The Platinum Metals in Temperature Measurement

A REVIEW OF THE FOURTH SYMPOSIUM

At the fourth symposium on "Temperature, its Measurement and Control in Science and Industry", held in Columbus, Ohio, from March 27th to 31st, 1961, some 250 papers were presented dealing with most aspects of temperature measurement and covering the range from the very lowest, below 1°K, to the very highest as encountered in plasma phenomena. The importance of the platinum metals in temperature measuring instruments was clearly seen by the number of papers devoted to the properties of platinum and its alloys in resistance and thermocouple thermometry at both high and low temperatures.

Purity and Resistance – Temperature Relationship

Great interest, of course, centres around very high purity platinum, for, both in resistance thermometers and thermocouples, the temperature sensitive properties are extremely dependent on the crystal lattice defects, whether due to impurity centres or to strain. The difficulties arising from such defects are particularly apparent in low-temperature platinum resistance thermometry where the variations in the resistance-temperature characteristics with purity present a serious problem of purity control in order to achieve a reasonable degree of reproducibility. Several papers (1 to 5) were devoted to the use of platinum thermometers over the temperature range from 10 to 90°K, where an attempt is being made to extend the International Practical Scale of Temperature below its present lower limit, the boiling point of oxygen (−182.97°C, 90.18°K). Although platinum thermometers have enough sensitivity down to 10°K to make possible measurements to a few thousandths of a degree, the general concensus of opinion was that for the definition of a temperature scale the lower limit should be 20°K. Many proposals were made for suitable interpolation procedures involving the use of the boiling points of hydrogen and oxygen and one or more intermediate points for calibration purposes. The resistance-temperature relation is found not to obey Matthiessen's rule sufficiently well to use it as a basis of calibration. The smaller the variations of purity, of course, the easier it is to obtain reproducibility of the resistance-temperature relation, and a minimum value of the alpha coefficient of 3.925×10^{-3} has been suggested as a suitable criterion of purity. The Sonderheimer-Wilson theory was used (2) to attempt to explain the divergences from the Matthiessen rule. The calibrations of sixteen thermometers were examined and it was found possible to divide them roughly into three groups having similar characteristics, suggesting some common dislocation factor of impurity or strain to each group. It is evident that the theory of the disturbances of the crystal lattice is not clearly understood but the assumption that they are all the same in their effect on the resistivity is by no means valid.

It is appreciated that the alpha coefficient of the platinum is not a completely reliable criterion of purity, and this was borne out by work designed to show the correlation between the impurities as measured by mass spectrometer and the alpha coefficients of specimens which ranged from 3.917 to 3.927×10^{-3} (6). There was no evidence of any correlation between the coefficients and the total impurity concentration, but when aluminium and silicon impurities were omitted there seemed to be some correspondence between the two quantities. The difficulties of determining low concentrations in platinum by spectrographic analysis are considerable, but radioactivation analysis indicated that only minute traces of osmium and iridium were present. It was concluded that specimens of platinum having high alpha coefficients have only small quantities of other platinum metals present with the exception of palladium. Zone melting has been tried for the improvement of the quality of thermometer platinum but so far without success.

New Design of Resistance Thermometer

Not only are attempts being made to extend the use of platinum thermometers as standard instruments to low temperatures, but also to high temperatures, up to the melting point of gold, 1063°C. A design of resistance thermometer was described (7) which was shown to be extremely stable up to this temperature. The thermometer was constructed in the form of an elongated birdcage in which 8 wires, 0.4 mm in diamater, were threaded through holes in 4 synthetic sapphire discs and welded together to form a continuous conductor. The sheath of the thermometer was a platinum tube about 6 mm in diameter and 5.3 mm in bore. The stability of this thermometer was equivalent to a few hundredths of a degree at 1063°C after exposure to this temperature for several hours. An interesting phenomenon revealed during this work was the variation of the alpha coefficient with the cooling time from high temperature, as if fast cooling caused the quenching-in of lattice vacancies.

In connection with gas temperature measurements using fine platinum and 10 per cent rhodium-platinum wires (0.0125 mm), some changes in wire resistance were observed which could be attributed to evaporation by oxidation of the metal and to absorption of gases (8). The evaporation was shown by measurements of wire diameter, the change of diameter being greater in oxygen than in air and negligible in nitrogen and argon; the temperatures involved were between 1200 and 1500°C. No evaporation took place in the hot gases below 1000°C, the resistance being reproducible to the limit of the measurements, about one in 50,000. Wires which had been heated above 1200°C for varying times gave temperature coefficients dependent on the time of heating and the gas used. A quartz-coated wire remained perfectly stable under the same conditions. The effects seemed to be due to gas absorption or desorption by the bare wires.

