Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

“Highlights of the WG-CTh since 2022“

WG-CTh - Members

WG-CTh:

Chairperson:

- Christof Gaiser (PTB)

Members:

- Robin Underwood (NPL)
- Jonathan Pearce (NPL)
- Murat Kalemci (TÜBİTAK UME)
- Roberto Gavioso (INRIM)
- Vladimir Gennadiy Kytin (VNIIFTRI)
- Tohru Nakano (NMIJ/AIST)
- Laurent Pitre (LNE-Cnam)
- Anatolii Pokhodun (VNIIM)
- Patrick Rourke (NRC)
- Weston Tew (NIST)
- Inseok Yang (KRISS)
- Xiaojuan Feng (NIM) substitutes Jintao Zhang (NIM)

Co-opted members:

- Richard Rusby (NPL)
- Bernd Fellmuth (PTB)
- Peter Steur (INRIM)
- Rod White (MSL)

Terms of references of WG-CTh

I. reviewing and reporting on measurements of $T - T_{90}$ and $T - T_{2000}$

II. recommending key comparisons in contact thermometry to the CCT

III. reviewing the research and application of primary contact thermometers to realize the kelvin

IV. updating the Mise en Pratique of the definition of the kelvin

V. updating the Guides to the Realization of the ITS-90 and the PLTS-2000

VI. reviewing novel contact thermometry techniques

Activities since 2022

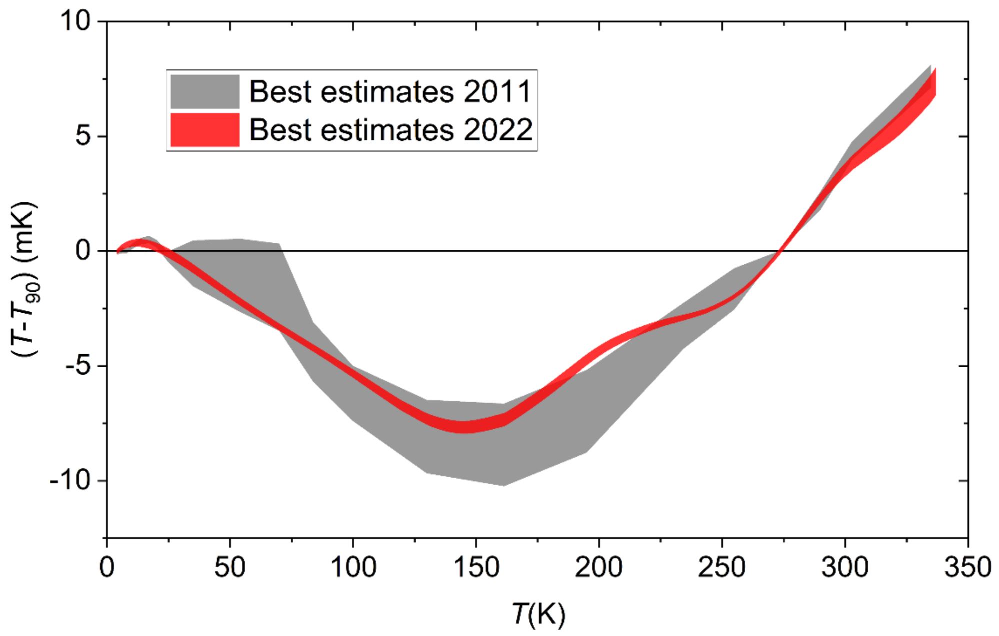
I. reviewing and reporting on measurements of $T - T_{90}$ and $T - T_{2000}$

Journal of Physical and Chemical Reference Data
ARTICLE
scitation.org/journal/jpr

2022 Update for the Differences Between Thermodynamic Temperature and ITS-90 Below 335 K

Cite as: J. Phys. Chem. Ref. Data 51, 043105 (2022); doi: 10.1063/5.0131026
Submitted: 17 October 2022 • Accepted: 23 November 2022 •
Published Online: 27 December 2022
View Online Export Citation CrossMark

Christof Gaiser,[1,a)] Bernd Fellmuth,[1] Roberto M. Gavioso,[2] Murat Kalemci,[3] Vladimir Kytin,[4] Tohru Nakano,[5] Anatolii Pokhodun,[6] Patrick M. C. Rourke,[7] Richard Rusby,[8] Fernando Sparasci,[9] Peter P. M. Steur,[2] Weston L. Tew,[10] Robin Underwood,[8] Rod White,[11,b)] Inseok Yang,[12] and Jintao Zhang[13]



