22. Storch, *Z. physik. Chem.*, **19,** 13 (1896).
23. Bray, *Trans. Am. Electrochem. Soc.*, **21,** 143 (1912).
24. Sloan, THIS JOURNAL, **32,** 946 (1910).
25. Kahlenberg, *J. physic. Chem.*, **5,** 339 (1901).
26. Washburn and MacInness, THIS JOURNAL, **33,** 1686 (1911).
27. Sprung, *Wied. Ann.*, **159,** 1 (1876).
28. Franklin and Kraus, *Am. Chem. J.*, **23,** 277 (1900); THIS JOURNAL, **27,** 191 (1901).
29. Franklin, *Z. physik. Chem.*, **69,** 272 (1909).
30. Fitzgerald, *J. Phys. Chem.*, **16,** 621 (1912).
31. Franklin and Gibbs, THIS JOURNAL, **29,** 1389 (1907).
32. Franklin, *J. Phys. Chem.*, **15,** 675 (1911).
33. Tammann, *Wied. Ann.*, **69,** 770 (1899).
34. Cohen, *Wied. Ann.*, **45,** 666 (1892).
35. Kohlrausch, *Wied. Ann.*, **6,** 196 (1879).
36. Sutherland, *Phil. Mag.*, **50,** 460 (1900).
37. Young and Mitchell, THIS JOURNAL, **26,** 1389 (1904).
38. Euler, *Z. physik. Chem.*, **25,** 536 (1898).
39. Washburn, THIS JOURNAL, **31,** 322 (1909).
40. Denison, *Z. physik. Chem.*, **43,** 596 (1903).
41. Buchbök, *Z. physik. Chem.*, **55,** 563 (1906).
42. Washburn, THIS JOURNAL, **33,** 1461 (1911).
43. Lewis, THIS JOURNAL, **34,** 1631 (1912).
44. Kendall, *J. Chem. Soc.*, **102,** 1275 (1912).
45. Noyes and Kato, THIS JOURNAL, **30,** 318 (1908)
46. Drucker, *Z. physik. Chem.*, **62,** 731 (1908).
47. Kohlrausch, *Proc. Roy. Soc.*, **71,** 338 (1903).
48. Danneel, *Z. Electrochem.*, **11,** 249 (1905).
49. Kraus and Bray, THIS JOURNAL, **35,** 1315 (1913).

BOSTON, MASS.

---

# CALIBRATION TABLES FOR COPPER-CONSTANTAN AND PLATINUM-PLATINRHODIUM THERMOELEMENTS.

BY L. H. ADAMS.

Received November 1, 1913.

In view of the fact that chemists are making more and more extensive use of thermoelements as a means of measuring high temperatures, it seemed desirable to present two tables which save much trouble in converting microvolts into degrees. Nothing will be said here as to the precautions to be observed in the use of thermoelements,[1] further than that experience has shown the necessity of frequent recalibration in order to insure trustworthy results. The experimental work required for such a calibration involves comparatively little time or labor, but interpolation between the fixed points can be accomplished accurately only by means of an empirical equation expressing the relation between electromotive force and temperature, and repeated recalculation of such an equation

[1] These precautions have been discussed by W. P. White, *Physic. Rev.*, **23,** 449 (1906); *Am. J. Sci.*, [4] **28,** 479 (1909).

may prove a somewhat tiresome task. This may be avoided by the use of a table representing a standard curve in conjunction with an appropriate "deviation curve"; the advantages of this procedure have already been pointed out by Sosman.[1] Such standard curves are arbitrary, but it is always advisable, for the sake of accuracy, that they represent closely the actual form of curve characteristic of the thermoelement, so that the deviations may be as small as possible.

Standard curves for use with platinum-platinrhodium[2] and copper-constantan[3] elements have been given in previous publications; but they now require amendment. Certain changes in the accepted temperature scale below 650° have necessitated a recalculation for the curve for the Pt-PtRh couple; and the superior qualities of the kind of constantan wire, which we have lately succeeded in obtaining, made it desirable to construct for copper-constantan elements a new table which should conform more closely to the actual observations with that kind of wire.

*The Copper-constantan Curve.*—(Table I.) The curve given in Table I represents very closely the observations for a sample of "Ideal" wire.[4] This wire is of such uniformity—a characteristic which is very desirable—that three lengths cut from the same spool did not differ in electromotive force against copper by as much as 1 part in 15,000.

