	5.734	5.744	5.754	5.764	5.774	5.783

TABLE 1A. *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*—Continued

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

°C	0	1	2	3	4	5	6	7	8	9
	Millivolts									
1100	5.793	5.803	5.813	5.823	5.832	5.842	5.852	5.862	5.872	5.882
1110	5.891	5.901	5.911	5.921	5.931	5.941	5.951	5.961	5.970	5.980
1120	5.990	6.000	6.010	6.020	6.030	6.040	6.050	6.060	6.070	6.080
1130	6.090	6.100	6.110	6.120	6.130	6.140	6.150	6.160	6.170	6.180
1140	6.190	6.200	6.210	6.220	6.230	6.240	6.250	6.260	6.270	6.280
1150	6.290	6.300	6.310	6.320	6.330	6.340	6.351	6.361	6.371	6.381
1160	6.391	6.401	6.411	6.421	6.432	6.442	6.452	6.462	6.472	6.482
1170	6.492	6.503	6.513	6.523	6.533	6.543	6.554	6.564	6.574	6.584
1180	6.594	6.605	6.615	6.625	6.635	6.646	6.656	6.666	6.676	6.687
1190	6.697	6.707	6.718	6.728	6.738	6.749	6.759	6.769	6.780	6.790
1200	6.800	6.811	6.821	6.831	6.842	6.852	6.863	6.873	6.883	6.894
1210	6.904	6.915	6.925	6.936	6.946	6.956	6.967	6.977	6.988	6.998
1220	7.009	7.019	7.030	7.040	7.051	7.061	7.072	7.082	7.093	7.103
1230	7.114	7.125	7.135	7.146	7.156	7.167	7.177	7.188	7.199	7.209
1240	7.220	7.230	7.241	7.252	7.262	7.273	7.284	7.294	7.305	7.316
1250	7.326	7.337	7.348	7.358	7.369	7.380	7.390	7.401	7.412	7.422
1260	7.433	7.444	7.455	7.465	7.476	7.487	7.498	7.508	7.519	7.530
1270	7.541	7.551	7.562	7.573	7.584	7.595	7.605	7.616	7.627	7.638
1280	7.649	7.659	7.670	7.681	7.692	7.703	7.714	7.725	7.735	7.746
1290	7.757	7.768	7.779	7.790	7.801	7.812	7.822	7.833	7.844	7.855
1300	7.866	7.877	7.888	7.899	7.910	7.921	7.932	7.943	7.954	7.965
1310	7.976	7.987	7.998	8.009	8.020	8.031	8.042	8.053	8.064	8.075
1320	8.086	8.097	8.108	8.119	8.130	8.141	8.152	8.163	8.174	8.185
1330	8.196	8.207	8.218	8.229	8.240	8.251	8.262	8.273	8.285	8.296
1340	8.307	8.318	8.329	8.340	8.351	8.362	8.373	8.385	8.396	8.407
1350	8.418	8.429	8.440	8.451	8.463	8.474	8.485	8.496	8.507	8.518
1360	8.530	8.541	8.552	8.563	8.574	8.585	8.597	8.608	8.619	8.630
1370	8.641	8.653	8.664	8.675	8.686	8.698	8.709	8.720	8.731	8.743
1380	8.754	8.765	8.776	8.788	8.799	8.810	8.821	8.833	8.844	8.855
1390	8.866	8.878	8.889	8.900	8.912	8.923	8.934	8.946	8.957	8.968
1400	8.979	8.991	9.002	9.013	9.025	9.036	9.047	9.059	9.070	9.081
1410	9.093	9.104	9.115	9.127	9.138	9.150	9.161	9.172	9.184	9.195
1420	9.206	9.218	9.229	9.241	9.252	9.263	9.275	9.286	9.297	9.309
1430	9.320	9.332	9.343	9.354	9.366	9.377	9.389	9.400	9.412	9.423
1440	9.434	9.446	9.457	9.469	9.480	9.492	9.503	9.514	9.526	9.537
1450	9.549	9.560	9.572	9.583	9.595	9.606	9.618	9.629	9.640	9.652
1460	9.663	9.675	9.686	9.698	9.709	9.721	9.732	9.744	9.755	9.767
1470	9.778	9.790	9.801	9.813	9.824	9.836	9.847	9.859	9.870	9.882
1480	9.893	9.905	9.916	9.928	9.939	9.951	9.963	9.974	9.986	9.997
1490	10.009	10.020	10.032	10.043	10.055	10.066	10.078	10.089	10.101	10.113

TABLE 1A. *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*—Continued

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

°C	0	1	2	3	4	5	6	7	8	9
	Millivolts									
1500	10.124	10.136	10.147	10.159	10.170	10.182	10.193	10.205	10.217	10.228
1510	10.240	10.251	10.263	10.274	10.286	10.298	10.309	10.321	10.332	10.344
1520	10.356	10.367	10.379	10.390	10.402	10.413	10.425	10.437	10.448	10.460
1530	10.471	10.483	10.495	10.506	10.518	10.529	10.541	10.553	10.564	10.576
1540	10.587	10.599	10.611	10.622	10.634	10.646	10.657	10.669	10.680	10.692
1550	10.704	10.715	10.727	10.739	10.750	10.762	10.773	10.785	10.797	10.808
1560	10.820	10.832	10.843	10.855	10.866	10.878	10.890	10.901	10.913	10.925
1570	10.936	10.948	10.960	10.971	10.983	10.995	11.006	11.018	11.029	11.041
1580	11.053	11.064	11.076	11.088	11.099	11.111	11.123	11.134	11.146	11.158
1590	11.169	11.181	11.193	11.204	11.216	11.228	11.239	11.251	11.263	11.274
1600	11.286	11.298	11.309	11.321	11.333	11.344	11.356	11.368	11.379	11.391
1610	11.403	11.414	11.426	11.438	11.449	11.461	11.473	11.484	11.496	11.508
1620	11.519	11.531	11.543	11.554	11.566	11.578	11.589	11.601	11.613	11.624
1630	11.636	11.648	11.659	11.671	11.683	11.694	11.706	11.718	11.729	11.741
1640	11.753	11.764	11.776	11.788	11.799	11.811	11.823	11.834	11.846	11.858
1650	11.869	11.881	11.893	11.905	11.916	11.928	11.940	11.951	11.963	11.975
1660	11.986	11.998	12.010	12.021	12.033	12.045	12.056	12.068	12.080	12.091
1670	12.103	12.115	12.126	12.138	12.150	12.161	12.173	12.185	12.196	12.208
1680	12.220	12.231	12.243	12.255	12.266	12.278	12.290	12.301	12.313	12.325
1690	12.336	12.348	12.360	12.371	12.383	12.395	12.406	12.418	12.430	12.441
1700	12.453	12.465	12.476	12.488	12.500	12.511	12.523	12.535	12.546	12.558
1710	12.570	12.581	12.593	12.605	12.616	12.628	12.640	12.651	12.663	12.675
1720	12.686	12.698	12.709	12.721	12.733	12.744	12.756	12.768	12.779	12.791
1730	12.803	12.814	12.826	12.838	12.849	12.861	12.872	12.884	12.896	12.907
1740	12.919	12.931	12.942	12.954	12.966	12.977	12.989	13.000	13.012	13.024
1750	13.035	13.047	13.059	13.070	13.082	13.093	13.105	13.117	13.128	13.140
1760	13.152	13.163	13.175	13.186	13.198	13.210	13.221	13.233	13.245	13.256
1770	13.268	13.279	13.291	13.303	13.314	13.326	13.337	13.349	13.361	13.372
1780	13.384	13.395	13.407	13.419	13.430	13.442	13.453	13.465	13.477	13.488
1790	13.500	13.511	13.523	13.534	13.546	13.558	13.569	13.581	13.592	13.604
1800	13.616	13.627	13.639	13.650	13.662	13.673	13.685	13.696	13.708	13.720
1810	13.731	13.743	13.754	13.766	13.777	13.789	13.801	13.812	13.824	13.835
1820	13.847									

