National Institute of Standards & Technology

# Certificate

## Standard Reference Material® 1749

### Gold versus Platinum Thermocouple
### Certified Thermometer for the Range 0 °C to 1000 °C
### on the International Temperature Scale of 1990

Serial No.

This Standard Reference Material (SRM) is intended for use as a highly accurate secondary reference thermometer in the range from 0 °C to 1000 °C [1]. SRM 1749 consists of a specially constructed gold versus platinum (Au/Pt) thermocouple, individually calibrated on the International Temperature Scale of 1990 (ITS-90) [2]. This SRM has an overall length of 1.9 m, as measured from the tip of the silica-glass sheath (7.0 mm outer diameter, 71 cm long) to the tip of the stainless steel sheath of the reference-junction probe (6.3 mm outer diameter, 28 cm long). The copper leads from the reference-junction probe of the SRM are 2.1 m long. In use, the reference-junction probe of the SRM is inserted into a properly prepared ice point bath and the copper leads are connected to a high-accuracy voltmeter. The relation of voltage readings of the SRM to the temperature of the measuring junction is provided in this certificate in tabular and mathematical forms.

**Certified Values and Confidence Limits:** The electromotive force (emf) of the SRM was measured in fixed-point cells at 961.78 °C (silver point), 660.323 °C (aluminum point), 419.527 °C (zinc point), 231.928 °C (tin point), and 156.5985 °C (indium point), and in an ice bath at 0.000 °C, with the reference junctions at the ice point. The measured values of emf are given in Table 1. The emf values computed from the reference function [3] were subtracted from the measured values, and the resulting emf deviations were modeled by a quadratic function of temperature up to 1000 °C. Coefficients of the quadratic function were determined by the method of least squares, and addition of these coefficients to those of the reference function gave the coefficients of the calibration function for this SRM. Table 2 gives corresponding values of the emf of the SRM in millivolts and the temperature of its measuring junction in degrees Celsius when the reference junctions are at 0 °C. Table 3 gives the coefficients of the equation that was used to compute the emf values given in Table 2. Figure 1 shows the deviations of the measured values of emf from values obtained from the Au/Pt reference function. The thermoelectric inhomogeneity of the thermocouple was assessed by measuring its immersion characteristics in the silver and aluminum fixed-point cells [1].

The uncertainty of an emf value can be expressed as an expanded uncertainty, $U = ku_c$, with $U$ determined from a combined standard uncertainty, $u_c$ and a coverage factor, $k = 2$. The expanded uncertainties of the emf values given in Tables 1 and 2 are estimated not to exceed the equivalent of 7 m°C in the range 0 °C to 660 °C, the equivalent of 8 m°C in the range 660 °C to 962 °C, and the equivalent of 14 m°C in the range 962 °C to 1000 °C. These uncertainties include a contribution for the inhomogeneity of the thermocouple.

Construction and calibration of the Au/Pt thermocouple were performed by G.W. Burns and D.C. Ripple of the NIST Process Measurements Division.

The support aspects involved in the preparation, certification, and issuance of this SRM were coordinated through the NIST Standard Reference Materials Program by J.W.L. Thomas and J.C. Colbert.

Gaithersburg, MD 20899
Certificate Issue Date: 18 March 1998

Thomas E. Gills, Chief
Standard Reference Materials Program

**Expiration of Certification:** The certification of this SRM is valid within the measurement uncertainties specified, for at least 1000 h of use at temperatures up to 963 °C, provided the SRM is used in accordance with the Notice and Warning to Users section of this certificate. No long term drift has been observed with several Au/Pt thermocouples that have been studied for periods of time exceeding 1000 h and that have been maintained in accordance with the procedures described in the Instructions for Use. Recertification may be arranged by contacting D.C. Ripple of the NIST Process Measurements Division by phone (301) 975-4801, fax (301) 548-0206, or e-mail dean.ripple@nist.gov. Certification is invalid if the SRM is damaged, contaminated, or modified.

**Maintenance of SRM Certification:** NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification, NIST will notify the purchaser. Return of the attached registration card will facilitate notification.

**Source of Material:** The gold wire (Bar 100-431) and the platinum wire (Bar 240-183) for the SRM have a reported purity as a mass fraction of 99.999+ % and were obtained from the Sigmund Cohn Corporation, Mount Vernon, NY. The alumina insulator tubes have a reported purity of 99.8+ % and were obtained from Vesuvius McDanel, Beaver Falls, PA.

## NOTICE AND WARNING TO USERS

**Storage:** SRM 1749 is a thermocouple thermometer, packaged in foam in a wooden case. When not in use, the thermocouple should be stored in its original case to avoid damage.

