A Decade of Temperature Measurement

SEVENTH INTERNATIONAL SYMPOSIUM REVIEWED

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Platinum has played a central role in temperature measurement for over 100 years, since the early development of platinum resistance thermometers by Siemens and Callendar, and platinum-rhodium thermocouples by Le Chatelier in the late nineteenth century. Platinum resistance thermometers are widely used industrially to BS 1904 (IEC 751) standards, and laboratory instruments with high purity platinum wires have always been the specified instruments for interpolation in the International Temperature Scale (ITS) for the most important part of the range. Currently, in the ITS–90, various patterns of platinum resistance thermometer are used from the triple point of hydrogen (−259.3467°C) to the freezing point of silver (961.78°C). While platinum-rhodium thermocouples are no longer specified for use in the realisation of the scale, they retain their importance as practical secondary standard instruments at high temperatures.

This Symposium was the seventh in a series which have been held in North America about every 10 years. It was organised and sponsored by the U.S. National Institute of Standards and Technology (NIST), the National Research Council (NRC) of Canada, the American Institute of Physics and the Instrument Society of America (ISA), and it was held in Toronto, Canada, from April 28th to May 1st, as part of the ISA spring meeting. About 500 people attended and some 250 papers were presented.

The opening keynote address, by Professor C. A. Swenson of Iowa State University, reviewed the work and events leading up to the adoption of the ITS–90. The technical sessions which followed included papers on all aspects of thermometry: thermodynamic measurements, fixed points and the ITS–90, radiation thermometry, spectroscopic and fibre-optic techniques, applications in industry, medicine and space, etc. Almost half of the papers were in some way concerned with the performance and application of devices using platinum or platinum group metals. Some of the more significant or interesting are now highlighted.

Platinum Resistance Thermometers

The development of the interpolation equations for platinum resistance thermometers now adopted in the ITS–90 was reviewed by L. Crovini of the Istituto di Metrologia "G. Colonnetti" (IMGC), Italy; other papers were concerned with evaluations of their effectiveness; for example, analysing the differences arising from using different thermometers (known as the non-uniqueness of the scale), and the inconsistencies which may arise consequent on the inclusion of overlapping alternative definitions in the scale. G. F. Strouse (NIST), D. I. Head and R. L. Rusby of the National Physical Laboratory (NPL), U.K., and others demonstrated that these effects are tolerably small, generally less than ±0.0005°C over the temperature range up to 420°C. K. D. Hill and D. J. Woods (NRC) described comparison measurements between standard platinum resistance thermometers in a caesium-filled heat pipe which showed differences of less than ±0.002°C in the range from 520°C to 620°C.

Several papers were concerned with the performance, calibration and use of the high temperature platinum resistance thermometers which are now specified for the range up to the freezing point of silver (961.78°C). These require carefully selected materials for their construction so as not to contaminate the platinum, and are generally of low resistance (0.25 to 2.5 ohm) to reduce the effect of electrical leakage at high temperatures. H. G. Nubbemeyer of the Physikalisch-Technische Bundesanstalt (PTB), Germany, reported on the development and performance of various high temperature platinum resistance thermometers, the short-term stability at the silver point being about 0.001 to 0.002°C, with a long-term value of about 0.005°C. In a joint paper from NIST and the Mendeleev Institute of Metrology in St. Petersburg, G. F. Strouse, B. W. Mangum, A. I. Pokhodun and N. P. Moiseeva reported the results of an investigation into the stability of high temperature platinum resistance thermometers up to the silver point and, in the case of some Russian thermometers, up to the gold point (1064.18°C). They found that extrapolation of the ITS–90 function beyond the silver point caused errors of only 0.004°C.

A European collaborative paper presented by M. V. Chattle (NPL) described the results obtained when thermometers which had been calibrated at the aluminium and silver freezing points were measured at NPL, and then recalibrated at the originating laboratories. In general, the results obtained using a variety of different types of high temperature platinum resistance thermometers and fixed point cells from different sources, showed agreement to within ±0.005°C and ±0.016°C at the aluminium and silver points, respectively.

In contrast to these experimental investigations, J. V. Nicholas, Department of Scientific and Industrial Research, New Zealand, presented a theoretical model for the thermodynamic behaviour of platinum resistivity.

Industrial platinum resistance thermometry was the subject of more than a dozen papers, ranging from one by M. Arai and H. Sakurai of the National Research Laboratory of Metrology (NRLM), Japan, concerning the development of a more robust platinum resistance thermometer for use up to 1100°C, to one by G. Ruffino, P. Coppa, L. de Santoli, A. Castelli and C. Cornaro of Rome University describing the design, construction and testing of a platinum resistance thermometer for inclusion in a probe for the exploration of the Titan atmosphere. Several authors had written papers concerning the resistance/temperature relationships of industrial platinum resistance thermometers together with stability studies carried out in various temperature ranges. J. J. Connolly of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia, reported on industrial platinum resistance thermometer interpolation procedures which lead to uncertainties as low as ±0.01°C up to 250°C, and ±0.05°C at 500°C.