TABLE 2A. *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*

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

Millivolts	0.000	0.010	0.020	0.030	0.040	0.050	0.060	0.070	0.080	0.090
	Degrees C									
0.	0.	67.3	83.4	96.2	107.1	116.8	125.6	133.8	141.4	148.6
0.100	155.4	161.8	168.0	174.0	179.7	185.3	190.6	195.9	200.9	205.8
0.200	210.7	215.3	219.9	224.4	228.8	233.1	237.3	241.5	245.5	249.5
0.300	253.5	257.4	261.2	264.9	268.6	272.3	275.9	279.4	282.9	286.4
0.400	289.8	293.2	296.5	299.8	303.1	306.3	309.5	312.7	315.8	318.9
0.500	322.0	325.0	328.0	331.0	334.0	336.9	339.8	342.7	345.6	348.4
0.600	351.2	354.0	356.8	359.5	362.2	364.9	367.6	370.3	372.9	375.6
0.700	378.2	380.8	383.3	385.9	388.4	391.0	393.5	396.0	398.5	400.9
0.800	403.4	405.8	408.2	410.6	413.0	415.4	417.8	420.1	422.5	424.8
0.900	427.1	429.4	431.7	434.0	436.3	438.5	440.8	443.0	445.2	447.4
1.000	449.6	451.8	454.0	456.2	458.4	460.5	462.7	464.8	466.9	469.0
1.100	471.1	473.2	475.3	477.4	479.5	481.5	483.6	485.6	487.7	489.7
1.200	491.7	493.7	495.8	497.8	499.7	501.7	503.7	505.7	507.6	509.6
1.300	511.5	513.5	515.4	517.4	519.3	521.2	523.1	525.0	526.9	528.8
1.400	530.7	532.5	534.4	536.3	538.1	540.0	541.8	543.7	545.5	547.3
1.500	549.2	551.0	552.8	554.6	556.4	558.2	560.0	561.8	563.6	565.3
1.600	567.1	568.9	570.6	572.4	574.1	575.9	577.6	579.3	581.1	582.8
1.700	584.5	586.2	588.0	589.7	591.4	593.1	594.8	596.4	598.1	599.8
1.800	601.5	603.2	604.8	606.5	608.1	609.8	611.5	613.1	614.7	616.4
1.900	618.0	619.7	621.3	622.9	624.5	626.1	627.8	629.4	631.0	632.6
2.000	634.2	635.8	637.4	638.9	640.5	642.1	643.7	645.3	646.8	648.4
2.100	650.0	651.5	653.1	654.6	656.2	657.7	659.3	660.8	662.3	663.9
2.200	665.4	666.9	668.5	670.0	671.5	673.0	674.5	676.0	677.5	679.0
2.300	680.5	682.0	683.5	685.0	686.5	688.0	689.5	691.0	692.4	693.9
2.400	695.4	696.9	698.3	699.8	701.2	702.7	704.2	705.6	707.1	708.5
2.500	710.0	711.4	712.8	714.3	715.7	717.1	718.6	720.0	721.4	722.8
2.600	724.3	725.7	727.1	728.5	729.9	731.3	732.7	734.1	735.5	736.9
2.700	738.3	739.7	741.1	742.5	743.9	745.3	746.7	748.1	749.4	750.8
2.800	752.2	753.6	754.9	756.3	757.7	759.0	760.4	761.7	763.1	764.5
2.900	765.8	767.2	768.5	769.9	771.2	772.5	773.9	775.2	776.6	777.9
3.000	779.2	780.6	781.9	783.2	784.5	785.9	787.2	788.5	789.8	791.1
3.100	792.5	793.8	795.1	796.4	797.7	799.0	800.3	801.6	802.9	804.2
3.200	805.5	806.8	808.1	809.4	810.7	812.0	813.2	814.5	815.8	817.1
3.300	818.4	819.7	820.9	822.2	823.5	824.7	826.0	827.3	828.6	829.8
3.400	831.1	832.3	833.6	834.9	836.1	837.4	838.6	839.9	841.1	842.4
3.500	843.6	844.9	846.1	847.4	848.6	849.9	851.1	852.3	853.6	854.8
3.600	856.1	857.3	858.5	859.8	861.0	862.2	863.4	864.7	865.9	867.1
3.700	868.3	869.5	870.8	872.0	873.2	874.4	875.6	876.8	878.0	879.2
3.800	880.5	881.7	882.9	884.1	885.3	886.5	887.7	888.9	890.1	891.3
3.900	892.5	893.6	894.8	896.0	897.2	898.4	899.6	900.8	902.0	903.1

TABLE 2A. *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*—Continued

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

Millivolts	0.000	0.010	0.020	0.030	0.040	0.050	0.060	0.070	0.080	0.090
	Degrees C									
4.000	904.3	905.5	906.7	907.9	909.0	910.2	911.4	912.6	913.7	914.9
4.100	916.1	917.2	918.4	919.6	920.7	921.9	923.1	924.2	925.4	926.5
4.200	927.7	928.8	930.0	931.2	932.3	933.5	934.6	935.8	936.9	938.1
4.300	939.2	940.3	941.5	942.6	943.8	944.9	946.1	947.2	948.3	949.5
4.400	950.6	951.7	952.9	954.0	955.1	956.3	957.4	958.5	959.6	960.8
4.500	961.9	963.0	964.1	965.3	966.4	967.5	968.6	969.7	970.9	972.0
4.600	973.1	974.2	975.3	976.4	977.5	978.6	979.8	980.9	982.0	983.1
4.700	984.2	985.3	986.4	987.5	988.6	989.7	990.8	991.9	993.0	994.1
4.800	995.2	996.3	997.4	998.5	999.6	1000.6	1001.7	1002.8	1003.9	1005.0
4.900	1006.1	1007.2	1008.3	1009.3	1010.4	1011.5	1012.6	1013.7	1014.8	1015.8
5.000	1016.9	1018.0	1019.1	1020.1	1021.2	1022.3	1023.4	1024.4	1025.5	1026.6
5.100	1027.6	1028.7	1029.8	1030.9	1031.9	1033.0	1034.1	1035.1	1036.2	1037.2
5.200	1038.3	1039.4	1040.4	1041.5	1042.5	1043.6	1044.7	1045.7	1046.8	1047.8
5.300	1048.9	1049.9	1051.0	1052.0	1053.1	1054.1	1055.2	1056.2	1057.3	1058.3
5.400	1059.4	1060.4	1061.5	1062.5	1063.6	1064.6	1065.7	1066.7	1067.7	1068.8
5.500	1069.8	1070.9	1071.9	1072.9	1074.0	1075.0	1076.0	1077.1	1078.1	1079.1
5.600	1080.2	1081.2	1082.2	1083.3	1084.3	1085.3	1086.4	1087.4	1088.4	1089.4
5.700	1090.5	1091.5	1092.5	1093.5	1094.6	1095.6	1096.6	1097.6	1098.7	1099.7
5.800	1100.7	1101.7	1102.7	1103.8	1104.8	1105.8	1106.8	1107.8	1108.8	1109.9
5.900	1110.9	1111.9	1112.9	1113.9	1114.9	1115.9	1116.9	1118.0	1119.0	1120.0
6.000	1121.0	1122.0	1123.0	1124.0	1125.0	1126.0	1127.0	1128.0	1129.0	1130.0
6.100	1131.0	1132.0	1133.0	1134.0	1135.0	1136.0	1137.0	1138.0	1139.0	1140.0
6.200	1141.0	1142.0	1143.0	1144.0	1145.0	1146.0	1147.0	1148.0	1149.0	1150.0
6.300	1151.0	1152.0	1153.0	1154.0	1155.0	1155.9	1156.9	1157.9	1158.9	1159.9
6.400	1160.9	1161.9	1162.9	1163.8	1164.8	1165.8	1166.8	1167.8	1168.8	1169.8
6.500	1170.7	1171.7	1172.7	1173.7	1174.7	1175.6	1176.6	1177.6	1178.6	1179.6
6.600	1180.5	1181.5	1182.5	1183.5	1184.4	1185.4	1186.4	1187.4	1188.3	1189.3
6.700	1190.3	1191.3	1192.2	1193.2	1194.2	1195.1	1196.1	1197.1	1198.0	1199.0
6.800	1200.0	1200.9	1201.9	1202.9	1203.8	1204.8	1205.8	1206.7	1207.7	1208.6
6.900	1209.6	1210.6	1211.5	1212.5	1213.4	1214.4	1215.3	1216.3	1217.2	1218.2
7.000	1219.2	1220.1	1221.1	1222.0	1223.0	1223.9	1224.9	1225.8	1226.8	1227.7
7.100	1228.7	1229.6	1230.6	1231.5	1232.5	1233.4	1234.4	1235.3	1236.2	1237.2
7.200	1238.1	1239.1	1240.0	1241.0	1241.9	1242.8	1243.8	1244.7	1245.7	1246.6
7.300	1247.5	1248.5	1249.4	1250.4	1251.3	1252.2	1253.2	1254.1	1255.0	1256.0
7.400	1256.9	1257.8	1258.8	1259.7	1260.6	1261.6	1262.5	1263.4	1264.4	1265.3
7.500	1266.2	1267.2	1268.1	1269.0	1269.9	1270.9	1271.8	1272.7	1273.7	1274.6
7.600	1275.5	1276.4	1277.4	1278.3	1279.2	1280.1	1281.1	1282.0	1282.9	1283.8
7.700	1284.7	1285.7	1286.6	1287.5	1288.4	1289.3	1290.3	1291.2	1292.1	1293.0
7.800	1293.9	1294.9	1295.8	1296.7	1297.6	1298.5	1299.4	1300.4	1301.3	1302.2
7.900	1303.1	1304.0	1304.9	1305.8	1306.8	1307.7	1308.6	1309.5	1310.4	1311.3