**Handling:** This SRM is supplied with a protective silica-glass sheath. If this sheath is damaged, the thermocouple may be subject to contamination with resulting degradations in performance. The thermocouple may be used with or without the protective sheath. However, use of the thermocouple without the protective sheath should be attempted only by trained personnel. Extreme care must be taken to ensure that the expansion coil is not damaged and that the thermocouple is used only in oxidizing environments free of vapors from metals or metal oxides.

**Instructions for Use:** To use, the copper leads of the SRM should be connected to a high-accuracy voltmeter. To achieve the highest level of accuracy with this SRM, the user should use a calibrated voltmeter with a resolution of 0.01 μV or better, and care must be taken to measure and correct for stray thermal emfs in the measurement circuit.

The reference-junction probe is designed to be inserted through the lid of a standard Dewar flask filled with crushed ice, with distilled water filling the voids between the ice particles. The tip of the reference-junction probe should be immersed 20 cm into the ice-water mixture. The ice should be made from distilled water, the flask should be at least 28 cm deep, and the ice should be lightly packed to the full depth of the flask. After inserting the probe into the ice bath, allow 10 min to 15 min for the probe to attain thermal equilibrium. The reference-junction probe should be kept clean of contaminants that could cause a depression of the melting point of the ice. Washing the probe in distilled water or wiping the probe with a tissue saturated in distilled water will aid in the removal of salts and other impurities.

The silica-glass sheath will devitrify and eventually crack if it is used at temperatures above 500 °C after being contaminated with oils or salts from handling of the sheath with bare hands or other sources. This problem may be avoided by wiping the sheath with a tissue saturated in ethanol or methanol prior to use at elevated temperatures.

The thermocouple should not be used at temperatures exceeding 1000 °C. Higher temperatures may cause slippage of grain boundaries in the gold wire. During use or annealing, not more than 65 cm of the portion of the SRM sheathed in silica glass, as measured from the tip of the sheath, should be heated.

Au/Pt thermocouples are fairly rugged devices, capable of withstanding repeated thermal cycling and small mechanical shocks. However, two maintenance procedures are necessary to ensure that there is no degradation in accuracy.

First, the platinum expansion coil at the measuring junction should be inspected periodically. The silica-glass sheath does not have a matte finish in the vicinity of the measuring junction. This allows the user to inspect the coil without removal of the protective sheath. At room temperature, both thermoelements should extend from the alumina tube by the same amount as when the SRM was first received from NIST. If the protrusion of one of the thermoelements increases by more than about 1 mm after a single period of heating to elevated temperatures and then cooling to room temperature, the thermoelement may have become slightly lodged in the bore of the alumina tube and may have been mechanically strained.

Second, Au/Pt thermocouples should be given a periodic maintenance anneal if they are removed quickly from high temperature environments or if they are used in different thermal environments. The procedure is to anneal the portion of the SRM sheathed in silica glass in a tube furnace at the fullest possible immersion (not more than 65 cm) into the furnace at 1000 °C for 30 min, cool slowly in the furnace to 450 °C, and maintain at 450 °C overnight. The anneal at 1000 °C is optional and only necessary to alleviate strains introduced if the thermocouple has been rapidly cooled.

## PREPARATION AND CERTIFICATION MEASUREMENTS

**Method of Preparation:** After being annealed in air, the Au and Pt thermoelements were inserted into a high purity alumina tube. The measuring junction of the Au/Pt thermocouple was formed by joining the thermoelements at one end with a small coil formed from Pt wire 0.12 mm in diameter. The thermocouple and alumina insulator were mounted inside a protective silica-glass sheath, with the alumina insulator secured in the sheath with a compression fitting. To minimize heat loss by piping of thermal radiation, the silica-glass sheath was given a matte finish. The thermoelements extending from the insulator were covered with coated fiberglass sleeving, and a crimp-type clamp was installed that compresses the sleeving against the thermoelements to anchor them near the end of the alumina insulator. At the end of the thermoelements opposite from the measuring junction, matched copper leads were attached to form the reference junctions. The reference junctions are contained within a stainless steel sheath. To remove residual stresses introduced in the assembly process, the portion of the SRM sheathed in silica glass was given a final furnace anneal.

**Measurement Techniques:** The emf measurements were made using a calibrated digital multimeter connected to a scanner. Stray thermal emfs from the scanner and voltmeter were carefully measured, and the data were appropriately corrected. Data acquisition was computer controlled. The freezing-point cells used for the calibration of this SRM were all constructed at NIST and intercompared with the reference cells maintained in the NIST Platinum Resistance Thermometer Calibration Laboratory.

