Determination of the Boltzmann constant for the redefinition of the kelvin

The need for the project

Since the establishment of the SI units in 1960, extraordinary advances have been made in relating them to invariant quantities such as the fundamental constants of physics and the properties of atoms.

The present definition of the unit of thermodynamic temperature was given by the 10th General Conference on Weights and Measures in 1954, which selected the triple point of water as a fundamental fixed point, so defining the unit kelvin. However, the development of new primary methods of thermometry that are difficult to link directly to the triple point of water led the Consultative Committee for Thermometry to propose a redefinition of the kelvin using the Boltzmann constant (k).

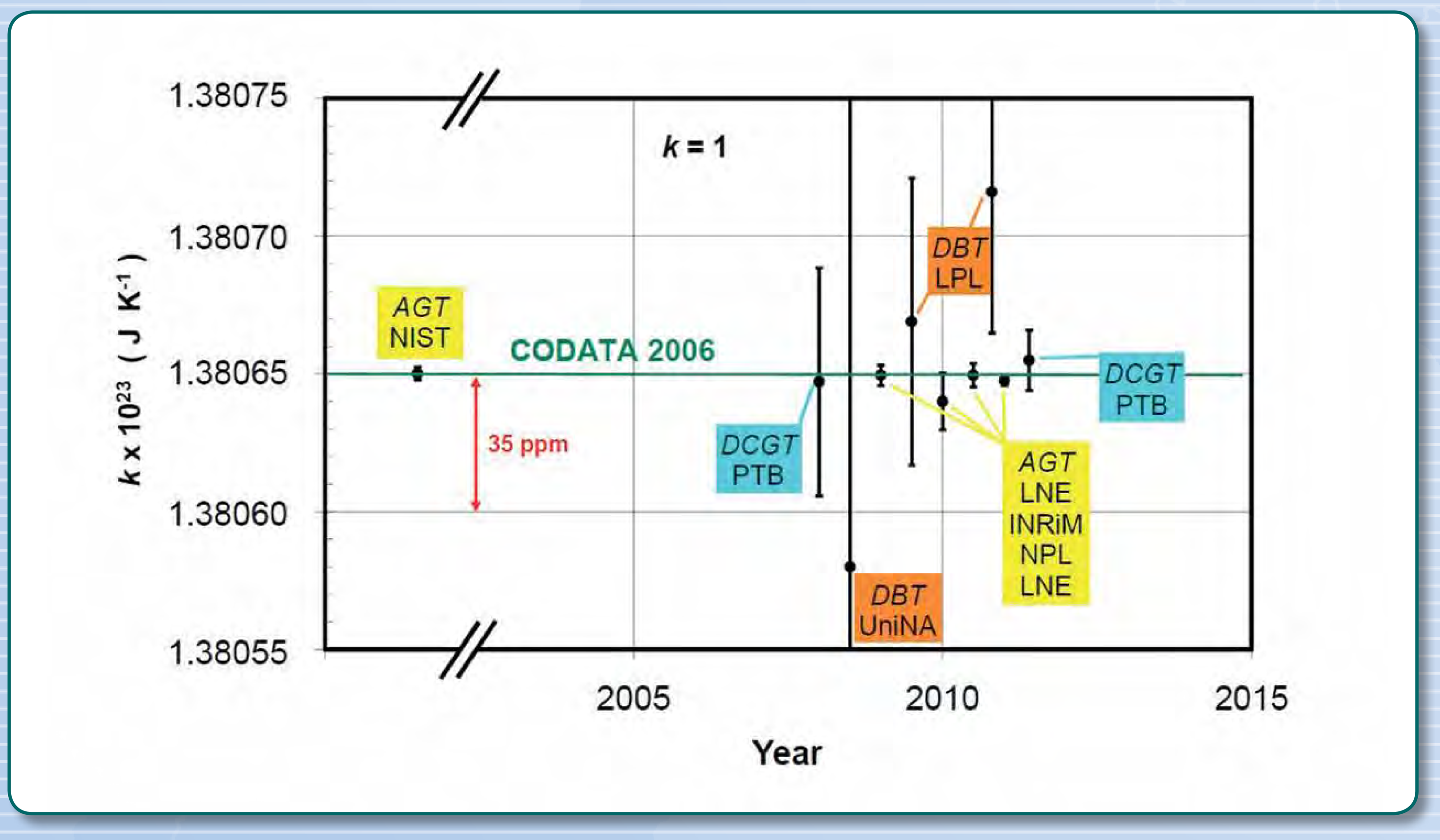
This project aimed to determine the Boltzmann constant, via a number of experimental routes.

Technical achievements

In order to reduce the uncertainty in the determination of k, advances have been achieved in the fields of physical acoustics, thermodynamics, microwave measurements, thermometry, dimensional measurements, residual gas analysis, perturbation theory, pressure and capacity measurement, and laser-spectroscopy.

The project achieved determinations of k by three methods; acoustic gas thermometry, Doppler broadening thermometry and dielectric constant gas thermometry. All results were consistent with the currently accepted value of k. The standard uncertainty of the project's most recent result corresponds to a reduction in uncertainty by a factor of 1.5.

AGT Cell - Spherical resonator for acoustic gas thermometry (AGT).



Results for the Boltzmann constant k obtained by dielectric constant gas thermometry (DCGT), Doppler broadening thermometry (DBT) and AGT.

The results of the project, including the uncertainty budgets, have been provided to the interdisciplinary Committee on Data for Science and Technology (CODATA) for evaluation and qualification of the measurements. The outcome of this evaluation should set the standard uncertainty of k at 0.9 ppm, corresponding to a reduction in the uncertainty by a factor of 2.