TABLE 2A. *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*—Continued

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

Millivolts	0.000	0.010	0.020	0.030	0.040	0.050	0.060	0.070	0.080	0.090
	Degrees C									
8.000	1312.2	1313.1	1314.0	1315.0	1315.9	1316.8	1317.7	1318.6	1319.5	1320.4
8.100	1321.3	1322.2	1323.1	1324.0	1324.9	1325.8	1326.7	1327.7	1328.6	1329.5
8.200	1330.4	1331.3	1332.2	1333.1	1334.0	1334.9	1335.8	1336.7	1337.6	1338.5
8.300	1339.4	1340.3	1341.2	1342.1	1343.0	1343.9	1344.8	1345.7	1346.6	1347.5
8.400	1348.4	1349.3	1350.2	1351.1	1352.0	1352.9	1353.8	1354.7	1355.6	1356.5
8.500	1357.4	1358.3	1359.1	1360.0	1360.9	1361.8	1362.7	1363.6	1364.5	1365.4
8.600	1366.3	1367.2	1368.1	1369.0	1369.9	1370.8	1371.7	1372.5	1373.4	1374.3
8.700	1375.2	1376.1	1377.0	1377.9	1378.8	1379.7	1380.6	1381.4	1382.3	1383.2
8.800	1384.1	1385.0	1385.9	1386.8	1387.7	1388.5	1389.4	1390.3	1391.2	1392.1
8.900	1393.0	1393.9	1394.7	1395.6	1396.5	1397.4	1398.3	1399.2	1400.0	1400.9
9.000	1401.8	1402.7	1403.6	1404.5	1405.3	1406.2	1407.1	1408.0	1408.9	1409.8
9.100	1410.6	1411.5	1412.4	1413.3	1414.2	1415.0	1415.9	1416.8	1417.7	1418.6
9.200	1419.4	1420.3	1421.2	1422.1	1423.0	1423.8	1424.7	1425.6	1426.5	1427.3
9.300	1428.2	1429.1	1430.0	1430.9	1431.7	1432.6	1433.5	1434.4	1435.2	1436.1
9.400	1437.0	1437.9	1438.7	1439.6	1440.5	1441.4	1442.2	1443.1	1444.0	1444.9
9.500	1445.7	1446.6	1447.5	1448.4	1449.2	1450.1	1451.0	1451.9	1452.7	1453.6
9.600	1454.5	1455.3	1456.2	1457.1	1458.0	1458.8	1459.7	1460.6	1461.4	1462.3
9.700	1463.2	1464.1	1464.9	1465.8	1466.7	1467.5	1468.4	1469.3	1470.1	1471.0
9.800	1471.9	1472.8	1473.6	1474.5	1475.4	1476.2	1477.1	1478.0	1478.8	1479.7
9.900	1480.6	1481.4	1482.3	1483.2	1484.0	1484.9	1485.8	1486.6	1487.5	1488.4
10.000	1489.3	1490.1	1491.0	1491.9	1492.7	1493.6	1494.4	1495.3	1496.2	1497.0
10.100	1497.9	1498.8	1499.6	1500.5	1501.4	1502.2	1503.1	1504.0	1504.8	1505.7
10.200	1506.6	1507.4	1508.3	1509.2	1510.0	1510.9	1511.8	1512.6	1513.5	1514.3
10.300	1515.2	1516.1	1516.9	1517.8	1518.7	1519.5	1520.4	1521.3	1522.1	1523.0
10.400	1523.8	1524.7	1525.6	1526.4	1527.3	1528.2	1529.0	1529.9	1530.7	1531.6
10.500	1532.5	1533.3	1534.2	1535.0	1535.9	1536.8	1537.6	1538.5	1539.4	1540.2
10.600	1541.1	1541.9	1542.8	1543.7	1544.5	1545.4	1546.2	1547.1	1548.0	1548.8
10.700	1549.7	1550.5	1551.4	1552.3	1553.1	1554.0	1554.8	1555.7	1556.6	1557.4
10.800	1558.3	1559.1	1560.0	1560.9	1561.7	1562.6	1563.4	1564.3	1565.2	1566.0
10.900	1566.9	1567.7	1568.6	1569.5	1570.3	1571.2	1572.0	1572.9	1573.8	1574.6
11.000	1575.5	1576.3	1577.2	1578.0	1578.9	1579.8	1580.6	1581.5	1582.3	1583.2
11.100	1584.1	1584.9	1585.8	1586.6	1587.5	1588.3	1589.2	1590.1	1590.9	1591.8
11.200	1592.6	1593.5	1594.3	1595.2	1596.1	1596.9	1597.8	1598.6	1599.5	1600.3
11.300	1601.2	1602.1	1602.9	1603.8	1604.6	1605.5	1606.3	1607.2	1608.1	1608.9
11.400	1609.8	1610.6	1611.5	1612.3	1613.2	1614.1	1614.9	1615.8	1616.6	1617.5
11.500	1618.3	1619.2	1620.1	1620.9	1621.8	1622.6	1623.5	1624.3	1625.2	1626.1
11.600	1626.9	1627.8	1628.6	1629.5	1630.3	1631.2	1632.1	1632.9	1633.8	1634.6
11.700	1635.5	1636.3	1637.2	1638.1	1638.9	1639.8	1640.6	1641.5	1642.3	1643.2
11.800	1644.0	1644.9	1645.8	1646.6	1647.5	1648.3	1649.2	1650.0	1650.9	1651.8
11.900	1652.6	1653.5	1654.3	1655.2	1656.0	1656.9	1657.8	1658.6	1659.5	1660.3

TABLE 2A. *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*—Continued

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

Millivolts	0.000	0.010	0.020	0.030	0.040	0.050	0.060	0.070	0.080	0.090
	Degrees C									
12.000	1661.2	1662.0	1662.9	1663.7	1664.6	1665.5	1666.3	1667.2	1668.0	1668.9
12.100	1669.7	1670.6	1671.5	1672.3	1673.2	1674.0	1674.9	1675.7	1676.6	1677.5
12.200	1678.3	1679.2	1680.0	1680.9	1681.7	1682.6	1683.5	1684.3	1685.2	1686.0
12.300	1686.9	1687.7	1688.6	1689.5	1690.3	1691.2	1692.0	1692.9	1693.7	1694.6
12.400	1695.5	1696.3	1697.2	1698.0	1698.9	1699.7	1700.6	1701.5	1702.3	1703.2
12.500	1704.0	1704.9	1705.7	1706.6	1707.5	1708.3	1709.2	1710.0	1710.9	1711.7
12.600	1712.6	1713.5	1714.3	1715.2	1716.0	1716.9	1717.8	1718.6	1719.5	1720.3
12.700	1721.2	1722.0	1722.9	1723.8	1724.6	1725.5	1726.3	1727.2	1728.1	1728.9
12.800	1729.8	1730.6	1731.5	1732.3	1733.2	1734.1	1734.9	1735.8	1736.6	1737.5
12.900	1738.4	1739.2	1740.1	1740.9	1741.8	1742.7	1743.5	1744.4	1745.2	1746.1
13.000	1747.0	1747.8	1748.7	1749.5	1750.4	1751.3	1752.1	1753.0	1753.8	1754.7
13.100	1755.6	1756.4	1757.3	1758.1	1759.0	1759.9	1760.7	1761.6	1762.4	1763.3
13.200	1764.2	1765.0	1765.9	1766.7	1767.6	1768.5	1769.3	1770.2	1771.1	1771.9
13.300	1772.8	1773.6	1774.5	1775.4	1776.2	1777.1	1778.0	1778.8	1779.7	1780.5
13.400	1781.4	1782.3	1783.1	1784.0	1784.8	1785.7	1786.6	1787.4	1788.3	1789.2
13.500	1790.0	1790.9	1791.8	1792.6	1793.5	1794.3	1795.2	1796.1	1796.9	1797.8
13.600	1798.7	1799.5	1800.4	1801.3	1802.1	1803.0	1803.8	1804.7	1805.6	1806.4
13.700	1807.3	1808.2	1809.0	1809.9	1810.8	1811.6	1812.5	1813.4	1814.2	1815.1
13.800	1816.0	1816.8	1817.7	1818.6	1819.4					

TABLE 3A *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*

(Temperatures in Degrees F. Electromotive Force in Absolute Millivolts. Reference Junctions at 32 °F.)

°F	0	1	2	3	4	5	6	7	8	9
	Millivolts									
30			0.000	− 0.000	− 0.000	− 0.000	− 0.000	− 0.001	− 0.001	− 0.001
40	− 0.001	− 0.001	− 0.001	− 0.001	− 0.001	− 0.001	− 0.001	− 0.002	− 0.002	− 0.002
50	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002
60	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002
70	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002
80	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002	− 0.002
90	− 0.002	− 0.002	− 0.002	− 0.001	− 0.001	− 0.001	− 0.001	− 0.001	− 0.001	− 0.001
100	− 0.001	− 0.001	− 0.001	− 0.000	− 0.000	− 0.000	− 0.000	0.000	0.000	0.000
110	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002
120	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.004	0.004
130	0.004	0.004	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.006
140	0.006	0.007	0.007	0.007	0.007	0.008	0.008	0.008	0.009	0.009
150	0.009	0.009	0.010	0.010	0.010	0.011	0.011	0.011	0.011	0.012
160	0.012	0.012	0.013	0.013	0.013	0.014	0.014	0.014	0.015	0.015
170	0.015	0.016	0.016	0.017	0.017	0.017	0.018	0.018	0.018	0.019
180	0.019	0.020	0.020	0.020	0.021	0.021	0.022	0.022	0.022	0.023
190	0.023	0.024	0.024	0.024	0.025	0.025	0.026	0.026	0.027	0.027
200	0.028	0.028	0.029	0.029	0.029	0.030	0.030	0.031	0.031	0.032
210	0.032	0.033	0.033	0.034	0.034	0.035	0.035	0.036	0.036	0.037
220	0.037	0.038	0.038	0.039	0.040	0.040	0.041	0.041	0.042	0.042
230	0.043	0.043	0.044	0.045	0.045	0.046	0.046	0.047	0.047	0.048
240	0.049	0.049	0.050	0.050	0.051	0.052	0.052	0.053	0.054	0.054
250	0.055	0.055	0.056	0.057	0.057	0.058	0.059	0.059	0.060	0.061
260	0.061	0.062	0.063	0.063	0.064	0.065	0.065	0.066	0.067	0.067
270	0.068	0.069	0.069	0.070	0.071	0.072	0.072	0.073	0.074	0.074
280	0.075	0.076	0.077	0.077	0.078	0.079	0.080	0.080	0.081	0.082
290	0.083	0.083	0.084	0.085	0.086	0.087	0.087	0.088	0.089	0.090
300	0.090	0.091	0.092	0.093	0.094	0.094	0.095	0.096	0.097	0.098
310	0.099	0.099	0.100	0.101	0.102	0.103	0.104	0.105	0.105	0.106
320	0.107	0.108	0.109	0.110	0.111	0.111	0.112	0.113	0.114	0.115
330	0.116	0.117	0.118	0.119	0.120	0.120	0.121	0.122	0.123	0.124
340	0.125	0.126	0.127	0.128	0.129	0.130	0.131	0.132	0.133	0.134
350	0.135	0.136	0.137	0.138	0.139	0.139	0.140	0.141	0.142	0.143
360	0.144	0.145	0.146	0.147	0.148	0.149	0.151	0.152	0.153	0.154
370	0.155	0.156	0.157	0.158	0.159	0.160	0.161	0.162	0.163	0.164
380	0.165	0.166	0.167	0.168	0.169	0.170	0.172	0.173	0.174	0.175
390	0.176	0.177	0.178	0.179	0.180	0.182	0.183	0.184	0.185	0.186
400	0.187	0.188	0.189	0.191	0.192	0.193	0.194	0.195	0.196	0.197
410	0.199	0.200	0.201	0.202	0.203	0.205	0.206	0.207	0.208	0.209
420	0.210	0.212	0.213	0.214	0.215	0.217	0.218	0.219	0.220	0.221
430	0.223	0.224	0.225	0.226	0.228	0.229	0.230	0.231	0.233	0.234
440	0.235	0.236	0.238	0.239	0.240	0.241	0.243	0.244	0.245	0.247
450	0.248	0.249	0.251	0.252	0.253	0.254	0.256	0.257	0.258	0.260
460	0.261	0.262	0.264	0.265	0.266	0.268	0.269	0.270	0.272	0.273
470	0.275	0.276	0.277	0.279	0.280	0.281	0.283	0.284	0.286	0.287
480	0.288	0.290	0.291	0.293	0.294	0.295	0.297	0.298	0.300	0.301
490	0.302	0.304	0.305	0.307	0.308	0.310	0.311	0.313	0.314	0.315

TABLE 3A *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*—Continued

(Temperatures in Degrees F. Electromotive Force in Absolute Millivolts. Reference Junctions at 32 °F.)