## COMPATABILITY WITH NIST STANDARD REFERENCE DATABASE 60

The equation in Table 3 is compatible with NIST Standard Reference Database 60, NIST ITS-90 Thermocouple Database. For further information, contact D.C. Ripple of the NIST Process Measurements Division by phone (301) 975-4801, fax (301) 548-0206, or e-mail dean.ripple@nist.gov.

## REFERENCES


[1] Burns, G.W. and Ripple, D., "Standard Reference Material 1749: Gold vs. Platinum Thermocouple," NIST Special Publication 260-134, U.S. Government Printing Office, Washington, DC, (1998).

[2] Preston-Thomas, H., "The International Temperature Scale of 1990," Metrologia, **27**, pp. 3-10, (1990) and Metrologia, **27**, p. 107, (1990).

[3] Burns, G.W., Strouse, G.F., Liu, B.M., and Mangum, B.W., "Gold versus Platinum Thermocouples: Performance Data and an ITS-90 Based Reference Function," in *Temperature: Its Measurement and Control in Science and Industry,* American Institute of Physics, New York, NY, p. 531, (1992).


*It is the responsibility of users of this SRM to assure that the certificate in their possession is current. This can be accomplished by contacting the SRM Program at: Phone (301) 975-6776 (select "Certificates"), Fax (301) 926-4751, e-mail srminfo@nist.gov, or via the Internet http://ts.nist.gov/srm.*

TABLE 1. Values of EMF Determined at Fixed Points for the Au/Pt Thermocouple with the Reference Junctions at 0 °C

| Temperature (°C, ITS-90) | | EMF (mV) |
|---|---|---|
| 961.78 | (silver point) | 16.12055 |
| 660.323 | (aluminum point) | 9.32034 |
| 419.527 | (zinc point) | 4.94553 |
| 231.928 | (tin point) | 2.23607 |
| 156.5985 | (indium point) | 1.35081 |
| 0.000 | (ice point) | -0.00005 |

TABLE 2. Values of EMF in Millivolts versus Temperature in Degrees Celsius (ITS-90) for the Au/Pt Thermocouple with Reference Junctions at 0 °C