The table was calculated from the equation

$$\mathbf{E} = 74.672t - 13892\,(1 - e^{-0.00261t}).$$

**E** being the electromotive force in microvolts, $t$ the temperature (Centigrade) and $e$ the base of the natural logarithms. The advantages of this form of equation, as compared with the ordinary power series, have been indicated in another paper;[5] that it is capable of reproducing the observations with high precision is evident from the following:

| Temp. | **E** (obs.) Microvolts. | **E** (calc.) Microvolts. | Difference. Microvolts.[6] |
|---|---|---|---|
| 24.30 | 961.1 | 960.9 | 0.2 |
| 49.59 | 2010.9 | 2010.8 | 0.1 |
| 78.75 | 2391.7 | 3291.4 | 0.3 |
| 100.0 | 4276. | (4276) * | ... |
| 217.95 | 10248. | (10248) * | ... |
| 305.9 | 15203. | (15203) * | ... |

[1] R. B. Sosman, *Am. J. Sci.*, [4] **30**, 7 (1910).

[2] *Ibid.*, [4] **30**, 9 (1910).

[3] L. H. Adams and J. Johnston, *Am. J. Sci.*, [4] **32**, 534 (1912).

[4] Practically identical with constantan. Obtainable from the Electrical Alloys Co., Morristown, N. J.; size No. 30 B. & S., double silk-covered, is perhaps the most convenient.

[5] L. H. Adams, *J. Wash. Acad.*, **3**, 469 (1913).

[6] 1 microvolt corresponds in this case to about 0.02°.

* Used in computing the equation.

*The Pt-PtRh Curve.*—(Table II.) For this element it proved impossible to find a single equation, with a reasonable number of constants, which would adequately express the relation between temperature and electromotive force over the whole range between 0° and 1755°, the melting point of platinum; a circumstance which is hardly surprising, in view of the magnitude of the range. Accordingly, the curve given in Table II was calculated in three overlapping sections: 0–400°, 300–1200°, 1100–1755°. The first section was computed from an exponential equation of the form,

$$\mathbf{E} = At + B(1 - e^{Ct});$$

the second from the equation,[1]

$$\mathbf{E} = -308 + 8.2294t + 0.001649t^2;$$

and the third by inverting the table of Sosman[2] so that the argument is in microvolts and not degrees. That this procedure introduced in this case no discontinuities in the slope of the curve at the points of transition from one section to another, was established by the identity of the results calculated in both ways for the overlapping portions. Any slight inequalities were evened out by adjustment of the successive differences.

*Remarks.*—It is understood, of course, that the cold junction is maintained at 0°, which is most conveniently done by means of a mixture of ice and water contained in a vacuum-jacketed flask; if the cold junction is not at 0°, corrections similar to those given in the table by Foote must be applied.[3]

The standard temperatures employed are based mainly upon the series of gas thermometer determinations made by Day and Sosman;[4] this scale does not differ materially from that advocated by the Bureau of Standards[5] or from that now in use at the Reichsanstalt up to 1100°,[6] and it is little likely to undergo any marked change for some time to come. The tables give temperatures (on the thermodynamic scale) and temperature differences for each 100 microvolts up to the limit of usefulness of each thermoelement; this form of table is more troublesome to calculate but is much more convenient to use. The last digit in each temperature value is given mainly for purposes of interpolation; otherwise it is meaning-

[1] A. L. Day and R. B. Sosman, *Am. J. Sci.*, [4] **33**, 528 (1912); *Ann. Physik*, **38**, 863 (1912).

[2] R. B. Sosman, *Am. J. Sci.*, [4] **30**, 9 (1910); *Carnegie Inst. Wash.*, *Pub.* **157**, 118.

[3] P. D. Foote, *Met. Chem. Eng.*, 11 329 (1913).

[4] Arthur L. Day and R. B. Sosman, *Am. J. Sci.*, [4] **29**, 93–161 (1910); **33**, 517–533 (1912); "High Temperature Gas Thermometry," *Carnegie Inst. Wash.*, *Pub.* **157**; *Jour. Physique*, [5] **2**, 727, 831, 899 (1912).