°F	0	1	2	3	4	5	6	7	8	9
	Millivolts									
500	0.317	0.318	0.320	0.321	0.323	0.324	0.326	0.327	0.329	0.330
510	0.332	0.333	0.335	0.336	0.338	0.339	0.341	0.342	0.344	0.345
520	0.347	0.348	0.350	0.351	0.353	0.354	0.356	0.358	0.359	0.361
530	0.362	0.364	0.365	0.367	0.368	0.370	0.372	0.373	0.375	0.376
540	0.378	0.380	0.381	0.383	0.384	0.386	0.388	0.389	0.391	0.392
550	0.394	0.396	0.397	0.399	0.401	0.402	0.404	0.405	0.407	0.409
560	0.410	0.412	0.414	0.415	0.417	0.419	0.420	0.422	0.424	0.425
570	0.427	0.429	0.431	0.432	0.434	0.436	0.437	0.439	0.441	0.442
580	0.444	0.446	0.448	0.449	0.451	0.453	0.455	0.456	0.458	0.460
590	0.462	0.463	0.465	0.467	0.469	0.470	0.472	0.474	0.476	0.477
600	0.479	0.481	0.483	0.485	0.486	0.488	0.490	0.492	0.494	0.495
610	0.497	0.499	0.501	0.503	0.504	0.506	0.508	0.510	0.512	0.514
620	0.515	0.517	0.519	0.521	0.523	0.525	0.527	0.528	0.530	0.532
630	0.534	0.536	0.538	0.540	0.542	0.543	0.545	0.547	0.549	0.551
640	0.553	0.555	0.557	0.559	0.561	0.563	0.564	0.566	0.568	0.570
650	0.572	0.574	0.576	0.578	0.580	0.582	0.584	0.586	0.588	0.590
660	0.592	0.594	0.596	0.598	0.600	0.602	0.604	0.606	0.608	0.610
670	0.612	0.614	0.616	0.618	0.620	0.622	0.624	0.626	0.628	0.630
680	0.632	0.634	0.636	0.638	0.640	0.642	0.644	0.646	0.648	0.650
690	0.652	0.654	0.656	0.659	0.661	0.663	0.665	0.667	0.669	0.671
700	0.673	0.675	0.677	0.679	0.682	0.684	0.686	0.688	0.690	0.692
710	0.694	0.696	0.698	0.701	0.703	0.705	0.707	0.709	0.711	0.714
720	0.716	0.718	0.720	0.722	0.724	0.726	0.729	0.731	0.733	0.735
730	0.737	0.740	0.742	0.744	0.746	0.748	0.751	0.753	0.755	0.757
740	0.759	0.762	0.764	0.766	0.768	0.771	0.773	0.755	0.777	0.780
750	0.782	0.784	0.786	0.789	0.791	0.793	0.795	0.798	0.800	0.802
760	0.804	0.807	0.809	0.811	0.814	0.816	0.818	0.820	0.823	0.825
770	0.827	0.830	0.832	0.834	0.837	0.839	0.841	0.844	0.846	0.848
780	0.851	0.853	0.855	0.858	0.860	0.862	0.865	0.867	0.869	0.872
790	0.874	0.877	0.879	0.881	0.884	0.886	0.888	0.891	0.893	0.896
800	0.898	0.900	0.903	0.905	0.908	0.910	0.913	0.915	0.917	0.920
810	0.922	0.925	0.927	0.930	0.932	0.934	0.937	0.939	0.942	0.944
820	0.947	0.949	0.952	0.954	0.957	0.959	0.962	0.964	0.967	0.969
830	0.972	0.974	0.976	0.979	0.982	0.984	0.987	0.989	0.992	0.994
840	0.997	0.999	1.002	1.004	1.007	1.009	1.012	1.014	1.017	1.019
850	1.022	1.025	1.027	1.030	1.032	1.035	1.037	1.040	1.042	1.045
860	1.048	1.050	1.053	1.055	1.058	1.061	1.063	1.066	1.068	1.071
870	1.074	1.076	1.079	1.081	1.084	1.087	1.089	1.092	1.095	1.097
880	1.100	1.103	1.105	1.108	1.110	1.113	1.116	1.118	1.121	1.124
890	1.126	1.129	1.132	1.134	1.137	1.140	1.143	1.145	1.148	1.151

TABLE 3A *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*—Continued

(Temperatures in Degrees F. Electromotive Force in Absolute Millivolts. Reference Junctions at 32 °F.)

°F	0	1	2	3	4	5	6	7	8	9
	Millivolts									
900	1.153	1.156	1.159	1.161	1.164	1.167	1.170	1.172	1.175	1.178
910	1.180	1.183	1.186	1.189	1.191	1.194	1.197	1.200	1.202	1.205
920	1.208	1.211	1.213	1.216	1.219	1.222	1.255	1.227	1.230	1.233
930	1.236	1.238	1.241	1.244	1.247	1.250	1.252	1.255	1.258	1.261
940	1.264	1.267	1.269	1.272	1.275	1.278	1.281	1.284	1.286	1.289
950	1.292	1.295	1.298	1.301	1.303	1.306	1.309	1.312	1.315	1.318
960	1.321	1.324	1.326	1.329	1.332	1.335	1.338	1.341	1.344	1.347
970	1.350	1.353	1.355	1.358	1.361	1.364	1.367	1.370	1.373	1.376
980	1.379	1.382	1.385	1.388	1.391	1.394	1.396	1.399	1.402	1.405
990	1.408	1.411	1.414	1.417	1.420	1.423	1.426	1.429	1.432	1.435
1000	1.438	1.441	1.444	1.447	1.450	1.453	1.456	1.459	1.462	1.465
1010	1.468	1.471	1.474	1.477	1.480	1.483	1.486	1.489	1.492	1.495
1020	1.499	1.502	1.505	1.508	1.511	1.514	1.517	1.520	1.523	1.526
1030	1.529	1.532	1.535	1.538	1.541	1.545	1.548	1.551	1.554	1.557
1040	1.560	1.563	1.566	1.569	1.573	1.576	1.579	1.582	1.585	1.588
1050	1.591	1.594	1.598	1.601	1.604	1.607	1.610	1.613	1.616	1.620
1060	1.623	1.626	1.629	1.632	1.635	1.639	1.642	1.645	1.648	1.651
1070	1.655	1.658	1.661	1.664	1.667	1.671	1.674	1.677	1.680	1.683
1080	1.687	1.690	1.693	1.696	1.700	1.703	1.706	1.709	1.712	1.716
1090	1.719	1.722	1.725	1.729	1.732	1.735	1.739	1.742	1.745	1.748
1100	1.752	1.755	1.758	1.761	1.765	1.768	1.771	1.775	1.778	1.781
1110	1.785	1.788	1.791	1.794	1.798	1.801	1.804	1.808	1.811	1.814
1120	1.818	1.821	1.824	1.828	1.831	1.834	1.838	1.841	1.844	1.848
1130	1.851	1.855	1.858	1.861	1.865	1.868	1.871	1.875	1.878	1.882
1140	1.885	1.888	1.892	1.895	1.898	1.902	1.905	1.909	1.912	1.916
1150	1.919	1.922	1.926	1.929	1.933	1.936	1.939	1.943	1.946	1.950
1160	1.953	1.957	1.960	1.964	1.967	1.970	1.974	1.977	1.981	1.984
1170	1.988	1.991	1.995	1.998	2.002	2.005	2.009	2.012	2.016	2.019
1180	2.023	2.026	2.030	2.033	2.037	2.040	2.044	2.047	2.051	2.054
1190	2.058	2.061	2.065	2.068	2.072	2.075	2.079	2.083	2.086	2.090
1200	2.093	2.097	2.100	2.104	2.107	2.111	2.115	2.118	2.122	2.125
1210	2.129	2.132	2.136	2.140	2.143	2.147	2.150	2.154	2.158	2.161
1220	2.165	2.168	2.172	2.176	2.179	2.183	2.186	2.190	2.194	2.197
1230	2.201	2.205	2.208	2.212	2.216	2.219	2.223	2.226	2.230	2.234
1240	2.237	2.241	2.245	2.248	2.252	2.256	2.259	2.263	2.267	2.271
1250	2.274	2.278	2.282	2.285	2.289	2.293	2.296	2.300	2.304	2.308
1260	2.311	2.315	2.319	2.322	2.326	2.330	2.334	2.337	2.341	2.345
1270	2.349	2.352	2.356	2.360	2.363	2.367	2.371	2.375	2.379	2.382
1280	2.386	2.390	2.394	2.397	2.401	2.405	2.409	2.412	2.416	2.420
1290	2.424	2.428	2.431	2.435	2.439	2.443	2.447	2.450	2.454	2.458

TABLE 3A *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*—Continued

(Temperatures in Degrees F. Electromotive Force in Absolute Millivolts. Reference Junctions at 32 °F.)