| °C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| | EMF (mV) | | | | | | | | | |
| 0 | -0.0001 | 0.0060 | 0.0121 | 0.0182 | 0.0244 | 0.0306 | 0.0369 | 0.0431 | 0.0495 | 0.0558 |
| 10 | 0.0622 | 0.0687 | 0.0751 | 0.0816 | 0.0882 | 0.0948 | 0.1014 | 0.1080 | 0.1147 | 0.1215 |
| 20 | 0.1282 | 0.1350 | 0.1419 | 0.1488 | 0.1557 | 0.1626 | 0.1696 | 0.1766 | 0.1837 | 0.1908 |
| 30 | 0.1979 | 0.2050 | 0.2122 | 0.2195 | 0.2267 | 0.2340 | 0.2413 | 0.2487 | 0.2561 | 0.2635 |
| 40 | 0.2710 | 0.2785 | 0.2861 | 0.2936 | 0.3012 | 0.3089 | 0.3165 | 0.3242 | 0.3320 | 0.3398 |
| 50 | 0.3476 | 0.3554 | 0.3633 | 0.3712 | 0.3791 | 0.3871 | 0.3951 | 0.4031 | 0.4112 | 0.4193 |
| 60 | 0.4274 | 0.4356 | 0.4437 | 0.4520 | 0.4602 | 0.4685 | 0.4768 | 0.4852 | 0.4936 | 0.5020 |
| 70 | 0.5104 | 0.5189 | 0.5274 | 0.5359 | 0.5445 | 0.5531 | 0.5617 | 0.5704 | 0.5791 | 0.5878 |
| 80 | 0.5966 | 0.6053 | 0.6142 | 0.6230 | 0.6319 | 0.6408 | 0.6497 | 0.6587 | 0.6676 | 0.6767 |
| 90 | 0.6857 | 0.6948 | 0.7039 | 0.7130 | 0.7222 | 0.7314 | 0.7406 | 0.7499 | 0.7592 | 0.7685 |
| 100 | 0.7778 | 0.7872 | 0.7966 | 0.8060 | 0.8154 | 0.8249 | 0.8344 | 0.8440 | 0.8535 | 0.8631 |
| 110 | 0.8728 | 0.8824 | 0.8921 | 0.9018 | 0.9115 | 0.9213 | 0.9311 | 0.9409 | 0.9507 | 0.9606 |
| 120 | 0.9705 | 0.9804 | 0.9904 | 1.0003 | 1.0103 | 1.0204 | 1.0304 | 1.0405 | 1.0506 | 1.0608 |
| 130 | 1.0709 | 1.0811 | 1.0913 | 1.1016 | 1.1119 | 1.1222 | 1.1325 | 1.1428 | 1.1532 | 1.1636 |
| 140 | 1.1740 | 1.1845 | 1.1950 | 1.2055 | 1.2160 | 1.2266 | 1.2371 | 1.2477 | 1.2584 | 1.2690 |
| 150 | 1.2797 | 1.2904 | 1.3012 | 1.3119 | 1.3227 | 1.3335 | 1.3443 | 1.3552 | 1.3661 | 1.3770 |
| 160 | 1.3879 | 1.3989 | 1.4099 | 1.4209 | 1.4319 | 1.4430 | 1.4540 | 1.4651 | 1.4763 | 1.4874 |
| 170 | 1.4986 | 1.5098 | 1.5210 | 1.5323 | 1.5436 | 1.5549 | 1.5662 | 1.5775 | 1.5889 | 1.6003 |
| 180 | 1.6117 | 1.6231 | 1.6346 | 1.6461 | 1.6576 | 1.6691 | 1.6807 | 1.6923 | 1.7039 | 1.7155 |
| 190 | 1.7272 | 1.7388 | 1.7505 | 1.7623 | 1.7740 | 1.7858 | 1.7976 | 1.8094 | 1.8212 | 1.8331 |
| 200 | 1.8450 | 1.8569 | 1.8688 | 1.8807 | 1.8927 | 1.9047 | 1.9167 | 1.9288 | 1.9408 | 1.9529 |
| 210 | 1.9650 | 1.9772 | 1.9893 | 2.0015 | 2.0137 | 2.0259 | 2.0381 | 2.0504 | 2.0627 | 2.0750 |
| 220 | 2.0873 | 2.0997 | 2.1120 | 2.1244 | 2.1369 | 2.1493 | 2.1618 | 2.1742 | 2.1867 | 2.1993 |
| 230 | 2.2118 | 2.2244 | 2.2370 | 2.2496 | 2.2622 | 2.2749 | 2.2875 | 2.3002 | 2.3130 | 2.3257 |
| 240 | 2.3385 | 2.3512 | 2.3640 | 2.3769 | 2.3897 | 2.4026 | 2.4155 | 2.4284 | 2.4413 | 2.4542 |
| 250 | 2.4672 | 2.4802 | 2.4932 | 2.5063 | 2.5193 | 2.5324 | 2.5455 | 2.5586 | 2.5717 | 2.5849 |
| 260 | 2.5981 | 2.6113 | 2.6245 | 2.6377 | 2.6510 | 2.6643 | 2.6776 | 2.6909 | 2.7042 | 2.7176 |
| 270 | 2.7310 | 2.7444 | 2.7578 | 2.7712 | 2.7847 | 2.7982 | 2.8117 | 2.8252 | 2.8387 | 2.8523 |
| 280 | 2.8659 | 2.8795 | 2.8931 | 2.9067 | 2.9204 | 2.9341 | 2.9478 | 2.9615 | 2.9752 | 2.9890 |
| 290 | 3.0028 | 3.0166 | 3.0304 | 3.0442 | 3.0581 | 3.0720 | 3.0859 | 3.0998 | 3.1137 | 3.1277 |
| 300 | 3.1416 | 3.1556 | 3.1696 | 3.1837 | 3.1977 | 3.2118 | 3.2259 | 3.2400 | 3.2541 | 3.2683 |
| 310 | 3.2824 | 3.2966 | 3.3108 | 3.3251 | 3.3393 | 3.3536 | 3.3679 | 3.3822 | 3.3965 | 3.4108 |
| 320 | 3.4252 | 3.4395 | 3.4539 | 3.4684 | 3.4828 | 3.4972 | 3.5117 | 3.5262 | 3.5407 | 3.5552 |
| 330 | 3.5698 | 3.5843 | 3.5989 | 3.6135 | 3.6281 | 3.6428 | 3.6574 | 3.6721 | 3.6868 | 3.7015 |
| 340 | 3.7163 | 3.7310 | 3.7458 | 3.7606 | 3.7754 | 3.7902 | 3.8050 | 3.8199 | 3.8348 | 3.8497 |
| 350 | 3.8646 | 3.8795 | 3.8945 | 3.9094 | 3.9244 | 3.9394 | 3.9545 | 3.9695 | 3.9846 | 3.9996 |
| 360 | 4.0147 | 4.0298 | 4.0450 | 4.0601 | 4.0753 | 4.0905 | 4.1057 | 4.1209 | 4.1362 | 4.1514 |
| 370 | 4.1667 | 4.1820 | 4.1973 | 4.2126 | 4.2280 | 4.2434 | 4.2587 | 4.2741 | 4.2896 | 4.3050 |
| 380 | 4.3205 | 4.3359 | 4.3514 | 4.3669 | 4.3825 | 4.3980 | 4.4136 | 4.4291 | 4.4447 | 4.4604 |
| 390 | 4.4760 | 4.4916 | 4.5073 | 4.5230 | 4.5387 | 4.5544 | 4.5702 | 4.5859 | 4.6017 | 4.6175 |
| 400 | 4.6333 | 4.6491 | 4.6650 | 4.6808 | 4.6967 | 4.7126 | 4.7285 | 4.7445 | 4.7604 | 4.7764 |