In a study of the stability of platinum resistance thermometers up to 630°C (9), it was concluded that in this temperature range the presence of oxygen in the thermometer as at present recommended was not necessary for good stability. In fact, better stability was found with inert gas fillings. The same calibrations were given with helium, nitrogen, oxygen and dry air, but a small change in absolute resistance, presumably due to gas absorption, was observed.

Thermocouples for Very High Temperatures

There is now an intense search for thermocouples suitable for high temperatures, and the performance of platinum thermocouples using various proportions of rhodium have been subjected to critical studies, while rarer alloys and combinations of metals are being tried. Work is in progress on establishing e.m.f.-temperature reference tables for several alloys of iridium and rhodium against iridium (10), and the tables for the Feussner couple, 40 per cent iridium-rhodium against iridium, for the range 0-2100°C have been completed. The combination gives 11.6 millivolts and 6.8 microvolts per °C at 2100°C. Thoria and beryllia insulators were used during the calibration, and although there was a considerable drop in insulation resistance at the high temperatures no serious errors resulted. Rectification of r.f. power by the insulators could be a serious source of error however.

An investigation has been conducted for a noble metal couple to replace chromel-alumel (11) for use in turbo-jet engines, it being required to match the e.m.f.'s so closely that no change in instrumentation would be required. Couples such as the Pallador thermocouple have been available for this purpose, consisting of 40 per cent palladium-gold against 10 per cent iridium-platinum, but the present authors described the use of the combination 3Au, 83Pd, 14Pt vs 65Au, 35Pd, giving 48 $\pm$0.2 mv at 1200°C compared with 48.89 mv for chromel-alumel. When this couple was heated for 2,000 hours at 1200°C its calibration changed by the equivalent of less than $-$2°C at 400°C and less than +2°C at 1200°C.

Effects of Nuclear Radiation

The effects of nuclear radiation on thermocouples has been studied (12) with particular reference to chromel-alumel and platinum 10 per cent rhodium-platinum couples. They were irradiated in various reactors up to a total of 4.2×10^{20} nvt and whereas no significant change in the e.m.f. of the chromel-alumel couple was observed, that of the platinum-rhodium couple at 1000°C fell by 3 per cent. The change could be attributed almost entirely to neutron capture and the consequent transmutation of rhodium to palladium.

There is a demand for reliable temperature measurements in nuclear experiments up to 1650°C, but the most suitable materials have high nuclear cross-sections. The order of acceptability for nuclear measurements of some of these metals was given as molybdenum, palladium, platinum, tungsten, rhenium, rhodium, and iridium. The transmutation error is only significant when the temperature gradient is within the neutron field. Investigations are in progress (13) on the platinum vs platinum-rhodium-palladium thermocouple systems consisting of additions of 1 to 2 per cent palladium to investigate the possibilities of reducing the calibration errors due to transmutations of rhodium.

As with the previous symposia, the proceedings of the symposium will be published in book form by Reinhold Publishing Corporation.

C.R.B.

References

1	R. J. Corruccini	Interpolation of Platinum Resistance Thermometers 20° to 273.15°K
2	A. F. A. Harper, W. R. G. Kemp and G. C. Lowenthal	Extension of the International Temperature Scale below —183°C
3	C. R. Barber	Low Temperature Scales from 90° to 10°K
4	M. P. Orlova	On the Methods of Practical Temperature Scale Reduction in the Range 10° to 90°K
5	H. van Dijk	On the Use of Platinum Thermometers for Thermometry below 90°K
6	W. Betteridge, D. W. Rhys and D. F. Withers	Laboratory Control of Production of Platinum for Thermometry
7	J. P. Evans and G. W. Burns	Stability and Reproducibility of High Temperature Platinum Resistance Thermometers
8	D. Bradley and A. G. Entwistle ..	Anomalous Resistance Effects in Small Diameter Platinum and Platinum-Rhodium Elements at Temperatures in excess of 1000°C in a Gaseous Environment
9	R. J. Berry	Stability of Platinum Resistance Thermometers at Temperatures up to 630°C
10	G. F. Blackburn	Reference Tables for 40 per cent Iridium-60 per cent Rhodium vs Iridium Thermocouples
11	D. J. Accinno and J. F. Schneider ..	Platinel—A Noble Metal Thermocouple
12	M. J. Kelly, W. W. Johnston and C. D. Boumann	Effects of Nuclear Radiation on Thermocouples
13	G. F. Levy and R. R. Fouse	Operation of Thermocouples under Conditions of High Temperature and Nuclear Radiation