

Bureau International des Poids et Mesures

Consultative Committee for Thermometry (CCT)

Minutes of the 29th meeting
Session 4
19 January 2021

Due to the present pandemic, the 29th meeting of the CCT is held on-line.
It is split into five sessions spanning over October 2020 until February 2021.

These minutes will be incorporated at a later stage into the CCT's Report to the CIPM.

LIST OF MEMBERS OF THE CONSULTATIVE COMMITTEE FOR THERMOMETRY

as of 20 October 2020

President

Y. Duan, member of the International Committee for Weights and Measures

Executive Secretary

S. Picard, International Bureau of Weights and Measures [BIPM], Sèvres

Members

Agency for Science, Technology and Research [A*STAR], Singapore.

All-Russian Scientific Research Institute of Physico-Technical Measurements, Rosstandart [VNIIFTRI], Moscow.

Centro Español de Metrología [CEM], Madrid.

Centro Nacional de Metrología [CENAM], Querétaro.

Conservatoire National des Arts et Métiers/Institut National de Métrologie [LNE-Cnam], La Plaine-Saint Denis.

Czech Metrology Institute [CMI], Brno.

D.I. Mendeleev Institute of metrology, Rosstandart [VNIIM], St Petersburg.

Instituto Nacional de Metrologia, Qualidade e Tecnologia [INMETRO], Rio de Janeiro.

Instituto Português da Qualidade [IPQ], Caparica.

Istituto Nazionale di Ricerca Metrologica [INRIM], Turin.

Korea Research Institute of Standards and Science [KRISS], Daejeon.

Measurement Standards Laboratory of New Zealand [MSL], Lower Hutt.

National Institute of Metrology [NIM], Beijing.

National Institute of Standards and Technology [NIST], Gaithersburg.

National Measurement Institute of Australia [NMIA], Lindfield.

National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology [NMIJ/AIST], Tsukuba.

National Metrology Institute of South Africa [NMISA], Pretoria.

National Metrology Institute of Turkey [UME], Gebze-Kocaeli.

National Physical Laboratory [NPL], Teddington.

National Research Council of Canada [NRC], Ottawa.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

Slovak Metrology Institute/Slovenský Metrologický Ústav [SMU], Bratislava.

VSL B.V. [VSL], Delft.

VTT Technical Research Centre of Finland Ltd, Centre for Metrology / Mittatekniikan keskus
[MIKES], Espoo

The Director of the International Bureau of Weights and Measures [BIPM], Sèvres.

Official Observer(s)

FSB - Laboratory for Process Measurements [DZM/FSB-LPM], Zagreb.

1 **OPENING OF THE MEETING; APPOINTMENT OF THE RAPPORTEUR; APPROVAL OF THE AGENDA**

The twenty-ninth meeting of the Consultative Committee for Thermometry (CCT) was held in five separate sessions via the web due to the pandemic crisis.

The following were present at the fourth session:

Z. Ahmed (NIST), N. Al Dawood (SASO-NMCC), I. Al Faleh (SASO-NMCC), N. Alqahtani (SASO-NMCC), M. Anagnostou (EMI), K. Anhalt (PTB), S. Bell (NPL), S. Bergstrand (BIPM), J. Bojkovski (MIRS/UL-FE/LMK), J. Brionizio (INMETRO), C. de Bruin (VSL), D. del Campo (CEM), Y. Duan (NIM), E. Ejigu (NMISA), L. Eusebio (IPQ), R. Feistel (IAWPS), X. Feng (NIM), V. Fericola (INRIM), S. Fil (NSC IM), J-R. Filtz (LNE), C. Gaiser (PTB), R. Gavioso (INRIM), M. Heinonen (MIKES), B. Il Choi (KRISS), F. Jahan (NMIA), Z. Jintao (NIM), M. Kalemci (UME), L. Knazovicka (CMI), V.G. Kytin (VNIIFTRI), L. Lira-Cortes (CENAM), J. Lovell-Smith (MSL), G. Machin (NPL), A. Merlone (INRIM), M. Milton (BIPM), R. Moretz Sohn (INMETRO), T. Nakano (NMIJ AIST), H. Nasibli (UME), J. Pearce (National Physical Laboratory), A. Peruzzi (NRC), A. Pokhodun (VNIIM), K. Quelhas (INMETRO), P. Rourke (NRC), S. Rudtsch (PTB), M. Sadli (LNE-LCM/Cnam), N. Sasajima (NMIJ AIST), P. Saunders (MSL), A.N. Schipunov (VNIIFTRI), Y. Shaochun (NMC, A*STAR), G. Snijders (VSL), F. Sparasci (LNE-LCM/Cnam), R. Strnad (CMI), W. Tew (NIST), A. Todd (NRC), C.M. Tsui (SCL), E. van der Ham (NMIA), M. Vinge (VNIIFTRI), L. Wang (NMC, A*STAR), R. White (MSL), N. Yamada (NMIJ AIST), I. Yang (KRISS), H. Yoon (NIST), Z. Yuan (NIM).