TABLE 2 (Continued). Values of EMF in Millivolts versus Temperature in Degrees Celsius (ITS-90) for the Au/Pt Thermocouple with Reference Junctions at 0 °C

| °C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| | EMF (mV) | | | | | | | | | |
| 400 | 4.6333 | 4.6491 | 4.6650 | 4.6808 | 4.6967 | 4.7126 | 4.7285 | 4.7445 | 4.7604 | 4.7764 |
| 410 | 4.7924 | 4.8084 | 4.8244 | 4.8404 | 4.8565 | 4.8725 | 4.8886 | 4.9047 | 4.9208 | 4.9370 |
| 420 | 4.9531 | 4.9693 | 4.9855 | 5.0017 | 5.0179 | 5.0342 | 5.0504 | 5.0667 | 5.0830 | 5.0993 |
| 430 | 5.1157 | 5.1320 | 5.1484 | 5.1648 | 5.1811 | 5.1976 | 5.2140 | 5.2304 | 5.2469 | 5.2634 |
| 440 | 5.2799 | 5.2964 | 5.3129 | 5.3295 | 5.3461 | 5.3627 | 5.3793 | 5.3959 | 5.4125 | 5.4292 |
| 450 | 5.4458 | 5.4625 | 5.4792 | 5.4959 | 5.5127 | 5.5294 | 5.5462 | 5.5630 | 5.5798 | 5.5966 |
| 460 | 5.6135 | 5.6303 | 5.6472 | 5.6641 | 5.6810 | 5.6979 | 5.7149 | 5.7318 | 5.7488 | 5.7658 |
| 470 | 5.7828 | 5.7998 | 5.8169 | 5.8339 | 5.8510 | 5.8681 | 5.8852 | 5.9023 | 5.9195 | 5.9366 |
| 480 | 5.9538 | 5.9710 | 5.9882 | 6.0054 | 6.0227 | 6.0399 | 6.0572 | 6.0745 | 6.0918 | 6.1091 |
| 490 | 6.1265 | 6.1438 | 6.1612 | 6.1786 | 6.1960 | 6.2134 | 6.2309 | 6.2484 | 6.2658 | 6.2833 |
| 500 | 6.3008 | 6.3184 | 6.3359 | 6.3535 | 6.3710 | 6.3886 | 6.4062 | 6.4239 | 6.4415 | 6.4592 |
| 510 | 6.4768 | 6.4945 | 6.5122 | 6.5300 | 6.5477 | 6.5655 | 6.5832 | 6.6010 | 6.6188 | 6.6367 |
| 520 | 6.6545 | 6.6724 | 6.6902 | 6.7081 | 6.7260 | 6.7440 | 6.7619 | 6.7799 | 6.7978 | 6.8158 |
| 530 | 6.8338 | 6.8518 | 6.8699 | 6.8879 | 6.9060 | 6.9241 | 6.9422 | 6.9603 | 6.9785 | 6.9966 |
| 540 | 7.0148 | 7.0330 | 7.0512 | 7.0694 | 7.0876 | 7.1059 | 7.1242 | 7.1424 | 7.1607 | 7.1791 |
| 550 | 7.1974 | 7.2157 | 7.2341 | 7.2525 | 7.2709 | 7.2893 | 7.3078 | 7.3262 | 7.3447 | 7.3631 |
| 560 | 7.3816 | 7.4002 | 7.4187 | 7.4372 | 7.4558 | 7.4744 | 7.4930 | 7.5116 | 7.5302 | 7.5489 |
| 570 | 7.5675 | 7.5862 | 7.6049 | 7.6236 | 7.6423 | 7.6611 | 7.6799 | 7.6986 | 7.7174 | 7.7362 |
| 580 | 7.7551 | 7.7739 | 7.7928 | 7.8116 | 7.8305 | 7.8494 | 7.8684 | 7.8873 | 7.9063 | 7.9252 |
| 590 | 7.9442 | 7.9632 | 7.9822 | 8.0013 | 8.0203 | 8.0394 | 8.0585 | 8.0776 | 8.0967 | 8.1158 |