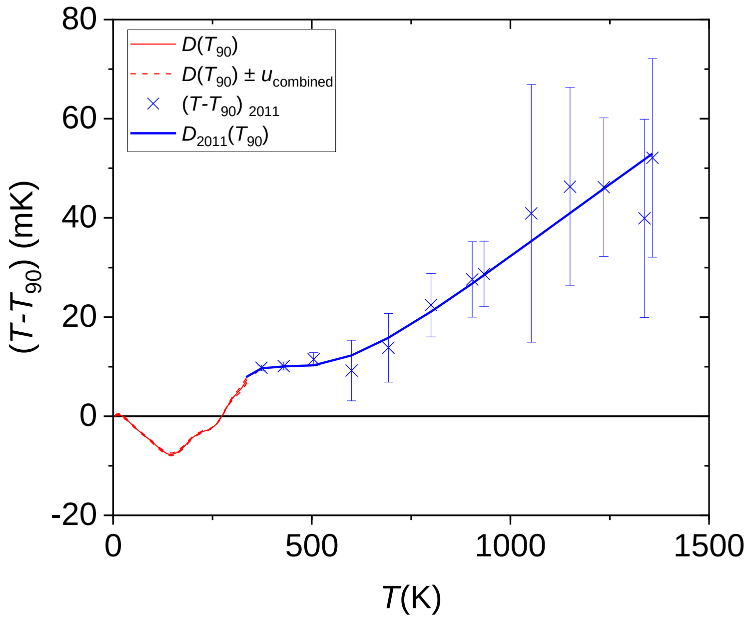
Activities since 2022

I. reviewing and reporting on measurements of $T - T_{90}$ and $T - T_{2000}$

BIPM
https://www.bipm.org › documents › Estimates... PDF

Updated Estimates of the Differences between ...

Above 335 K, Table 1 summarizes the **best estimates** of **T-T90** in 2011. These are still considered the **best estimates** in this temperature region due to the paucity ...



Updated Estimates of the Differences between Thermodynamic Temperature *T* and the ITS-90 Temperature T_{90}

In 2010, at the CCT's request, Working Group 4 (WG4) critically reviewed all available measurements of T-T_{90} including constant-volume gas thermometry, acoustic gas thermometry, spectral radiation thermometry, total radiation thermometry, noise thermometry, and dielectric-constant gas thermometry. These were published in 2011 [1]. Consensus estimates were provided for $T - T_{90}$, deduced from selected measurements from 4.2 K to 1358 K, as well as a recommendation for analytic approximations to T-T_{90} for the range 0.65 K to 1358 K [1]. Due to significant progress in the field of contact thermometry below 335 K since that time, CCT working group on contact thermometry (WG-CTh) according to its terms of reference reviewed all new available T-T_{90} data sets since 2011 leading to updated values for T-T_{90} [2] with in part a reduction of one order of magnitude in uncertainty compared to the 2011 estimates. Note that the best estimate of the thermodynamic temperature of the triple point of water remains 273.1600(1) K with the standard uncertainty given in brackets, and readers who wish to use the triple point of water as a thermodynamic reference point should continue to use this value and uncertainty.

For T-T_{90} above 400 K new experiments are needed

International Committee for Weights and Measures

Proceedings of Session I of the 110th meeting

CCT

Dr Duan presented the activities of the CCT as detailed in report CIPM/2021-06.02. He commented that a new key comparison for body temperature measurements is planned and that a Task Group for body temperature measurement will be set up within the CCT Working Group for Contact Thermometry (CCT-WG-CTh). In addition, a CCT Task Group for Air Temperature (CCT-TG-Env-AirT) has been established within the CCT Working Group for Environment (CCT-WG-Env).

The CCT has proposed a Recommendation to the CIPM on “Requirement for new determinations of thermodynamic temperature above 400 K”. The recommendation is as follows: “*that Member State NMIs improve their capabilities in primary thermometry, by various means, above 400 K to improve determination of* $T-T_{90}$*, accompanied by appropriate research to ensure that International Temperature Scale realization remains fit for purpose, allowing access to lower uncertainty thermodynamic temperature values over a wide range for a broader community*.”