Invited: P. Blombergen (Netherlands), C. Morales (INM (CO))

Also present: S. Picard (Executive Secretary of the CCT).

Excused: M.K. Ho (NMIA)

The President of the CCT, Dr Y. Duan opened the meeting and welcomed the participants. Dr M. Milton welcomed the participants and transmitted his best wishes for a happy new year.

Dr I. Yang (KRISS) was appointed *rappporteur* for the fourth session.

The agenda of the meeting was approved with no changes or additions [CCT/20-06].

2 **Report from WG-CTh, Christof Gaiser (PTB)**

Dr C. Gaiser presented a combined report of the feedback from the Working Group meeting [CCT/20-68] and thermodynamic temperature data [CCT/20-50] as the two items are highly correlated.

Dr C. Gaiser (PTB) made first a feedback from the Working Group meeting [CCT/20-68] and recalled the Terms of reference. The meeting focused on the revision of the consensus values for $T - T_{90}$ from 4 K to 303 K and the status of sealed metal fix-point cells (SMFPCs).

An additional issue was the study of xenon for use in triple point cells where a recent working document by Dr P.M.C. Rourke *et al.* has demonstrated that Xe gas with sufficiently low content of Kr is now available from several providers, but more experience with cells for long-stem SPRTs is needed. [CCT/20-66].

Another issue concerned Ar contamination of O₂, where a sub-group within the WG-CTh will be formed to amend a working document drafted by Dr P. Steur (Italy) and Dr F. Pavese (Italy) [CCT/20-76]. It is likely that Dr B. Fellmuth (Germany), Dr P. Rourke (NRC) and Dr W. Tew (NIST) will take part, who will report the outcome.

Dr C. Gaiser drew attention to the recent publication “Direct comparison of ITS-90 and PLTS-2000 from 0.65 K to 1 K at LNE-Cnam” by Dr C. Pan *et al.* [CCT/20-70]. The outcome of this challenging study indicates that ITS-90 is wrong by 1 mK below 1 K. Therefore, in his conclusion, the recommendation of CCT, using either PLTS-2000 or PTB-2006, is independently confirmed, and the statement will be transferred to an open access CCT document prepared by the WG-CTh.

Dr C. Gaiser also presented a revised draft version of a *Recommendation* that the WG-CTh presents to the CCT [CCT/20-48rev], to be further discussed at the WG for Strategic Planning and at the CCT Session 5.

Coming back to the revision of the consensus values for $T - T_{90}$ from 4 K to 303 K, Dr C. Gaiser presented the consensus values of 2011. He gave an overview of recent results obtained using different primary techniques including dielectric constant, acoustic and refractive index gas thermometry. It was clear from the presentations given by WG-CTh members at the occasion of the WG meeting that much improvement had been reached and that there is a need for an update. All WG members agreed that an update of at least some portion of the temperature range is useful. However, no consensus was reached on how to use older data, and it was agreed that the PTB perform different evaluation schemes to extract new consensus values. These schemes should consider the traceability to the 2011 determination, but also simplicity. The first results of this evaluation will be discussed in an additional WG-CTh meeting early spring 2021.

The subject of SMFPCs was also vividly discussed at the WG meeting. The question is to which extent sealed cells require calibration, or alternatively if ITS-90 is directly realized using this type of cells. This question was raised because of “*Uncertainties in the realization of ITS-90 metal freezing-points using sealed cells*” https://www.bipm.org/utis/common/pdf/ITS-90/Guide ITS-90_2_4_MetalFixedPoints_Appendix-1_2018.pdf, drafted by Dr R. White (MSL) *et al.* and issued as the Appendix 1 to “*Metal fixed points for contact thermometry*” https://www.bipm.org/utis/common/pdf/ITS-90/Guide ITS-90_2_4_MetalFixedPoints_2018.pdf within the frame of *Guide to the realization of the ITS-90* <https://www.bipm.org/en/committees/cc/cct/publications-cc.html>. This latter document notably balances an uncertainty estimation including the possible impact by pressure effects, and the much smaller observed uncertainty of a larger set of fixed-point cells.