| 600 | 8.1350 | 8.1542 | 8.1733 | 8.1926 | 8.2118 | 8.2310 | 8.2502 | 8.2695 | 8.2888 | 8.3081 |
| 610 | 8.3274 | 8.3467 | 8.3661 | 8.3855 | 8.4048 | 8.4242 | 8.4436 | 8.4631 | 8.4825 | 8.5020 |
| 620 | 8.5215 | 8.5409 | 8.5605 | 8.5800 | 8.5995 | 8.6191 | 8.6387 | 8.6582 | 8.6779 | 8.6975 |
| 630 | 8.7171 | 8.7368 | 8.7564 | 8.7761 | 8.7958 | 8.8156 | 8.8353 | 8.8551 | 8.8748 | 8.8946 |
| 640 | 8.9144 | 8.9342 | 8.9541 | 8.9739 | 8.9938 | 9.0137 | 9.0336 | 9.0535 | 9.0734 | 9.0934 |
| 650 | 9.1133 | 9.1333 | 9.1533 | 9.1733 | 9.1933 | 9.2134 | 9.2334 | 9.2535 | 9.2736 | 9.2937 |
| 660 | 9.3139 | 9.3340 | 9.3542 | 9.3743 | 9.3945 | 9.4147 | 9.4350 | 9.4552 | 9.4754 | 9.4957 |
| 670 | 9.5160 | 9.5363 | 9.5566 | 9.5770 | 9.5973 | 9.6177 | 9.6381 | 9.6585 | 9.6789 | 9.6993 |
| 680 | 9.7198 | 9.7402 | 9.7607 | 9.7812 | 9.8017 | 9.8223 | 9.8428 | 9.8634 | 9.8840 | 9.9046 |
| 690 | 9.9252 | 9.9458 | 9.9664 | 9.9871 | 10.0078 | 10.0285 | 10.0492 | 10.0699 | 10.0906 | 10.1114 |
| 700 | 10.1322 | 10.1530 | 10.1738 | 10.1946 | 10.2154 | 10.2363 | 10.2572 | 10.2780 | 10.2989 | 10.3199 |
| 710 | 10.3408 | 10.3618 | 10.3827 | 10.4037 | 10.4247 | 10.4457 | 10.4668 | 10.4878 | 10.5089 | 10.5299 |
| 720 | 10.5510 | 10.5722 | 10.5933 | 10.6144 | 10.6356 | 10.6568 | 10.6780 | 10.6992 | 10.7204 | 10.7416 |
| 730 | 10.7629 | 10.7842 | 10.8055 | 10.8268 | 10.8481 | 10.8694 | 10.8908 | 10.9121 | 10.9335 | 10.9549 |
| 740 | 10.9764 | 10.9978 | 11.0192 | 11.0407 | 11.0622 | 11.0837 | 11.1052 | 11.1267 | 11.1483 | 11.1698 |
| 750 | 11.1914 | 11.2130 | 11.2346 | 11.2563 | 11.2779 | 11.2996 | 11.3212 | 11.3429 | 11.3646 | 11.3864 |
| 760 | 11.4081 | 11.4299 | 11.4516 | 11.4734 | 11.4952 | 11.5170 | 11.5389 | 11.5607 | 11.5826 | 11.6045 |
| 770 | 11.6264 | 11.6483 | 11.6702 | 11.6922 | 11.7142 | 11.7361 | 11.7581 | 11.7801 | 11.8022 | 11.8242 |
| 780 | 11.8463 | 11.8684 | 11.8904 | 11.9126 | 11.9347 | 11.9568 | 11.9790 | 12.0012 | 12.0233 | 12.0456 |
| 790 | 12.0678 | 12.0900 | 12.1123 | 12.1345 | 12.1568 | 12.1791 | 12.2014 | 12.2238 | 12.2461 | 12.2685 |
| 800 | 12.2909 | 12.3133 | 12.3357 | 12.3581 | 12.3806 | 12.4030 | 12.4255 | 12.4480 | 12.4705 | 12.4930 |