New data on T-T_{90} above 400 K mandatory for a new ITS

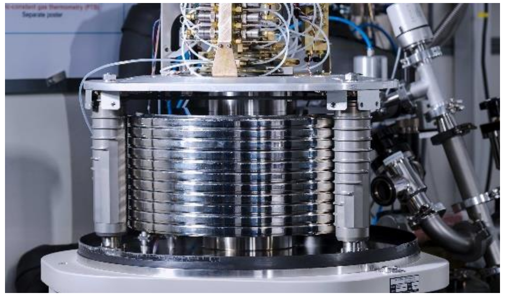
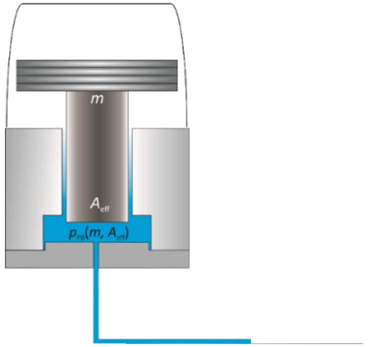
Top level primary thermometers needed for a direct realization

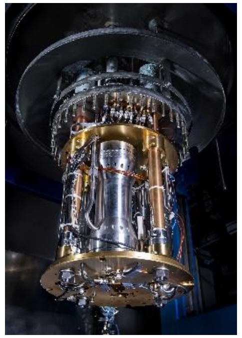
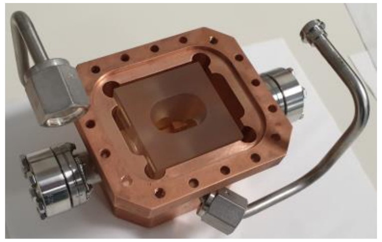
Applications of T-T_{90}

At the moment the best access to T for users via T_{90} realisation and T-T_{90} estimates

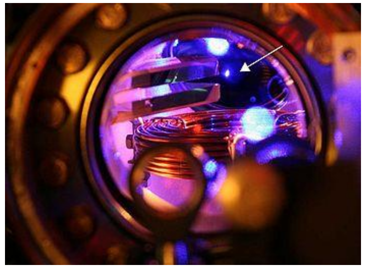
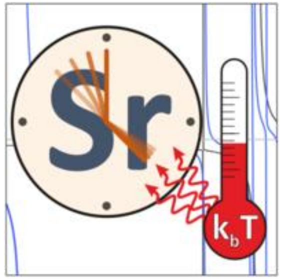
Examples where a correction from T_{90} to T is needed

Example 1
pressure standards

Example 2
Optical clocks

Activities since 2022

III. reviewing the research and application of primary contact thermometers to realize the kelvin

Dissemination of the redefined kelvin

Short Name: DireK-T, Project Number: 22IEM02

An old style industrial thermometer

COORDINATOR
Roberto Maria Gavioso (INRIM)

Implementing primary thermometry in European industry

Temperature is one of the most measured parameters in industry. Primary thermometry

PARTICIPATING EURAMET NMIS AND DIS

- CEM (Spain)
- CMI (Czechia)
- INRIM (Italy)
- INTiBS (Poland)
- LNE (France)
- LNE-LCM/CNAM (France)
- MIRS/UL-FE/LMK (Slovenia)
- NPL (United Kingdom)
- PTB (Germany)
- SMD (Belgium)
- UME (Türkiye)

OTHER PARTICIPANTS

Industrial Technology Research Institute (Taiwan, Province of China)
National Institute of Metrology - NIM (China)
Technical Institute of Physics and Chemistry of the Chinese Academy of Sciences (China)

INFORMATION

PROGRAMME
Metrology Partnership

FIELD
Integrated European Metrology

CALL
2022

DURATION
2023-2026

TOTAL EU CONTRIBUTION (IN M €)
1,676

See presentation by Roberto Gavioso

Activities since 2022

IV. updating the Mise en Pratique of the definition of the kelvin

OPEN ACCESS
IOP Publishing | Bureau International des Poids et Mesures Metrologia
Metrologia **61** (2024) 022001 (23pp) https://doi.org/10.1088/1681-7575/ad2273

Review

Practical realisation of the kelvin by Johnson noise thermometry

Samuel P Benz[1], Kevin J Coakley[1], Nathan E Flowers-Jacobs[1], Horst Rogalla[1], Weston L Tew[2], Jifeng Qu[3], D Rod White[4,*], Christof Gaiser[5], Alessio Pollarolo[6] and Chiharu Urano[7]

[1] National Institute of Standards and Technology, Boulder, CO 80305, United States of America
[2] National Institute of Standards and Technology, Gaithersburg, MD 20899, United States of America
[3] National Institute of Metrology (NIM), Beijing 100029, People's Republic of China
[4] Independent Researcher, Lower Hutt, New Zealand
[5] Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany
[6] Measurements International (MI), Prescott, Canada
[7] National Metrology Institute of Japan (NMIJ), AIST, Tsukuba, Japan