L. Crovini, A. Actis, G. Coggiola and A. Mangano (IMGC) reported the results of their measurements on 100 ohm industrial platinum resistance thermometers of European manufacture; they found that selected thermometers could provide interpolation to within ±0.02°C in the range up to 630°C. However, thermometers for use at higher temperatures (up to 850°C) were less stable and required an additional term to allow for electrical leakage above 630°C. The results of this work will lead to a proposal for revision of the International Standard Tables for industrial platinum resistance thermometers contained in IEC 751, in order to up-date them to the ITS–90.

The low temperature characteristics of industrial platinum resistance thermometers were reported in papers by Mao Yuzhu, Lin Peng, Zhang Qinggeng and Yue Yi of the Chinese Academy of Sciences with Yao Quanfa and Zhang Jipei of the Shanghai Institute of Process Automation Instrumentation (SIPAI), and by H. Sakurai (NRLM) and T. Nakajima of the Tokyo Metropolitan Industrial Technology Center. Zhang Jipei and his colleagues also reported the results of an investigation into the characteristics of 35 Chinese industrial platinum resistance thermometers at temperatures up to 850°C.

Noble Metal Thermocouples

A number of papers on platinum-rhodium thermocouples presented the results of measurements made to relate the e.m.f.s of types S, R and B thermocouples to temperatures on the ITS–90. Several of them were collaborative papers involving the national standards laboratories of U.S.A., U.K., Italy, The Netherlands, Japan, Korea, China and Russia. The results were collated and analysed in a paper presented by G. W. Burns (NIST) and this will form the basis of a proposal to be made regarding the revision of the International Standard Tables for noble metal thermocouples contained in IEC 584–1, in order to align them with the ITS–90.

R. Holanda (NASA) and K. G. Kreider (NIST) both presented papers describing their work on thin-film platinum-rhodium thermocouples; these look promising at temperatures up to about 1500°C. A paper reporting performance data and an ITS–90 based reference function for gold versus platinum thermocouples was presented by G. W. Burns, G. F. Strouse, B. M. Liu and B. W. Mangum (NIST); these thermocouples show promise as highly reproducible secondary standards in the range from 600°C to 1000°C.

Papers on tungsten-rhenium thermocouples included one by Li Baozhang (SIPAI) and Ma Zhenglin (Kunshan Instrument Material Works) which reviewed the development of manufacturing techniques in China and the application of these thermocouples, which are currently undergoing tests in the steel industry as possible alternatives to platinum-rhodium thermocouples. A paper, by N. S. Cannon and R. C. Knight (Westinghouse Hanford Company, U.S.A.), reviewed calibration techniques for tungsten-rhenium thermocouples, with particular reference to the effects of drift.

Other Applications

While platinum resistance thermometers and the platinum-rhodium thermocouples represent the main and indispensable uses of the platinum group metals in temperature measurement, many other notable applications were reported at the Symposium. One of these which has seen considerable development in the last ten years is in the use of resistance thermometers based on an alloy of rhodium with 0.5 per cent iron. Originally these were developed for use at very low temperatures (see *Platinum Metals Rev.*, 1992, **36**, (1), 11, and *ibid.*, 1981, **25**, (2), 57) and this continues to be their main role. G. Schuster (PTB) described the remarkable precision of measurements below 0.05 K, and W. E. Fogle, J. H. Colwell and R. J. Soulen Jr. (NIST) reported on the excellent stability for which the thermometers are noted. O. Tamura and H. Sakurai (NRLM) described the effects of various annealing treatments and the characteristics of wire-wound and film type thermometers, while Zhang Jipei (SIPAI) presented reference functions for industrial rhodium-iron thermometers over the whole range from 1 K to 500°C.

Other more exotic uses of platinum group metals at low temperatures included nuclear susceptibility measurements in platinum by magnetic resonance (D. Hechtfischer and G. Schuster, PTB), and the use of superconductive transitions in iridium, at about 0.1 K (J. Bremer and M. Durieux, Leiden University). Electronic (Johnson) noise thermometry was reported at high temperatures by L. Crovini, A. Actis and R. Galleano of IMGC, R. L. Shepard, R. M. Carroll, D. D. Falter of Oak Ridge National Laboratory, Tennessee, with T. V. Blalock and M. J. Roberts of the University of Tennessee, and H. Brixy, R. Hecker, J. Oehmen and W. Setiawan of the Institut für Angewandte Werkstofforschung with K. F. Rittinghaus and E. Zimmermann of the Zentrallabor für Elektronik, Jülich, using platinum or refractory alloy resistors as the source of the noise. Industrial applications of combined noise and thermocouple sensors are of interest because they allow the thermocouple calibration to be monitored in situ. Absolute measurements of freezing point temperatures are also becoming possible with good accuracy, such as to challenge the primacy of gas thermometers and radiation thermometers.

In summary, the Symposium was an opportunity to review ten years of development in the standards and practice of temperature measurement and to look forward to future prospects in the field. One point which is not in doubt is the continued dependence of temperature measurement on the platinum group metals. The proceedings of the Symposium are expected to be published towards the end of 1992, by the American Institute of Physics.