°F	0	1	2	3	4	5	6	7	8	9
	Millivolts									
1300	2.462	2.466	2.470	2.473	2.477	2.481	2.485	2.489	2.493	2.496
1310	2.500	2.504	2.508	2.512	2.516	2.520	2.523	2.527	2.531	2.535
1320	2.539	2.543	2.547	2.551	2.554	2.558	2.562	2.566	2.570	2.574
1330	2.578	2.582	2.586	2.589	2.593	2.597	2.601	2.605	2.609	2.613
1340	2.617	2.621	2.625	2.629	2.633	2.637	2.641	2.644	2.648	2.652
1350	2.656	2.660	2.664	2.668	2.672	2.676	2.680	2.684	2.688	2.692
1360	2.696	2.700	2.704	2.708	2.712	2.716	2.720	2.724	2.728	2.732
1370	2.736	2.740	2.744	2.748	2.752	2.756	2.760	2.764	2.768	2.772
1380	2.776	2.780	2.784	2.788	2.792	2.796	2.800	2.804	2.808	2.812
1390	2.816	2.821	2.825	2.829	2.833	2.837	2.841	2.845	2.849	2.853
1400	2.857	2.861	2.865	2.869	2.874	2.878	2.882	2.886	2.890	2.894
1410	2.898	2.902	2.906	2.910	2.915	2.919	2.923	2.927	2.931	2.935
1420	2.939	2.943	2.948	2.952	2.956	2.960	2.964	2.968	2.972	2.977
1430	2.981	2.985	2.989	2.993	2.997	3.002	3.006	3.010	3.014	3.018
1440	3.023	3.027	3.031	3.035	3.039	3.043	3.048	3.052	3.056	3.060
1450	3.064	3.069	3.073	3.077	3.081	3.086	3.090	3.094	3.098	3.102
1460	3.107	3.111	3.115	3.119	3.124	3.128	3.132	3.136	3.141	3.145
1470	3.149	3.153	3.158	3.162	3.166	3.170	3.175	3.179	3.183	3.188
1480	3.192	3.196	3.200	3.205	3.209	3.213	3.218	3.222	3.226	3.231
1490	3.235	3.239	3.243	3.248	3.252	3.256	3.261	3.265	3.269	3.274
1500	3.278	3.282	3.287	3.291	3.295	3.300	3.304	3.308	3.313	3.317
1510	3.321	3.326	3.330	3.335	3.339	3.343	3.348	3.352	3.356	3.361
1520	3.365	3.369	3.374	3.378	3.383	3.387	3.391	3.396	3.400	3.405
1530	3.409	3.413	3.418	3.422	3.427	3.431	3.435	3.440	3.444	3.449
1540	3.453	3.458	3.462	3.466	3.471	3.475	3.480	3.484	3.489	3.493
1550	3.497	3.502	3.506	3.511	3.515	3.520	3.524	3.529	3.533	3.538
1560	3.542	3.547	3.551	3.556	3.560	3.564	3.569	3.573	3.578	3.582
1570	3.587	3.591	3.596	3.600	3.605	3.609	3.614	3.618	3.623	3.627
1580	3.632	3.637	3.641	3.646	3.650	3.655	3.659	3.664	3.668	3.673
1590	3.677	3.682	3.686	3.691	3.696	3.700	3.705	3.709	3.714	3.718
1600	3.723	3.727	3.732	3.737	3.741	3.746	3.750	3.755	3.759	3.764
1610	3.769	3.773	3.778	3.782	3.787	3.792	3.796	3.801	3.805	3.810
1620	3.815	3.819	3.824	3.829	3.833	3.838	3.842	3.847	3.852	3.856
1630	3.861	3.866	3.870	3.875	3.879	3.884	3.889	3.893	3.898	3.903
1640	3.907	3.912	3.917	3.921	3.926	3.931	3.935	3.940	3.945	3.949
1650	3.954	3.959	3.963	3.968	3.973	3.978	3.982	3.987	3.992	3.996
1660	4.001	4.006	4.010	4.015	4.020	4.025	4.029	4.034	4.039	4.044
1670	4.048	4.053	4.058	4.062	4.067	4.072	4.077	4.081	4.086	4.091
1680	4.096	4.100	4.105	4.110	4.115	4.119	4.124	4.129	4.134	4.139
1690	4.143	4.148	4.153	4.158	4.162	4.167	4.172	4.177	4.182	4.186

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TABLE 3A *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*—Continued

(Temperatures in Degrees F. Electromotive Force in Absolute Millivolts. Reference Junctions at 32 °F.)

°F	0	1	2	3	4	5	6	7	8	9
	Millivolts									
1700	4.191	4.196	4.201	4.206	4.210	4.215	4.220	4.225	4.230	4.234
1710	4.239	4.244	4.249	4.254	4.259	4.263	4.268	4.273	4.278	4.283
1720	4.288	4.292	4.297	4.302	4.307	4.312	4.317	4.322	4.326	4.331
1730	4.336	4.341	4.346	4.351	4.356	4.360	4.365	4.370	4.375	4.380
1740	4.385	4.390	4.395	4.400	4.404	4.409	4.414	4.419	4.424	4.429
1750	4.434	4.439	4.444	4.449	4.454	4.458	4.463	4.468	4.473	4.478
1760	4.483	4.488	4.493	4.498	4.503	4.508	4.513	4.518	4.523	4.528
1770	4.533	4.538	4.543	4.547	4.552	4.557	4.562	4.567	4.572	4.577
1780	4.582	4.587	4.592	4.597	4.602	4.607	4.612	4.617	4.622	4.627
1790	4.632	4.637	4.642	4.647	4.652	4.657	4.662	4.667	4.672	4.677
1800	4.682	4.687	4.692	4.697	4.702	4.707	4.712	4.717	4.722	4.728
1810	4.733	4.738	4.743	4.748	4.753	4.758	4.763	4.768	4.773	4.778
1820	4.783	4.788	4.793	4.798	4.803	4.808	4.814	4.819	4.824	4.829
1830	4.834	4.839	4.844	4.849	4.854	4.859	4.864	4.870	4.875	4.880
1840	4.885	4.890	4.895	4.900	4.905	4.910	4.916	4.921	4.926	4.931
1850	4.936	4.941	4.946	4.951	4.957	4.962	4.967	4.972	4.977	4.982
1860	4.987	4.993	4.998	5.003	5.008	5.013	5.018	5.024	5.029	5.034
1870	5.039	5.044	5.049	5.055	5.060	5.065	5.070	5.075	5.080	5.086
1880	5.091	5.096	5.101	5.106	5.112	5.117	5.122	5.127	5.132	5.138
1890	5.143	5.148	5.153	5.158	5.164	5.169	5.174	5.179	5.185	5.190
1900	5.195	5.200	5.206	5.211	5.216	5.221	5.226	5.232	5.237	5.242
1910	5.247	5.253	5.258	5.263	5.268	5.274	5.279	5.284	5.290	5.295
1920	5.300	5.305	5.311	5.316	5.321	5.326	5.332	5.337	5.342	5.348
1930	5.353	5.358	5.363	5.369	5.374	5.379	5.385	5.390	5.395	5.401
1940	5.406	5.411	5.417	5.422	5.427	5.432	5.438	5.443	5.448	5.454
1950	5.459	5.464	5.470	5.475	5.480	5.486	5.491	5.496	5.502	5.507
1960	5.512	5.518	5.523	5.529	5.534	5.539	5.545	5.550	5.555	5.561
1970	5.566	5.571	5.577	5.582	5.588	5.593	5.598	5.604	5.609	5.614
1980	5.620	5.625	6.631	5.636	5.641	5.647	5.652	5.658	5.663	5.668
1990	5.674	5.679	5.685	5.690	5.695	5.701	5.706	5.712	5.717	5.723
2000	5.728	5.733	5.739	5.744	5.750	5.755	5.761	5.766	5.771	5.777
2010	5.782	5.788	5.793	5.799	5.804	5.809	5.815	5.820	5.826	5.831
2020	5.837	5.842	5.848	5.853	5.859	5.864	5.870	5.875	5.880	5.886
2030	5.891	5.897	5.902	5.908	5.913	5.919	5.924	5.930	5.935	5.941
2040	5.946	5.952	5.957	5.963	5.968	5.974	5.979	5.985	5.990	5.996
2050	6.001	6.007	6.012	6.018	6.023	6.029	6.034	6.040	6.045	6.051
2060	6.056	6.062	6.068	6.073	6.079	6.084	6.090	6.095	6.101	6.106
2070	6.112	6.117	6.123	6.128	6.134	6.140	6.145	6.151	6.156	6.162
2080	6.167	6.173	6.178	6.184	6.190	6.195	6.201	6.206	6.212	6.217
2090	6.223	6.229	6.234	6.240	6.245	6.251	6.257	6.262	6.268	6.273

TABLE 3A *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples* – Continued

(Temperatures in Degrees F. Electromotive Force in Absolute Millivolts. Reference Junctions at 32 °F.)

°F	0	1	2	3	4	5	6	7	8	9
	Millivolts									
2100	6.279	6.284	6.290	6.296	6.301	6.307	6.312	6.318	6.324	6.329
2110	6.335	6.340	6.346	6.352	6.357	6.363	6.369	6.374	6.380	6.385
2120	6.391	6.397	6.402	6.408	6.414	6.419	6.425	6.430	6.436	6.442
2130	6.447	6.453	6.459	6.464	6.470	6.476	6.481	6.487	6.492	6.498
2140	6.504	6.509	6.515	6.521	6.526	6.532	6.538	6.543	6.549	6.555
2150	6.560	6.566	6.572	6.577	6.583	6.589	6.594	6.600	6.606	6.611
2160	6.617	6.623	6.629	6.634	6.640	6.646	6.651	6.657	6.663	6.668
2170	6.674	6.680	6.686	6.691	6.697	6.703	6.708	6.714	6.720	6.726
2180	6.731	6.737	6.743	6.749	6.754	6.760	6.766	6.772	6.777	6.783
2190	6.789	6.795	6.800	6.806	6.812	6.818	6.823	6.829	6.835	6.841
2200	6.846	6.852	6.858	6.864	6.870	6.875	6.881	6.887	6.893	6.898
2210	6.904	6.910	6.916	6.922	6.927	6.933	6.939	6.945	6.951	6.956
2220	6.962	6.968	6.974	6.980	6.986	6.991	6.997	7.003	7.009	7.015
2230	7.020	7.026	7.032	7.038	7.044	7.050	7.055	7.061	7.067	7.073
2240	7.079	7.085	7.091	7.096	7.102	7.108	7.114	7.120	7.126	7.132
2250	7.137	7.143	7.149	7.155	7.161	7.167	7.173	7.179	7.184	7.190
2260	7.196	7.202	7.208	7.214	7.220	7.226	7.232	7.237	7.243	7.249
2270	7.255	7.261	7.267	7.273	7.279	7.285	7.291	7.297	7.302	7.308
2280	7.314	7.320	7.326	7.332	7.338	7.344	7.350	7.356	7.362	7.368
2290	7.374	7.380	7.386	7.391	7.397	7.403	7.409	7.415	7.421	7.427
2300	7.433	7.439	7.445	7.451	7.457	7.463	7.469	7.475	7.481	7.487
2310	7.493	7.499	7.505	7.511	7.517	7.523	7.529	7.535	7.541	7.547
2320	7.553	7.559	7.565	7.571	7.577	7.583	7.589	7.595	7.601	7.607
2330	7.613	7.619	7.625	7.631	7.637	7.643	7.649	7.655	7.661	7.667
2340	7.673	7.679	7.685	7.691	7.697	7.703	7.709	7.715	7.721	7.727
2350	7.733	7.739	7.745	7.751	7.757	7.763	7.769	7.775	7.781	7.787
2360	7.793	7.799	7.806	7.812	7.818	7.824	7.830	7.836	7.842	7.848
2370	7.854	7.860	7.866	7.872	7.878	7.884	7.890	7.896	7.903	7.909
2380	7.915	7.921	7.927	7.933	7.939	7.945	7.951	7.957	7.963	7.970
2390	7.976	7.982	7.988	7.994	8.000	8.006	8.012	8.018	8.024	8.031
2400	8.037	8.043	8.049	8.055	8.061	8.067	8.073	8.079	8.086	8.092
2410	8.098	8.104	8.110	8.116	8.122	8.128	8.135	8.141	8.147	8.153
2420	8.159	8.165	8.171	8.177	8.184	8.190	8.196	8.202	8.208	8.214
2430	8.221	8.227	8.233	8.239	8.245	8.251	8.257	8.264	8.270	8.276
2440	8.282	8.288	8.294	8.301	8.307	8.313	8.319	8.325	8.331	8.338
2450	8.344	8.350	8.356	8.362	8.368	8.375	8.381	8.387	8.393	8.399
2460	8.406	8.412	8.418	8.424	8.430	8.436	8.443	8.449	8.455	8.461
2470	8.467	8.474	8.480	8.486	8.492	8.498	8.505	8.511	8.517	8.523
2480	8.530	8.536	8.542	8.548	8.554	8.561	8.567	8.573	8.579	8.585
2490	8.592	8.598	8.604	8.610	8.617	8.623	8.629	8.635	8.641	8.648