[5] See G. K. Burgess, *Report 8th Intern. Congr. Appl. Chem.*, **22**, 53–63; *J. chim. phys.*, **11**, 529 (1913).

[6] It should be remarked, however, that the official calibrations issued by the Reichsanstalt are, so far as we know, still based on their old temperature scale, which at 1000° leads to temperature values about 1.5° higher than those given here.

TABLE

| E. | 0. | 1000. | 2000. | 3000. | 4000. |
|---|---|---|---|---|---|
| 0 | 0 | 25.27 | 49.20 | 72.08 | 94.07 |
| | *2.60* | *2.45* | *2.33* | *2.23* | *2.16* |
| 100 | 2.60 | 27.72 | 51.53 | 74.31 | 96.23 |
| | *2.57* | *2.43* | *2.32* | *2.23* | *2.15* |
| 200 | 5.17 | 30.15 | 53.85 | 76.54 | 98.38 |
| | *2.56* | *2.42* | *2.31* | *2.22* | *2.14* |
| 300 | 7.73 | 32.57 | 56.16 | 78.76 | 100.52 |
| | *2.55* | *2.41* | *2.30* | *2.21* | *2.14* |
| 400 | 10.28 | 34.98 | 58.46 | 80.97 | 102.66 |
| | *2.53* | *2.40* | *2.30* | *2.20* | *2.13* |
| 500 | 12.81 | 37.38 | 60.76 | 83.17 | 104.79 |
| | *2.52* | *2.39* | *2.28* | *2.20* | *2.12* |
| 600 | 15.33 | 39.77 | 63.04 | 85.37 | 106.91 |
| | *2.50* | *2.38* | *2.27* | *2.19* | *2.11* |
| 700 | 17.83 | 42.15 | 65.31 | 87.56 | 109.02 |
| | *2.49* | *2.36* | *2.27* | *2.18* | *2.10* |
| 800 | 20.32 | 44.51 | 67.58 | 89.74 | 111.12 |
| | *2.48* | *2.35* | *2.25* | *2.17* | *2.10* |
| 900 | 22.80 | 46.86 | 69.83 | 91.91 | 113.22 |
| | *2.47* | *2.34* | *2.25* | *2.16* | *2.09* |
| 1000 | 25.27 | 49.20 | 72.08 | 94.07 | 115.31 |

| E. | 10000. | 11000. | 12000. | 13000. | 14000. |
|---|---|---|---|---|---|
| 0 | 213.36 | 231.74 | 249.82 | 267.60 | 285.13 |
| | *1.85* | *1.82* | *1.79* | *1.76* | *1.74* |
| 100 | 215.21 | 233.56 | 251.61 | 269.36 | 286.87 |
| | *1.85* | *1.82* | *1.79* | *1.76* | *1.74* |
| 200 | 217.06 | 235.38 | 253.40 | 271.12 | 288.61 |
| | *1.85* | *1.82* | *1.78* | *1.76* | *1.74* |
| 300 | 218.91 | 237.20 | 255.18 | 272.88 | 290.35 |
| | *1.84* | *1.81* | *1.78* | *1.76* | *1.73* |
| 400 | 220.75 | 239.01 | 256.96 | 274.64 | 292.08 |
| | *1.84* | *1.81* | *1.78* | *1.76* | *1.73* |
| 500 | 222.59 | 240.82 | 258.74 | 276.40 | 293.81 |
| | *1.84* | *1.81* | *1.78* | *1.75* | *1.73* |
| 600 | 224.43 | 242.63 | 260.52 | 278.15 | 295.54 |
| | *1.83* | *1.80* | *1.77* | *1.75* | *1.72* |
| 700 | 226.26 | 244.43 | 262.29 | 279.90 | 297.26 |
| | *1.83* | *1.80* | *1.77* | *1.75* | *1.72* |
| 800 | 228.09 | 246.23 | 264.06 | 281.65 | 298.98 |
| | *1.83* | *1.80* | *1.77* | *1.74* | *1.72* |
| 900 | 229.92 | 248.03 | 265.83 | 283.39 | 300.70 |
| | *1.82* | *1.79* | *1.77* | *1.74* | *1.72* |
| 1000 | 231.74 | 249.82 | 267.60 | 285.13 | 302.42 |