TABLE 2 (Continued). Values of EMF in Millivolts versus Temperature in Degrees Celsius (ITS-90) for the Au/Pt Thermocouple with Reference Junctions at 0 °C

| °C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| | EMF (mV) | | | | | | | | | |
| 800 | 12.2909 | 12.3133 | 12.3357 | 12.3581 | 12.3806 | 12.4030 | 12.4255 | 12.4480 | 12.4705 | 12.4930 |
| 810 | 12.5156 | 12.5381 | 12.5607 | 12.5833 | 12.6059 | 12.6285 | 12.6511 | 12.6738 | 12.6965 | 12.7191 |
| 820 | 12.7418 | 12.7646 | 12.7873 | 12.8100 | 12.8328 | 12.8556 | 12.8784 | 12.9012 | 12.9240 | 12.9469 |
| 830 | 12.9697 | 12.9926 | 13.0155 | 13.0384 | 13.0613 | 13.0843 | 13.1072 | 13.1302 | 13.1532 | 13.1762 |
| 840 | 13.1992 | 13.2222 | 13.2453 | 13.2684 | 13.2914 | 13.3145 | 13.3377 | 13.3608 | 13.3839 | 13.4071 |
| 850 | 13.4303 | 13.4535 | 13.4767 | 13.4999 | 13.5231 | 13.5464 | 13.5697 | 13.5930 | 13.6163 | 13.6396 |
| 860 | 13.6629 | 13.6863 | 13.7096 | 13.7330 | 13.7564 | 13.7798 | 13.8033 | 13.8267 | 13.8502 | 13.8737 |
| 870 | 13.8972 | 13.9207 | 13.9442 | 13.9677 | 13.9913 | 14.0149 | 14.0385 | 14.0621 | 14.0857 | 14.1093 |
| 880 | 14.1330 | 14.1566 | 14.1803 | 14.2040 | 14.2277 | 14.2515 | 14.2752 | 14.2990 | 14.3228 | 14.3466 |
| 890 | 14.3704 | 14.3942 | 14.4180 | 14.4419 | 14.4658 | 14.4897 | 14.5136 | 14.5375 | 14.5614 | 14.5854 |
| 900 | 14.6093 | 14.6333 | 14.6573 | 14.6813 | 14.7054 | 14.7294 | 14.7535 | 14.7776 | 14.8017 | 14.8258 |
| 910 | 14.8499 | 14.8740 | 14.8982 | 14.9224 | 14.9465 | 14.9708 | 14.9950 | 15.0192 | 15.0435 | 15.0677 |
| 920 | 15.0920 | 15.1163 | 15.1406 | 15.1650 | 15.1893 | 15.2137 | 15.2380 | 15.2624 | 15.2868 | 15.3113 |
| 930 | 15.3357 | 15.3602 | 15.3846 | 15.4091 | 15.4336 | 15.4581 | 15.4827 | 15.5072 | 15.5318 | 15.5564 |
| 940 | 15.5810 | 15.6056 | 15.6302 | 15.6548 | 15.6795 | 15.7042 | 15.7289 | 15.7536 | 15.7783 | 15.8030 |
| 950 | 15.8278 | 15.8526 | 15.8773 | 15.9021 | 15.9270 | 15.9518 | 15.9766 | 16.0015 | 16.0264 | 16.0513 |
| 960 | 16.0762 | 16.1011 | 16.1260 | 16.1510 | 16.1760 | 16.2010 | 16.2260 | 16.2510 | 16.2760 | 16.3011 |
| 970 | 16.3261 | 16.3512 | 16.3763 | 16.4014 | 16.4266 | 16.4517 | 16.4769 | 16.5020 | 16.5272 | 16.5524 |
| 980 | 16.5777 | 16.6029 | 16.6282 | 16.6534 | 16.6787 | 16.7040 | 16.7293 | 16.7547 | 16.7800 | 16.8054 |
| 990 | 16.8308 | 16.8561 | 16.8816 | 16.9070 | 16.9324 | 16.9579 | 16.9834 | 17.0088 | 17.0343 | 17.0599 |
| 1000 | 17.0854 | | | | | | | | | |

TABLE 3. Coefficients of the Equation Used to Compute the EMF Values Given in Table 2

The equation for computing values of emf as a function of temperature is of the form:

$$E = a_0 + a_1(t_{90}) + a_2(t_{90})^2 + a_3(t_{90})^3 + a_4(t_{90})^4 + a_5(t_{90})^5 + a_6(t_{90})^6 + a_7(t_{90})^7 + a_8(t_{90})^8 + a_9(t_{90})^9,$$

where $E$ is the emf in millivolts and $t_{90}$ is the temperature in degrees Celsius (ITS-90). The coefficients for the indicated temperature range are:

0 °C to 1000 °C

| | | |
|---|---|---|
| $a_0$ | = | -0.547124675E-04 |
| $a_1$ | = | 0.603578828E-02 |
| $a_2$ | = | 0.193678547E-04 |
| $a_3$ | = | -0.222998614E-07 |
| $a_4$ | = | 0.328711859E-10 |
| $a_5$ | = | -0.424206193E-13 |
| $a_6$ | = | 0.456927038E-16 |
| $a_7$ | = | -0.339430259E-19 |
| $a_8$ | = | 0.142981590E-22 |
| $a_9$ | = | -0.251672787E-26 |

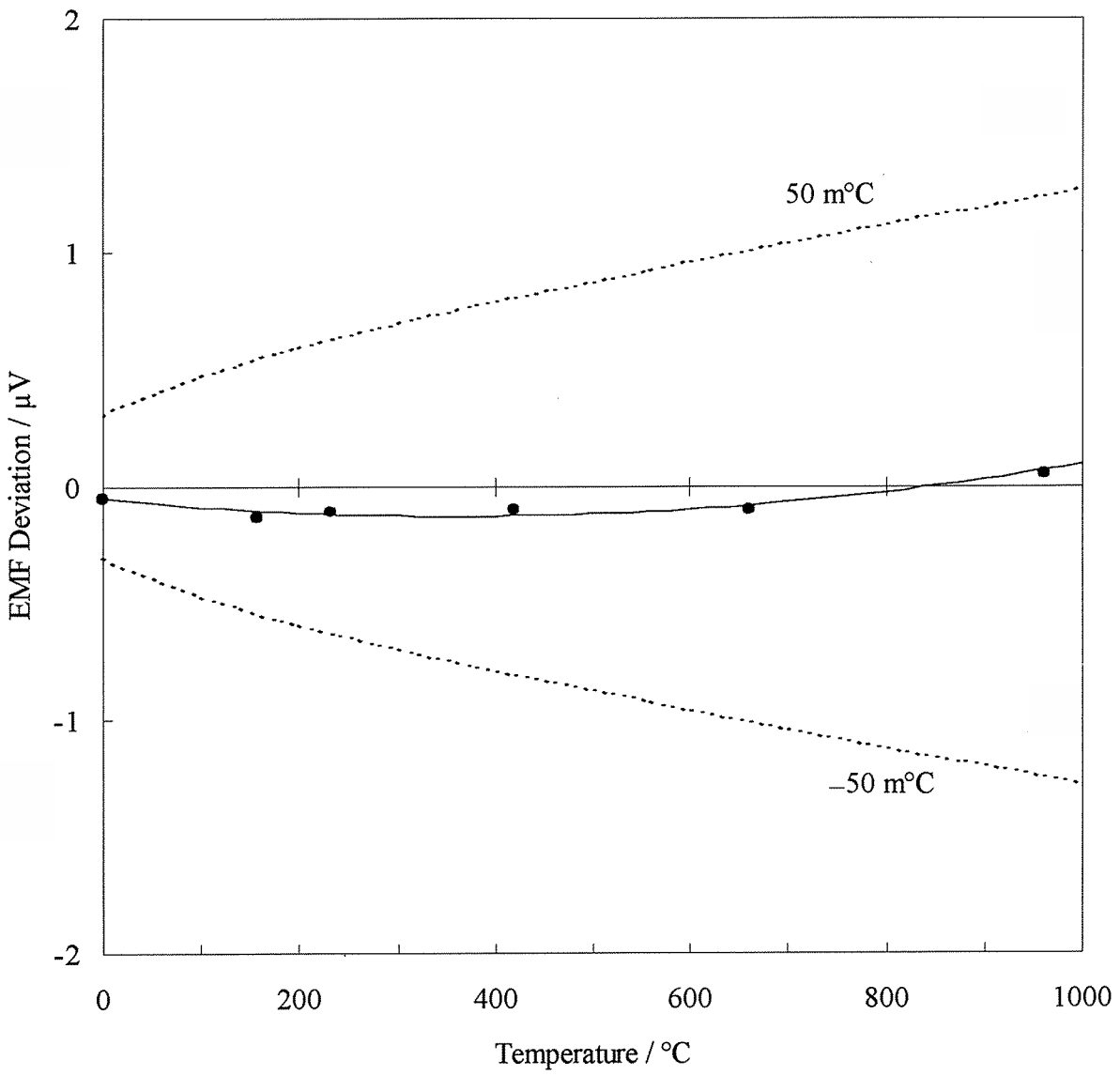


Figure 1: This figure shows the deviation of the emf of the Au/Pt thermocouple from an emf/temperature reference function for Au/Pt thermocouples given in Reference [3]. The deviation equals the thermocouple emf minus the reference function emf. The dots denote measured values and the solid curve is calculated from a polynomial fitted to the data by the method of least squares. The dashed lines indicate an emf deviation equivalent to 0.05 °C