TABLE 3A *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*—Continued

(Temperatures in Degrees F. Electromotive Force in Absolute Millivolts. Reference Junctions at 32 °F.)

°F	0	1	2	3	4	5	6	7	8	9
	Millivolts									
2500	8.654	8.660	8.666	8.673	8.679	8.685	8.691	8.698	8.704	8.710
2510	8.716	8.723	8.729	8.735	8.741	8.748	8.754	8.760	8.766	8.773
2520	8.779	8.785	8.791	8.798	8.804	8.810	8.816	8.823	8.829	8.835
2530	8.841	8.848	8.854	8.860	8.866	8.873	8.879	8.885	8.892	8.898
2540	8.904	8.910	8.917	8.923	8.929	8.935	8.942	8.948	8.954	8.961
2550	8.967	8.973	8.979	8.986	8.992	8.998	9.005	9.011	9.017	9.023
2560	9.030	9.036	9.042	9.049	9.055	9.061	9.068	9.074	9.080	9.086
2570	9.093	9.099	9.105	9.112	9.118	9.124	9.131	9.137	9.143	9.150
2580	9.156	9.162	9.168	9.175	9.181	9.187	9.194	9.200	9.206	9.213
2590	9.219	9.225	9.232	9.238	9.244	9.251	9.257	9.263	9.270	9.276
2600	9.282	9.289	9.295	9.301	9.308	9.314	9.320	9.327	9.333	9.339
2610	9.346	9.352	9.358	9.365	9.371	9.377	9.384	9.390	9.396	9.403
2620	9.409	9.415	9.422	9.428	9.434	9.441	9.447	9.453	9.460	9.466
2630	9.473	9.479	9.485	9.492	9.498	9.504	9.511	9.517	9.523	9.530
2640	9.536	9.542	9.549	9.555	9.562	9.568	9.574	9.581	9.587	9.593
2650	9.600	9.606	9.612	9.619	9.625	9.632	9.638	9.644	9.651	9.657
2660	9.663	9.670	9.676	9.683	9.689	9.695	9.702	9.708	9.714	9.721
2670	9.727	9.734	9.740	9.746	9.753	9.759	9.766	9.772	9.778	9.785
2680	9.791	9.797	9.804	9.810	9.817	9.823	9.829	9.836	9.842	9.849
2690	9.855	9.861	9.868	9.874	9.881	9.887	9.893	9.900	9.906	9.913
2700	9.919	9.925	9.932	9.938	9.945	9.951	9.957	9.964	9.970	9.977
2710	9.983	9.989	9.996	10.002	10.009	10.015	10.021	10.028	10.034	10.041
2720	10.047	10.054	10.060	10.066	10.073	10.079	10.086	10.092	10.098	10.105
2730	10.111	10.118	10.124	10.131	10.137	10.143	10.150	10.156	10.163	10.169
2740	10.175	10.182	10.188	10.195	10.201	10.208	10.214	10.220	10.227	10.233
2750	10.240	10.246	10.253	10.259	10.265	10.272	10.278	10.285	10.291	10.298
2760	10.304	10.310	10.317	10.323	10.330	10.336	10.343	10.349	10.355	10.362
2770	10.368	10.375	10.381	10.388	10.394	10.401	10.407	10.413	10.420	10.426
2780	10.433	10.439	10.446	10.452	10.459	10.465	10.471	10.478	10.484	10.491
2790	10.497	10.504	10.510	10.517	10.523	10.529	10.536	10.542	10.549	10.555
2800	10.562	10.568	10.575	10.581	10.587	10.594	10.600	10.607	10.613	10.620
2810	10.626	10.633	10.639	10.646	10.652	10.658	10.665	10.671	10.678	10.684
2820	10.691	10.697	10.704	10.710	10.717	10.723	10.729	10.736	10.742	10.749
2830	10.755	10.762	10.768	10.775	10.781	10.788	10.794	10.801	10.807	10.813
2840	10.820	10.826	10.833	10.839	10.846	10.852	10.859	10.865	10.872	10.878
2850	10.885	10.891	10.898	10.904	10.910	10.917	10.923	10.930	10.936	10.943
2860	10.949	10.956	10.962	10.969	10.975	10.982	10.988	10.995	11.001	11.007
2870	11.014	11.020	11.027	11.033	11.040	11.046	11.053	11.059	11.066	11.072
2880	11.079	11.085	11.092	11.098	11.105	11.111	11.118	11.124	11.130	11.137
2890	11.143	11.150	11.156	11.163	11.169	11.176	11.182	11.189	11.195	11.202

TABLE 3A *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*—Continued

(Temperatures in Degrees F. Electromotive Force in Absolute Millivolts. Reference Junctions at 32 °F.)

°F	0	1	2	3	4	5	6	7	8	9
	Millivolts									
2900	11.208	11.215	11.221	11.228	11.234	11.241	11.247	11.254	11.260	11.266
2910	11.273	11.279	11.286	11.292	11.299	11.305	11.312	11.318	11.325	11.331
2920	11.338	11.344	11.351	11.357	11.364	11.370	11.377	11.383	11.390	11.396
2930	11.403	11.409	11.416	11.422	11.429	11.435	11.441	11.448	11.454	11.461
2940	11.467	11.474	11.480	11.487	11.493	11.500	11.506	11.513	11.519	11.526
2950	11.532	11.539	11.545	11.552	11.558	11.565	11.571	11.578	11.584	11.591
2960	11.597	11.604	11.610	11.617	11.623	11.530	11.636	11.642	11.649	11.655
2970	11.662	11.668	11.675	11.681	11.688	11.694	11.701	11.707	11.714	11.720
2980	11.727	11.733	11.740	11.746	11.753	11.759	11.766	11.772	11.779	11.785
2990	11.792	11.798	11.805	11.811	11.818	11.824	11.831	11.837	11.844	11.850
3000	11.857	11.863	11.869	11.876	11.882	11.889	11.895	11.902	11.908	11.915
3010	11.921	11.928	11.934	11.941	11.947	11.954	11.960	11.967	11.973	11.980
3020	11.986	11.993	11.999	12.006	12.012	12.019	12.025	12.032	12.038	12.045
3030	12.051	12.058	12.064	12.071	12.077	12.084	12.090	12.096	12.103	12.109
3040	12.116	12.122	12.129	12.135	12.142	12.148	12.155	12.161	12.168	12.174
3050	12.181	12.187	12.194	12.200	12.207	12.213	12.220	12.226	12.233	12.239
3060	12.246	12.252	12.259	12.265	12.272	12.278	12.285	12.291	12.297	12.304
3070	12.310	12.317	12.323	12.330	12.336	12.343	12.349	12.356	12.362	12.369
3080	12.375	12.382	12.388	12.395	12.401	12.408	12.414	12.421	12.427	12.434
3090	12.440	12.447	12.453	12.459	12.466	12.472	12.479	12.485	12.492	12.498
3100	12.505	12.511	12.518	12.524	12.531	12.537	12.544	12.550	12.557	12.563
3110	12.570	12.576	12.583	12.589	12.596	12.602	12.608	12.615	12.621	12.628
3120	12.634	12.641	12.647	12.654	12.660	12.667	12.673	12.680	12.686	12.693
3130	12.699	12.706	12.712	12.719	12.725	12.731	12.738	12.744	12.751	12.757
3140	12.764	12.770	12.777	12.783	12.790	12.796	12.803	12.809	12.816	12.822
3150	12.829	12.835	12.841	12.848	12.854	12.861	12.867	12.874	12.880	12.887
3160	12.893	12.900	12.906	12.913	12.919	12.926	12.932	12.938	12.945	12.951
3170	12.958	12.964	12.971	12.977	12.984	12.990	12.997	13.003	13.010	13.016
3180	13.022	13.029	13.035	13.042	13.048	13.055	13.061	13.068	13.074	13.081
3190	13.087	13.093	13.100	13.106	13.113	13.119	13.126	13.132	13.139	13.145
3200	13.152	13.158	13.165	13.171	13.177	13.184	13.190	13.197	13.203	13.210
3210	13.216	13.223	13.229	13.235	13.242	13.248	13.255	13.261	13.268	13.274
3220	13.281	13.287	13.294	13.300	13.306	13.313	13.319	13.326	13.332	13.339
3230	13.345	13.352	13.358	13.364	13.371	13.377	13.384	13.390	13.397	13.403
3240	13.410	13.416	13.422	13.429	13.435	13.442	13.448	13.455	13.461	13.468
3250	13.474	13.480	13.487	13.493	13.500	13.506	13.513	13.519	13.525	13.532
3260	13.538	13.545	13.551	13.558	13.564	13.570	13.577	13.583	13.590	13.596
3270	13.603	13.609	13.615	13.622	13.628	13.635	13.641	13.648	13.654	13.660
3280	13.667	13.673	13.680	13.686	13.693	13.699	13.705	13.712	13.718	13.725
3290	13.731	13.738	13.744	13.750	13.757	13.763	13.770	13.776	13.783	13.789
3300	13.795	13.802	13.808	13.815	13.821	13.827	13.834	13.840	13.847	

TABLE 4A. *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*

(Electromotive Force in Absolute Millivolts. Temperatures in Degrees F. Reference Junctions at 32 °F.)