Standard calibration curve for copper-constantan thermo-element giving the tem-
For use in conjunction with a deviation curve determined by calibration of the

| | |
|---|---|
| Water.......... | b. p. |
| Naphthalene.... | b. p. |
| Sn............. | m. p. |
| Benzophenone... | b. p. |
| Cd............. | m. p. |

I.

| 5000. | | 6000. | | 7000. | | 8000. | | 9000. | | E. |
|---|---|---|---|---|---|---|---|---|---|---|
| 115.31 | | 135.91 | | 155.95 | | 175.50 | | 194.62 | | 0 |
| | *2.09* | | *2.03* | | *1.97* | | *1.93* | | *1.89* | |
| 117.40 | | 137.94 | | 157.92 | | 177.43 | | 196.51 | | 100 |
| | *2.08* | | *2.02* | | *1.97* | | *1.93* | | *1.89* | |
| 119.48 | | 139.96 | | 159.89 | | 179.36 | | 198.40 | | 200 |
| | *2.08* | | *1.92* | | *1.97* | | *1.92* | | *1.88* | |
| 121.56 | | 141.98 | | 161.86 | | 181.28 | | 200.28 | | 300 |
| | *2.07* | | *2.01* | | *1.96* | | *1.92* | | *1.88* | |
| 123.63 | | 143.99 | | 163.82 | | 183.20 | | 202.16 | | 400 |
| | *2.06* | | *2.01* | | *1.96* | | *1.91* | | *1.88* | |
| 125.69 | | 146.00 | | 165.78 | | 185.11 | | 204.04 | | 500 |
| | *2.06* | | *2.00* | | *1.95* | | *1.91* | | *1.87* | |
| 127.75 | | 148.00 | | 167.73 | | 187.02 | | 205.91 | | 600 |
| | *2.05* | | *2.00* | | *1.95* | | *1.91* | | *1.87* | |
| 129.80 | | 150.00 | | 169.68 | | 188.93 | | 207.78 | | 700 |
| | *2.04* | | *1.99* | | *1.94* | | *1.90* | | *1.86* | |
| 131.84 | | 151.99 | | 171.62 | | 190.83 | | 209.64 | | 800 |
| | *2.04* | | *1.99* | | *1.94* | | *1.90* | | *1.86* | |
| 133.88 | | 153.97 | | 173.56 | | 192.73 | | 211.50 | | 900 |
| | *2.03* | | *1.98* | | *1.94* | | *1.89* | | *1.86* | |
| 135.91 | | 155.95 | | 175.50 | | 194.62 | | 213.36 | | 1000 |

| 15000. | | 16000. | | 17000. | | 18000. | | | | E. |
|---|---|---|---|---|---|---|---|---|---|---|
| 302.42 | | 319.49 | | 336.36 | | 353.09 | | .... | | 0 |
| | *1.72* | | *1.70* | | *1.68* | | .. | | .. | |
| 304.14 | | 321.19 | | 338.04 | | .... | | .... | | 100 |
| | *1.71* | | *1.69* | | *1.68* | | .. | | .. | |
| 305.85 | | 322.88 | | 339.72 | | .... | | .... | | 200 |
| | *1.71* | | *1.69* | | *1.68* | | .. | | .. | |
| 307.56 | | 324.57 | | 341.40 | | .... | | .... | | 300 |
| | *1.71* | | *1.69* | | *1.67* | | .. | | .. | |
| 309.27 | | 326.26 | | 343.07 | | .... | | .... | | 400 |
| | *1.71* | | *1.69* | | *1.67* | | .. | | .. | |
| 310.98 | | 327.95 | | 344.74 | | .... | | .... | | 500 |
| | *1.71* | | *1.69* | | *1.67* | | .. | | .. | |
| 312.69 | | 329.64 | | 346.41 | | .... | | .... | | 600 |
| | *1.70* | | *1.68* | | *1.67* | | .. | | .. | |
| 314.39 | | 331.32 | | 348.08 | | .... | | .... | | 700 |
| | *1.70* | | *1.68* | | *1.67* | | .. | | .. | |
| 316.09 | | 333.00 | | 349.75 | | .... | | .... | | 800 |
| | *1.70* | | *1.68* | | *1.67* | | .. | | .. | |
| 317.79 | | 334.68 | | 351.42 | | .... | | .... | | 900 |
| | *1.70* | | *1.68* | | *1.67* | | .. | | .. | |
| 319.49 | | 336.36 | | 353.09 | | .... | | .... | | 1000 |

perature and temperature differences for every 100 microvolts. Cold junction at 0°.
particular element at some of the follo ing fixed points:

| | |
|---|---|
| 100° | 4276 $\mu v$ |
| 217.95° | 10248 $\mu v$ |
| 231.9° | 11009 $\mu v$ |
| 305.9° | 15203 $\mu v$ |
| 320.9° | 16083 $\mu v$ |

