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Hoge H J & Brickwedde F G. Establishment of a temperature scale for the calibration of thermometers between 14° and 83° K. *J. Res. Nat. Bur. Stand.* 22:351-73, 1939.
[US Department of Commerce, National Bureau of Standards, Washington, DC]

In the 1930s there was no good way to measure thermodynamic temperatures in the range 14 to 83 K except to calibrate your own thermocouple or resistance thermometer against a gas thermometer. The temperature scale described in this paper relieved the individual worker of this formidable job by providing calibration at the National Bureau of Standards. [The SCI® indicates that this paper has been cited in over 150 publications since 1955.]

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The field of low-temperature physics was expanding in 1935 when I took a job at the National Bureau of Standards (NBS). The bureau was being urged to calibrate thermometers for use below the oxygen point (~90 K), where there was no generally accepted, relatively simple method of approximating the thermodynamic temperature scale. I was a green PhD in physics from Yale, and my first job was to establish a provisional scale to fill the gap. My coauthor, F.G. Brickwedde, supervised the project. We established the new temperature scale by using a helium-gas thermometer to calibrate a group of six platinum resistance thermometers.

The NBS informs me that none of the six original thermometers remains in usable condition today. But the scale that they carried, since redesigned for the more stable modern thermometers, could still be used; however, modern scales are preferred. The original scale had its widest use from 1939 to 1968. It was disseminated not only in the US but also to laboratories in other countries. In 1955, on the basis of new determinations of some fixed points in the range of the scale, a slight modification of our original scale was made. This new scale, the "NBS 1955 Provisional Scale," remained in use until the "International Practical Temperature Scale of 1968" was adopted. (I am indebted to current NBS staff members, especially George T. Furukawa, for the above information.)

One reason that our 1939 temperature scale succeeded was that it was based on a "smooth" master table, the result of many numerical smoothing operations and plottings of deviations, which reduced irregularities in the table and its principal derivatives. Heat capacities measured on the scale did not show sharp breaks or jumps. Subsequent work has shown that our scale does in fact wander above and below the thermodynamic scale, but the deviations do not exceed ±20 mK. This was the accuracy we claimed for the scale when it was published.

New methods of measuring thermodynamic temperature have come into use, but gas thermometry has not been superseded. A recent investigation by P.P.M. Steur and M. Durieux[1] is surprisingly similar in scope to our 1939 work. Their accuracy appears to be at least 10 times better than ours. Those interested in the present status of temperature measurement in general, not limited to low temperatures, could well begin by consulting "The International Practical Temperature Scale,"[2] a short paper written by three experts in the field.

Cryogenic physicists and chemists have always been more concerned about the accuracy of their temperature measurements than researchers working at ordinary temperatures. Low temperatures have traditionally been hard to achieve and to measure. This accounts, I think, for the relatively large number of citations our paper has received. Even now, an investigator reporting a value for the triple-point temperature of oxygen, for example, might cite our paper in the course of comparing the value with previously published values.

Our paper probably influenced a subsequent improvement in the temperature scale: In the course of our work we tidied up the derivations of the equations for computing temperature in gas thermometry and for making corrections for gas imperfections. These equations were made much simpler if "Giauque's proposal"[3] was applied, thus strengthening support of the proposal. W.F. Giauque proposed defining the Kelvin (thermodynamic) temperature scale by assigning a temperature to a single fixed point rather than by assigning the value of 100 degrees to the interval between the ice and steam points. This eminently sensible proposal met with some resistance from advocates of the traditional scale; however, it was adopted in 1954 by the 10th General Conference on Weights and Measures. I remember needling some of the traditionalists by calling their temperature scale a "rubber scale," since it stretched or shrank every time a new and improved set of gas-thermometer data was published.

1. **Steur P P M & Durieux M.** Constant-volume gas thermometry between 4 K and 100 K. *Metrologia* 23:1-18, 1986.
2. **Preston-Thomas H, Quinn T J & Hudson R P.** The international practical temperature scale. *Metrologia* 21:75-9, 1985.
3. **Giauque W F.** A proposal to redefine the thermodynamic temperature scale: with a parable of measures to improve weights. *Nature* 143:623-6, 1939.

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