Millivolts	0.000	0.010	0.020	0.030	0.040	0.050	0.060	0.070	0.080	0.090
	Degrees F									
0.	32.0	153.2	182.2	205.1	224.8	242.3	258.2	272.8	286.5	299.4
0.100	311.7	323.3	334.5	345.2	355.5	365.5	375.2	384.5	393.7	402.5
0.200	411.2	419.6	427.9	435.9	443.8	451.6	459.2	466.6	474.0	481.2
0.300	488.3	495.2	502.1	508.9	515.5	522.1	528.6	535.0	541.3	547.5
0.400	553.7	559.7	565.8	571.7	577.6	583.4	589.1	594.8	600.5	606.0
0.500	611.6	617.0	622.5	627.8	633.2	638.4	643.7	648.9	654.0	659.1
0.600	664.2	669.2	674.2	679.1	684.0	688.9	693.7	698.5	703.3	708.0
0.700	712.7	717.4	722.0	726.6	731.2	735.7	740.3	744.7	749.2	753.6
0.800	758.1	762.4	766.8	771.1	775.4	779.7	784.0	788.2	792.4	796.6
0.900	800.8	804.9	809.1	813.2	817.3	821.3	825.4	829.4	833.4	837.4
1.000	841.4	845.3	849.2	853.1	857.0	860.9	864.8	868.6	872.4	876.3
1.100	880.0	883.8	887.6	891.3	895.1	898.8	902.5	906.2	909.8	913.5
1.200	917.1	920.7	924.4	928.0	931.5	935.1	938.7	942.2	945.8	949.3
1.300	952.8	956.3	959.8	963.2	966.7	970.1	973.6	977.0	980.4	983.8
1.400	987.2	990.6	993.9	997.3	1000.6	1004.0	1007.3	1010.6	1013.9	1017.2
1.500	1020.5	1023.8	1027.0	1030.3	1033.5	1036.7	1040.0	1043.2	1046.4	1049.6
1.600	1052.8	1055.9	1059.1	1062.3	1065.4	1068.6	1071.7	1074.8	1077.9	1081.0
1.700	1084.1	1087.2	1090.3	1093.4	1096.4	1099.5	1102.6	1105.6	1108.6	1111.7
1.800	1114.7	1117.7	1120.7	1123.7	1126.7	1129.6	1132.6	1135.6	1138.5	1141.5
1.900	1144.4	1147.4	1150.3	1153.2	1156.2	1159.1	1162.0	1164.9	1167.7	1170.6
2.000	1173.5	1176.4	1179.2	1182.1	1184.9	1187.8	1190.6	1193.5	1196.3	1199.1
2.100	1201.9	1204.7	1207.5	1210.3	1213.1	1215.9	1218.7	1221.4	1224.2	1227.0
2.200	1229.7	1232.5	1235.2	1238.0	1240.7	1243.4	1246.1	1248.9	1251.6	1254.3
2.300	1257.0	1259.7	1262.4	1265.0	1267.7	1270.4	1273.1	1275.7	1278.4	1281.0
2.400	1283.7	1286.3	1289.0	1291.6	1294.2	1296.9	1299.5	1302.1	1304.7	1307.3
2.500	1309.9	1312.5	1315.1	1317.7	1320.3	1322.9	1325.4	1328.0	1330.6	1333.1
2.600	1335.7	1338.2	1340.8	1343.3	1345.9	1348.4	1350.9	1353.5	1356.0	1358.5
2.700	1361.0	1363.5	1366.0	1368.5	1371.0	1373.5	1376.0	1378.5	1381.0	1383.5
2.800	1385.9	1388.4	1390.9	1393.3	1395.8	1398.2	1400.7	1403.1	1405.6	1408.0
2.900	1410.5	1412.9	1415.3	1417.7	1420.2	1422.6	1425.0	1427.4	1429.8	1432.2
3.000	1434.6	1437.0	1439.4	1441.8	1444.2	1446.6	1448.9	1451.3	1453.7	1456.1
3.100	1458.4	1460.8	1463.1	1465.5	1467.8	1470.2	1472.5	1474.9	1477.2	1479.6
3.200	1481.9	1484.2	1486.6	1488.9	1491.2	1493.5	1495.8	1498.1	1500.5	1502.8
3.300	1505.1	1507.4	1509.7	1512.0	1514.3	1516.5	1518.8	1521.1	1523.4	1525.7
3.400	1528.0	1530.2	1532.5	1534.8	1537.0	1539.3	1541.6	1543.8	1546.1	1548.3
3.500	1550.6	1552.8	1555.1	1557.3	1559.5	1561.8	1564.0	1566.2	1568.5	1570.7
3.600	1572.9	1575.1	1577.3	1579.6	1581.8	1584.0	1586.2	1588.4	1590.6	1592.8
3.700	1595.0	1597.2	1599.4	1601.6	1603.7	1605.9	1608.1	1610.3	1612.5	1614.6
3.800	1616.8	1619.0	1621.2	1623.3	1625.5	1627.6	1629.8	1632.0	1634.1	1636.3
3.900	1638.4	1640.6	1642.7	1644.8	1647.0	1649.1	1651.3	1653.4	1655.5	1657.6

TABLE 4A. *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*—Continued

(Electromotive Force in Absolute Millivolts. Temperatures in Degrees F. Reference Junctions at 32 °F.)

Millivolts	0.000	0.010	0.020	0.030	0.040	0.050	0.060	0.070	0.080	0.090
	Degrees F									
4.000	1659.8	1661.9	1664.0	1666.1	1668.3	1670.4	1672.5	1674.6	1676.7	1678.8
4.100	1680.9	1683.0	1685.1	1687.2	1689.3	1691.4	1693.5	1695.6	1697.7	1699.8
4.200	1701.8	1703.9	1706.0	1708.1	1710.2	1712.2	1714.3	1716.4	1718.4	1720.5
4.300	1722.6	1724.6	1726.7	1728.7	1730.8	1732.8	1734.9	1736.9	1739.0	1741.0
4.400	1743.1	1745.1	1747.2	1749.2	1751.2	1753.3	1755.3	1757.3	1759.4	1761.4
4.500	1763.4	1765.4	1767.5	1769.5	1771.5	1773.5	1775.5	1777.5	1779.5	1781.6
4.600	1783.6	1785.6	1787.6	1789.6	1791.6	1793.6	1795.6	1797.6	1799.6	1801.5
4.700	1803.5	1805.5	1807.5	1809.5	1811.5	1813.5	1815.4	1817.4	1819.4	1821.4
4.800	1823.3	1825.3	1827.3	1829.2	1831.2	1833.2	1835.1	1837.1	1839.1	1841.0
4.900	1843.0	1844.9	1846.9	1848.8	1850.8	1852.7	1854.7	1856.6	1858.6	1860.5
5.000	1862.4	1864.4	1866.3	1868.3	1870.2	1872.1	1874.1	1876.0	1877.9	1879.8
5.100	1881.8	1883.7	1885.6	1887.5	1889.5	1891.4	1893.3	1895.2	1897.1	1899.0
5.200	1900.9	1902.9	1904.8	1906.7	1908.6	1910.5	1912.4	1914.3	1916.2	1918.1
5.300	1920.0	1921.9	1923.8	1925.7	1927.6	1929.5	1931.3	1933.2	1935.1	1937.0
5.400	1938.9	1940.8	1942.7	1944.5	1946.4	1948.3	1950.2	1952.0	1953.9	1955.8
5.500	1957.7	1959.5	1961.4	1963.3	1965.1	1967.0	1968.9	1970.7	1972.6	1974.5
5.600	1976.3	1978.2	1980.0	1981.9	1983.7	1985.6	1987.4	1989.3	1991.1	1993.0
5.700	1994.8	1996.7	1998.5	2000.4	2002.2	2004.1	2005.9	2007.7	2009.6	2011.4
5.800	2013.3	2015.1	2016.9	2018.8	2020.6	2022.4	2024.3	2026.1	2027.9	2029.7
5.900	2031.6	2033.4	2035.2	2037.0	2038.9	2040.7	2042.5	2044.3	2046.1	2047.9
6.000	2049.8	2051.6	2053.4	2055.2	2057.0	2058.8	2060.6	2062.4	2064.2	2066.1
6.100	2067.9	2069.7	2071.5	2073.3	2075.1	2076.9	2078.7	2080.5	2082.3	2084.1
6.200	2085.9	2087.7	2089.5	2091.2	2093.0	2094.8	2096.6	2098.4	2100.2	2102.0
6.300	2103.8	2105.6	2107.3	2109.1	2110.9	2112.7	2114.5	2116.3	2118.0	2119.8
6.400	2121.6	2123.4	2125.1	2126.9	2128.7	2130.5	2132.2	2134.0	2135.8	2137.6
6.500	2139.3	2141.1	2142.9	2144.6	2146.4	2148.2	2149.9	2151.7	2153.5	2155.2
6.600	2157.0	2158.7	2160.5	2162.3	2164.0	2165.8	2167.5	2169.3	2171.0	2172.8
6.700	2174.5	2176.3	2178.0	2179.8	2181.5	2183.2	2185.0	2186.7	2188.5	2190.2
6.800	2191.9	2193.7	2195.4	2197.2	2198.9	2200.6	2202.4	2204.1	2205.8	2207.5
6.900	2209.3	2211.0	2212.7	2214.4	2216.2	2217.9	2219.6	2221.3	2223.0	2224.8
7.000	2226.5	2228.2	2229.9	2231.6	2233.3	2235.1	2236.8	2238.5	2240.2	2241.9
7.100	2243.6	2245.3	2247.0	2248.7	2250.4	2252.1	2253.8	2255.5	2257.2	2258.9
7.200	2260.6	2262.3	2264.0	2265.7	2267.4	2269.1	2270.8	2272.5	2274.2	2275.9
7.300	2277.6	2279.3	2281.0	2282.6	2284.3	2286.0	2287.7	2289.4	2291.1	2292.8
7.400	2294.4	2296.1	2297.8	2299.5	2301.2	2302.8	2304.5	2306.2	2307.9	2309.5
7.500	2311.2	2312.9	2314.6	2316.2	2317.9	2319.6	2321.2	2322.9	2324.6	2326.2
7.600	2327.9	2329.6	2331.2	2332.9	2334.6	2336.2	2337.9	2339.6	2341.2	2342.9
7.700	2344.5	2346.2	2347.9	2349.5	2351.2	2352.8	2354.5	2356.1	2357.8	2359.4
7.800	2361.1	2362.7	2364.4	2366.0	2367.7	2369.3	2371.0	2372.6	2374.3	2375.9
7.900	2377.6	2379.2	2380.9	2382.5	2384.2	2385.8	2387.4	2389.1	2390.7	2392.4