TABLE

| E. | 0. | | 1000. | | 2000. | | 3000. | | 4000. | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | | 147.1 | | 265.4 | | 374.3 | | 478.1 | |
| | | *17.8* | | *12.6* | | *11.2* | | *10.6* | | *10.2* |
| 100 | 17.8 | | 159.7 | | 276.6 | | 384.9 | | 488.3 | |
| | | *16.7* | | *12.4* | | *11.1* | | *10.5* | | *10.1* |
| 200 | 34.5 | | 172.1 | | 287.7 | | 395.4 | | 498.4 | |
| | | *15.8* | | *12.3* | | *11.0* | | *10.5* | | *10.1* |
| 300 | 50.3 | | 184.3 | | 298.7 | | 405.9 | | 508.5 | |
| | | *15.1* | | *12.0* | | *11.0* | | *10.4* | | *10.1* |
| 400 | 65.4 | | 196.3 | | 309.7 | | 416.3 | | 518.6 | |
| | | *14.6* | | *11.8* | | *10.9* | | *10.4* | | *10.0* |
| 500 | 80.0 | | 208.1 | | 320.6 | | 426.7 | | 528.6 | |
| | | *14.1* | | *11.6* | | *10.9* | | *10.4* | | *10.0* |
| 600 | 94.1 | | 219.7 | | 331.5 | | 437.1 | | 538.6 | |
| | | *13.7* | | *11.5* | | *10.8* | | *10.3* | | *10.0* |
| 700 | 107.8 | | 231.2 | | 342.3 | | 447.4 | | 548.6 | |
| | | *13.4* | | *11.5* | | *10.7* | | *10.3* | | *9.9* |
| 800 | 121.2 | | 242.7 | | 353.0 | | 457.7 | | 558.5 | |
| | | *13.1* | | *11.4* | | *10.7* | | *10.2* | | *9.9* |
| 900 | 134.3 | | 254.1 | | 363.7 | | 467.9 | | 568.4 | |
| | | *12.8* | | *11.3* | | *10.6* | | *10.2* | | *9.9* |
| 1000 | 147.1 | | 265.4 | | 374.3 | | 478.1 | | 578.3 | |

| E. | 10000. | | 11000. | | 12000. | | 13000. | | 14000. | |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1037.3 | | 1122.2 | | 1205.9 | | 1289.3 | | 1372.4 | |
| | | *8.6* | | *8.4* | | *8.3* | | *8.4* | | *8.3* |
| 100 | 1045.9 | | 1130.6 | | 1214.2 | | 1297.7 | | 1380.7 | |
| | | *8.5* | | *8.4* | | *8.4* | | *8.3* | | *8.3* |
| 200 | 1054.4 | | 1139.0 | | 1222.6 | | 1306.0 | | 1389.0 | |
| | | *8.5* | | *8.4* | | *8.3* | | *8.3* | | *8.3* |
| 300 | 1062.9 | | 1147.4 | | 1230.9 | | 1314.3 | | 1397.3 | |
| | | *8.5* | | *8.4* | | *8.4* | | *8.3* | | *8.3* |
| 400 | 1071.4 | | 1155.8 | | 1239.3 | | 1322.6 | | 1405.6 | |
| | | *8.5* | | *8.4* | | *8.3* | | *8.3* | | *8.2* |
| 500 | 1079.9 | | 1164.2 | | 1247.6 | | 1330.9 | | 1413.8 | |
| | | *8.5* | | *8.3* | | *8.3* | | *8.3* | | *8.2* |
| 600 | 1088.4 | | 1172.5 | | 1255.9 | | 1339.2 | | 1422.0 | |
| | | *8.5* | | *8.4* | | *8.4* | | *8.3* | | *8.2* |
| 700 | 1096.9 | | 1180.9 | | 1264.3 | | 1347.5 | | 1430.2 | |
| | | *8.5* | | *8.3* | | *8.3* | | *8.3* | | *8.2* |
| 800 | 1105.4 | | 1189.2 | | 1272.6 | | 1355.8 | | 1438.4 | |
| | | *8.4* | | *8.4* | | *8.4* | | *8.3* | | *8.2* |
| 900 | 1113.8 | | 1197.6 | | 1281.0 | | 1364.1 | | 1446.6 | |
| | | *8.4* | | *8.3* | | *8.3* | | *8.3* | | *8.2* |
| 1000 | 1122.2 | | 1205.9 | | 1289.3 | | 1372.4 | | 1454.8 | |