Improving temperature measurement

Worked closely with the Consultative Committee for Thermometry and its task group on the Mise en Pratique for the Definition of the kelvin to help improve temperature measurement.

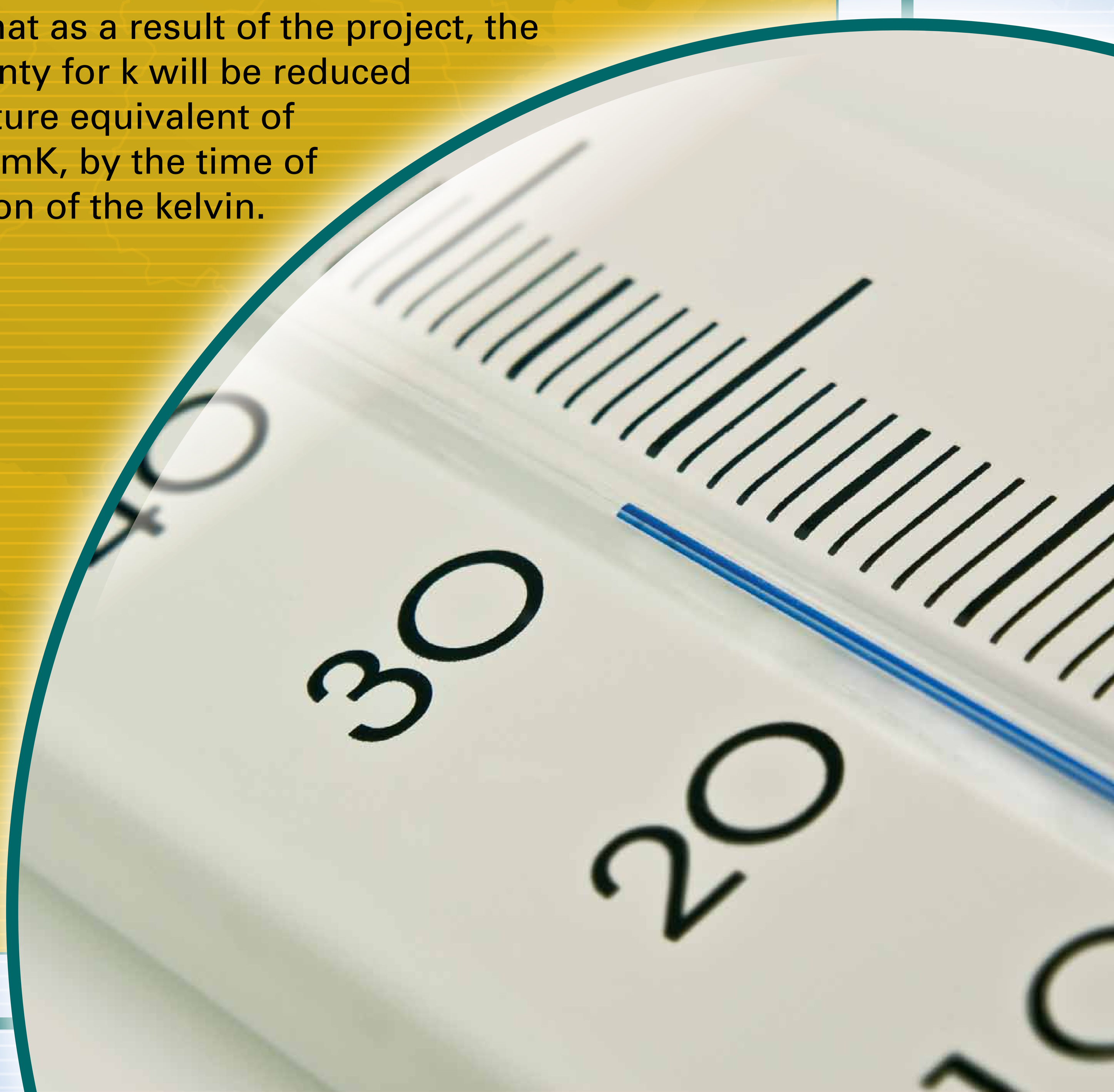
The kelvin can be calculated in two ways, by calibrating a working-standard thermometer against the readings of a primary thermometer and by using the International Temperature Scales. Although the International Temperature Scales do not rule out methods based on primary thermometry, the lack of their recognition leads to confusion. This project helped reduce this confusion by developing International Temperature Scales in the context of other methods.

Developing primary thermometry methods

Fostered the development of a number of primary thermometry methods (e.g. absolute spectral-band radiometry used in steel production) and developed special Johnson noise thermometers, benefitting manufacturers of low temperature refrigerators, superconducting magnets and ultra-sensitive sensors.

Supporting a redefinition of the kelvin

Reduced the uncertainty when measuring k by a factor of 1.5 and submitted results to CODATA for evaluation. It is anticipated that as a result of the project, the final uncertainty for k will be reduced to a temperature equivalent of $u(k=1) \approx 0.25$ mK, by the time of the redefinition of the kelvin.



Joint Research Project (JRP) Short Name: Boltzmann constant • JRP-Coordinator: Joachim Fischer (PTB) • JRP-Partners: CEM (Spain), CNAM (France), DFM (Denmark), INRIM (Italy), JRC (EC), LNE (France), NPL (UK), PTB (Germany)

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EMRP European Metrology Research Programme ▶ Programme of EURAMET

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