TABLE 4A. *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples* — Continued

(Electromotive Force in Absolute Millivolts. Temperatures in Degrees F. Reference Junctions at 32 °F.)

Millivolts	0.000	0.010	0.020	0.030	0.040	0.050	0.060	0.070	0.080	0.090
	Degrees F									
8.000	2394.0	2395.6	2397.3	2398.9	2400.6	2402.2	2403.8	2405.5	2407.1	2408.7
8.100	2410.4	2412.0	2413.6	2415.3	2416.9	2418.5	2420.2	2421.8	2423.4	2425.0
8.200	2426.7	2428.3	2429.9	2431.5	2433.2	2434.8	2436.4	2438.0	2439.7	2441.3
8.300	2442.9	2444.5	2446.2	2447.8	2449.4	2451.0	2452.6	2454.3	2455.9	2457.5
8.400	2459.1	2460.7	2462.3	2464.0	2465.6	2467.2	2468.8	2470.4	2472.0	2473.6
8.500	2475.2	2476.9	2478.5	2480.1	2481.7	2483.3	2484.9	2486.5	2488.1	2489.7
8.600	2491.3	2492.9	2494.6	2496.2	2497.8	2499.4	2501.0	2502.6	2504.2	2505.8
8.700	2507.4	2509.0	2510.6	2512.2	2513.8	2515.4	2517.0	2518.6	2520.2	2521.8
8.800	2523.4	2525.0	2526.6	2528.2	2529.8	2531.4	2533.0	2534.6	2536.2	2537.8
8.900	2539.3	2540.9	2542.5	2544.1	2545.7	2547.3	2548.9	2550.5	2552.1	2553.7
9.000	2555.3	2556.9	2558.4	2560.0	2561.6	2563.2	2564.8	2566.4	2568.0	2569.6
9.100	2571.1	2572.7	2574.3	2575.9	2577.5	2579.1	2580.7	2582.2	2583.8	2585.4
9.200	2587.0	2588.6	2590.2	2591.7	2593.3	2594.9	2596.5	2598.1	2599.6	2601.2
9.300	2602.8	2604.4	2606.0	2607.5	2609.1	2610.7	2612.3	2613.9	2615.4	2617.0
9.400	2618.6	2620.2	2621.7	2623.3	2624.9	2626.5	2628.0	2629.6	2631.2	2632.8
9.500	2634.3	2635.9	2637.5	2639.0	2640.6	2642.2	2643.8	2645.3	2646.9	2648.5
9.600	2650.0	2651.6	2653.2	2654.8	2656.3	2657.9	2659.5	2661.0	2662.6	2664.2
9.700	2665.7	2667.3	2668.9	2670.4	2672.0	2673.6	2675.1	2676.7	2678.3	2679.8
9.800	2681.4	2683.0	2684.5	2686.1	2687.7	2689.2	2690.8	2692.3	2693.9	2695.5
9.900	2697.0	2698.6	2700.2	2701.7	2703.3	2704.8	2706.4	2708.0	2709.5	2711.1
10.000	2712.7	2714.2	2715.8	2717.3	2718.9	2720.5	2722.0	2723.6	2725.1	2726.7
10.100	2728.2	2729.8	2731.4	2732.9	2734.5	2736.0	2737.6	2739.1	2740.7	2742.3
10.200	2743.8	2745.4	2746.9	2748.5	2750.0	2751.6	2753.2	2754.7	2756.3	2757.8
10.300	2759.4	2760.9	2762.5	2764.0	2765.6	2767.1	2768.7	2770.3	2771.8	2773.4
10.400	2774.9	2776.5	2778.0	2779.6	2781.1	2782.7	2784.2	2785.8	2787.3	2788.9
10.500	2790.4	2792.0	2793.5	2795.1	2796.6	2798.2	2799.7	2801.3	2802.8	2804.4
10.600	2805.9	2807.5	2809.0	2810.6	2812.1	2813.7	2815.2	2816.8	2818.3	2819.9
10.700	2821.4	2823.0	2824.5	2826.1	2827.6	2829.2	2830.7	2832.3	2833.8	2835.4
10.800	2836.9	2838.5	2840.0	2841.6	2843.1	2844.6	2846.2	2847.7	2849.3	2850.8
10.900	2852.4	2853.9	2855.5	2857.0	2858.6	2860.1	1861.7	2863.2	2864.8	2866.3
11.000	2867.8	2869.4	2870.9	2872.5	2874.0	2875.6	2877.1	2878.7	2880.2	2881.7
11.100	2883.3	2884.8	2886.4	2887.9	2889.5	2891.0	2892.6	2894.1	2895.6	2897.2
11.200	2898.7	2900.3	2901.8	2903.4	2904.9	2906.5	2908.0	2909.5	2911.1	2912.6
11.300	2914.2	2915.7	2917.3	2918.8	2920.3	2921.9	2923.4	2925.0	2926.5	2928.1
11.400	2929.6	2931.1	2932.7	2934.2	2935.8	2937.3	2938.9	2940.4	2941.9	2943.5
11.500	2945.0	2946.6	2948.1	2949.7	2951.2	2952.7	2954.3	2955.8	2957.4	2958.9
11.600	2960.4	2962.0	2963.5	2965.1	2966.6	2968.2	2969.7	2971.2	2972.8	2974.3
11.700	2975.9	2977.4	2979.0	2980.5	2982.0	2983.6	2985.1	2986.7	2988.2	2989.7
11.800	2991.3	2992.8	2994.4	2995.9	2997.5	2999.0	3000.5	3002.1	3003.6	3005.2
11.900	3006.7	3008.2	3009.8	3011.3	3012.9	3014.4	3016.0	3017.5	3019.0	3020.6

TABLE 4A. *Platinum-30 percent Rhodium versus Platinum-6 Percent Rhodium Thermocouples*—Continued

(Electromotive Force in Absolute Millivolts. Temperatures in Degrees F. Reference Junctions at 32 °F

Millivolts	0.000	0.010	0.020	0.030	0.040	0.050	0.060	0.070	0.080	0.090
	Degrees F									
12.000	3022.1	3023.7	3025.2	3026.7	3028.3	3029.8	3031.4	3032.9	3034.5	3036.0
12.100	3037.5	3039.1	3040.6	3042.2	3043.7	3045.3	3046.8	3048.3	3049.9	3051.4
12.200	3053.0	3054.5	3056.0	3057.6	3059.1	3060.7	3062.2	3063.8	3065.3	3066.8
12.300	3068.4	3069.9	3071.5	3073.0	3074.6	3076.1	3077.6	3079.2	3080.7	3082.3
12.400	3083.8	3085.4	3086.9	3088.4	3090.0	3091.5	3093.1	3094.6	3096.2	3097.7
12.500	3099.3	3100.8	3102.3	3103.9	3105.4	3107.0	3108.5	3110.1	3111.6	3113.1
12.600	3114.7	3116.2	3117.8	3119.3	3120.9	3122.4	3124.0	3125.5	3127.0	3128.6
12.700	3130.1	3131.7	3133.2	3134.8	3136.3	3137.9	3139.4	3141.0	3142.5	3144.0
12.800	3145.6	3147.1	3148.7	3150.2	3151.8	3153.3	3154.9	3156.4	3158.0	3159.5
12.900	3161.1	3162.6	3164.1	3165.7	3167.2	3168.8	3170.3	3171.9	3173.4	3175.0
13.000	3176.5	3178.1	3179.6	3181.2	3182.7	3184.3	3185.8	3187.4	3188.9	3190.5
13.100	3192.0	3193.6	3195.1	3196.7	3198.2	3199.8	3201.3	3202.9	3204.4	3206.0
13.200	3207.5	3209.0	3210.6	3212.1	3213.7	3215.3	3216.8	3218.4	3219.9	3221.5
13.300	3223.0	3224.6	3226.1	3227.7	3229.2	3230.8	3232.3	3233.9	3235.4	3237.0
13.400	3238.5	3240.1	3241.6	3243.2	3244.7	3246.3	3247.8	3249.4	3250.9	3252.5
13.500	3254.0	3255.6	3257.2	3258.7	3260.3	3261.8	3263.4	3264.9	3266.5	3268.0
13.600	3269.6	3271.1	3272.7	3274.3	3275.8	3277.4	3278.9	3280.5	3282.0	3283.6
13.700	3285.1	3286.7	3288.3	3289.8	3291.4	3292.9	3294.5	3296.0	3297.6	3299.2
13.800	3300.7	3302.3	3303.8	3305.4	3307.0					

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