Standard calibration curve for Pt-Pt.Rh (10% Rh) thermoelement, giving the tem-
For use in conjunction with a deviation curve determined by calibration of the

| | | | |
|---|---|---|---|
| Water........ | b. p. | 100° | 643 μv |
| Naphthalene.. | b. p. | 217.95° | 1585 μv |
| Sn........... | m. p. | 231.9° | 1706 μv |
| Benzophenone. | b. p. | 305.9° | 2365 μv |
| Cd........... | m. p. | 320.9° | 2503 μv |
| Zn........... | m. p. | 419.4° | 3430 μv |
| Sulfur........ | b. p. | 444.55° | 3672 μv |
| Sb........... | m. p. | 630.0° | 5530 μv |
| Al........... | m. p. | 658.7° | 5827 μv |

II.

| 5000. | 6000. | 7000. | 8000. | 9000. | E. |
|---|---|---|---|---|---|
| 578.3 | 675.3 | 769.5 | 861.1 | 950.4 | 0 |
| *9.8* | *9.5* | *9.3* | *9.0* | *8.8* | |
| 588.1 | 684.8 | 778.8 | 870.1 | 959.2 | 100 |
| *9.8* | *9.5* | *9.2* | *9.0* | *8.8* | |
| 597.9 | 694.3 | 788.0 | 879.1 | 968.0 | 200 |
| *9.8* | *9.5* | *9.2* | *9.0* | *8.7* | |
| 607.7 | 703.8 | 797.2 | 888.1 | 976.7 | 300 |
| *9.7* | *9.5* | *9.2* | *9.0* | *8.7* | |
| 617.4 | 713.3 | 806.4 | 897.1 | 985.4 | 400 |
| *9.7* | *9.4* | *9.2* | *9.0* | *8.7* | |
| 627.1 | 722.7 | 815.6 | 906.1 | 994.1 | 500 |
| *9.7* | *9.4* | *9.1* | *8.9* | *8.7* | |
| 636.8 | 732.1 | 824.7 | 915.0 | 1002.8 | 600 |
| *9.7* | *9.4* | *9.1* | *8.9* | *8.7* | |
| 646.5 | 741.5 | 833.8 | 923.9 | 1011.5 | 700 |
| *9.6* | *9.4* | *9.1* | *8.9* | *8.6* | |
| 656.1 | 750.9 | 842.9 | 932.8 | 1020.1 | 800 |
| *9.6* | *9.3* | *9.1* | *8.8* | *8.6* | |
| 665.7 | 760.2 | 852.0 | 941.6 | 1028.7 | 900 |
| *9.6* | *9.3* | *9.1* | *8.8* | *8.6* | |
| 675.3 | 769.5 | 861.1 | 950.4 | 1037.3 | 1000 |