E-mail: rodwhitenz@gmail.com

Now part of the MeP-K 19D

See presentation by Patrick Rourke

Long lasting task finalized under the leadership of Rod White

Outlook

Additional tasks for the years

Collation of new data for high-quality reference points

Update of WG2 article by Bedford and colleagues

metrologia

Recommended values of temperature on the International Temperature Scale of 1990 for a selected set of secondary reference points

R. E. Bedford, G. Bonnier, H. Maas and F. Pavese

Working Group 2 of the Comité Consultatif de Thermométrie

Abstract. Recommended values of temperature on the International Temperature Scale of 1990 are given for a large number of secondary reference points, together with assessments of the uncertainties of these values.

Review of Scientific Instruments REVIEW scitation.org/journal/rsi

High-accuracy realization of temperature fixed and reference points

Cite as: Rev. Sci. Instrum. 94, 011102 (2023); doi: 10.1063/5.0110125
Submitted: 15 July 2022 • Accepted: 23 November 2022 •
Published Online: 20 January 2023

View Online Export Citation CrossMark

Bernd Fellmuth[a] and Christof Gaiser[b]

AFFILIATIONS

Physikalisch-Technische Bundesanstalt (PTB), Abbestrasse 2-12, 10587 Berlin, Germany

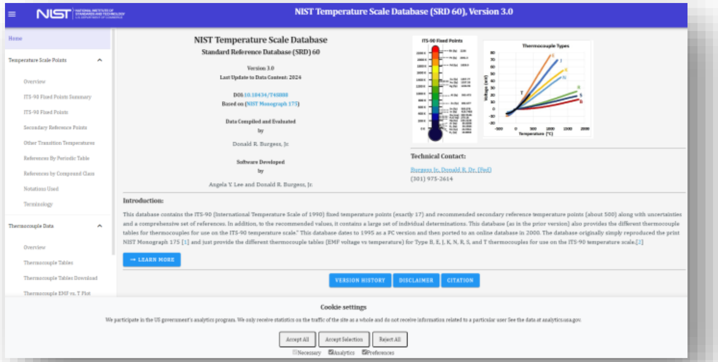
[a]Author to whom correspondence should be addressed: Bernd.Fellmuth@PTB.de
[b]Christof.Gaiser@PTB.de

ABSTRACT

The harmonization of international temperature measurements requires the high-accuracy realization of many different temperature reference points. This results from the feature of the intensive measurand temperature that temperatures cannot simply be divided or multiplied. Thus, the points must cover the whole range of interest, at present from 1 mK to a few 1000 K. Furthermore, instruments are necessary for the interpolation between the non-continuous guide values. This led to the establishment of International Temperature Scales (ITS). The ITS prescribe interpolation instruments and assign fixed temperature values to suitable phase transitions without uncertainty. The large temperature range can only be covered by applying very different phase transitions. This includes the classical transitions, namely triple, melting, and freezing points, but also second-order transitions, as superfluid and superconducting ones, and the very new eutectic or peritectic points of metal-carbon compositions. A high-accuracy realization requires a reliable uncertainty estimation. This is, therefore, the central topic of this review. Since a given non-ideal condition of a sample, especially the impurity content, cannot be reproduced as accurate as necessary, the fixed- and reference-point temperatures are defined for ideal substances under ideal conditions. Thus, the estimation of the uncertainty of the realizations must be based on estimating the magnitude of all physical effects influencing the observed phase-transition temperature. The application of this methodology is discussed in the paper as unifying topic independent of the individual problems to be solved. Furthermore, recommendations of the *Consultative Committee for Thermometry* are summarized, and own experiences are supplemented.

NOMENCLATURE

Anisotropy effect (AE)	Decrease of the superconducting transition temperature in anisotropic superconductors due to smoothing out of anisotropy by the scattering effect of impurities	GRT	Germanium resistance thermometer: One type from a variety of thermometers for low temperatures having a negative temperature coefficient (Rubin *et al.*, 1982)
Cryogenic gases	Gases having boiling-point temperatures below 0 °C	Heat-flux correction	Correction of the depression of the lambda-transition temperature of helium-4 caused by a heat flux through the normal-fluid to super-



Task for WG-CTh and partially also for WG-NCTh (Eutectics)

Outlook

Why do we need an update of the Bedford article?

1) For a new ITS or an amendment (e.g. substitution of TPHg)
2) For relative primary thermometry (e.g. λ-point of ^{4}He for T measurements below 2K)

Thanks to all the members of WG-CTh

and thank you for your attention!