| 15000. | 16000. | 17000. | 18000. | | E. |
|---|---|---|---|---|---|
| 1454.8 | 1537.5 | 1620.9 | 1704.3 | .... | 0 |
| *8.2* | *8.3* | *8.3* | *8.3* | ... | |
| 1463.0 | 1545.8 | 1629.2 | 1712.6 | .... | 100 |
| *8.2* | *8.3* | *8.4* | *8.4* | ... | |
| 1471.2 | 1554.1 | 1637.6 | 1721.0 | .... | 200 |
| *8.2* | *8.3* | *8.3* | *8.3* | ... | |
| 1479.4 | 1562.4 | 1645.9 | 1729.3 | .... | 300 |
| *8.3* | *8.4* | *8.4* | *8.4* | ... | |
| 1487.7 | 1570.8 | 1654.3 | 1737.7 | .... | 400 |
| *8.3* | *8.3* | *8.3* | *8.3* | ... | |
| 1496.0 | 1579.1 | 1662.6 | 1746.0 | .... | 500 |
| *8.3* | *8.4* | *8.3* | *8.3* | ... | |
| 1504.3 | 1587.5 | 1670.9 | 1754.3 | .... | 600 |
| *8.3* | *8.3* | *8.4* | ... | ... | |
| 1512.6 | 1595.8 | 1679.3 | .... | .... | 700 |
| *8.3* | *8.4* | *8.3* | ... | ... | |
| 1520.9 | 1604.2 | 1687.6 | .... | .... | 800 |
| *8.3* | *8.3* | *8.4* | ... | ... | |
| 1529.2 | 1612.5 | 1696.0 | .... | .... | 900 |
| *8.3* | *8.4* | *8.3* | ... | ... | |
| 1537.5 | 1620.9 | 1704.3 | .... | .... | 1000 |

perature and temperature differences for every 100 microvolts. Cold junction at 0°.
particular element at some of the following fixed points:

| | | | |
|---|---|---|---|
| Ag........... | m. p. | 960.2° | 9111 μv |
| Au........... | m. p. | 1062.6° | 10296 μv |
| Cu........... | m. p. | 1082.8° | 10534 μv |
| $Li_2SiO_3$........ | m. p. | 1201° | 11941 μv |
| Diopside...... | m. p. | 1391.5° | 14230 μv |
| Ni............ | m. p. | 1452.6° | 14973 μv |
| Pd........... | m. p. | 1549.5° | 16144 μv |
| Pt............ | m. p. | 1755° | 18608 μv |

less except at the lower end of the scale. Similarly, in the list of fixed points given at the foot of Table II, the magnitude of the uncertainty in the temperature scale is such that the temperatures above 1000° may be rounded off to the nearest degree.

The reference curves given in Tables I and II are intended for use in conjunction with the appropriate deviation curve. This correction curve is determined for each element by calibration at several of the fixed points —preferably three or more—given at the foot of each table; whence it is simply constructed by plotting[1] $\Delta\mathbf{E}$ as ordinate ($\Delta\mathbf{E} = \mathbf{E}$ observed — $\mathbf{E}$ standard) against $\mathbf{E}_{obs.}$ as abscissa, and joining up the various points. Then in order to obtain the temperatures corresponding to the electromotive force reading indicated by the element, the appropriate value of $\Delta\mathbf{E}$ (as obtained from its deviation curve by inspection) is subtracted algebraically from the observed value of $\mathbf{E}$ before the latter is converted into degrees by means of the table. There need be no apprehension of error in the use of this method even with deviations of as much as 100 microvolts; especially if sufficient calibration points be taken within the specific temperature range, and if the deviation curve so obtained does not depart too far from a straight line.

It should be borne in mind that neither of these tables has an *absolute* significance; it represents merely an arbitrary reference curve which is substantially the mean of the three elements (E, F, G) used by Day and Sosman as standards; for the curve does not differ from the average reading of these elements by more than 1 microvolt, except at the somewhat less certain nickel point, where the divergence amounts to 5 microvolts.

GEOPHYSICAL LABORATORY,
CARNEGIE INSTITUTION OF WASHINGTON,
WASHINGTON, D. C.

## NOTE.

*An Electrical Contact Vapor-Pressure Thermoregulator.*—The change in the pressure of a saturated vapor with change in temperature has been made use of by various investigators as a means of automatic temperature control. Andreae[2] devised a thermoregulator in which a small quantity of some volatile liquid, such as ether, alcohol, or water, was utilized to increase the change of pressure per degree of a suitably enclosed volume of air or other gas. Lothar Meyer[3] made use of the same principle. Benoit[4] described a thermoregulator similar to the foregoing, with certain mechanical improvements. Kahlbaum[5]

[1] It is obvious that the required accuracy is secured by plotting on a small scale; a sheet of coördinate paper 20 × 20 cm. is ample.

[2] *Wied. Annalen*, **4**, 614.

[3] *Ber.*, **16**, 1088 (1883).

[4] *Wied. Beibl.*, **4**, 296.

[5] *Ber.*, **19**, 2860 (1886).