The WG agreed at the meeting that SMFPCs can be used to realize ITS-90 (although not at its highest level), the subject should be included in the *Guide* and remain under the responsibility of WG-CTh. Nevertheless, future guidance and documentation should be given by WG-CMC and could also be a subject for the TG-GoTh. The WG concluded by requesting an editorial change of section 2.4 and a revised Appendix 1, stating that either the SMFPC need an internal calibration, or the worst-case uncertainty should be applied. This position should be reflected in the Guides issued by WG-CMC and TG-GoTh.

Dr A. Peruzzi (NRC), being the origin for this question, and in his role as WG-KC Chair, made a survey amongst the CCT delegates in December 2020. This survey showed that most of the

delegates that replied (CEM, GULFMET, NIST, NMISA, NPL, NRC) were critical to making a calibration mandatory and only two institutes (NMIA and UME) supported calibration.

A longer discussion took place on pressure effects of SMFPCs. Dr M. Heinonen (MIKES) asked if there has been an observed problem with SMFPCs. Dr A. Peruzzi informed that most participants in key comparisons used open cells. Dr D. del Campo (CEM) considered that this is an issue for the WG-CMC and should be studied case-by-case. A user relying on one single SMFPC should need more precaution that the ITS-90 is correctly realized. It should be the WG-CMC to establish the rules how to support CMCs relying on the SMFPCs.

Dr A. Peruzzi expected that if a realistic uncertainty assessment were established there should be no problem. He noted that also open cells are not necessarily pressure-controlled, and the difference between the SMFPCs and open cells is that SMFPCs are attributed a larger uncertainty. Dr D. del Campo emphasized that the CMC review protocol for SMFPCs should clarify this point. Dr S. Rudtsch (PTB), recalling that depending on the temperature of the cell at the time of the sealing, the deviation can be as large as several millikelvin, noted that finding a realistic estimation of the pressure effect represents a problem, and in many cases the pressure effect is a major contribution to the uncertainty budget.

Dr A. Peruzzi considered that the estimation is the task of the institute, and the “worst case” should be indicated. Dr S. Rudtsch asked how a user may have any knowledge about the cell when buying it. Which values should be followed?

Dr E. van der Ham and Dr A. Peruzzi exchanged views on the difference in the degree of control of the pressure in the open and sealed cells as a primary realization. Dr S. Picard asked whether the CMC claims using SMFPCs were not supported by a comparison. Dr A. Peruzzi cited the NPL reply “*It is not helpful for NMIs, who have spent their hard-won money buying fixed points to establish their realization of the ITS-90, to be told that they have to spend more money getting their cells certified.*”. He highlighted that many institutes would not afford to have an open cell or several cells. Dr J. Zhang (NIM) indicated that NIM has sets of an open cell and 4 SMFPCs for all metal fixed points and that in intra-laboratory comparisons they have observed consistency within the uncertainties.

Dr C. Gaiser noted that in addition to the pressure effect, contamination is another possible source of uncertainty in SMFPCs. He identified a compromise where the worst case estimate is a good starting point for uncertainty for both issues.

Dr Y. Duan highlighted that comparison data could support a smaller uncertainty. Dr A. Peruzzi noted that comparison can support uncertainty estimation and check sealed cells, but he noted that the comparison result should not be used to apply corrections to the cells.

Dr J. Bojkovski (MIRS/UL-FE/LMK) asked if explicit information on whether the cell used for the CMC was open or sealed cell could be retrieved from the KCDB. Dr S. Picard indicated that, if that has been indicated during the review process, that was possible to retrieve.

Dr Y. Duan emphasized the need to make the realization of the ITS-90 available also for emerging metrology institutes, and that this should also be considered. He added that the WG report was very informative and congratulated for the findings on $T - T_{90}$ and observed that ITS-90 can be realized using SMFPCs.

3 On thermodynamic temperature data, Christof Gaiser (PTB)

Dr Y. Duan recalled the draft recommendation on “*Requirement for new determinations of thermodynamic temperature above 400 K*” [CCT/20-48rev] that was evoked at the previous agenda point. He encouraged to form a smaller group to agree on the draft recommendation contents, where Dr C. Gaiser (PTB) and Dr G. Machin (NPL), representing contact and non-contact thermometry, will collaborate on a revised draft that will be carried forward to the Strategic Planning Working Group meeting, and ultimately the CCT. They will be supported by a small group of delegates.

Dr M. Sadli (LNE-LCM/Cnam) commented on “Direct comparison of ITS-90 and PLTS-2000 from 0.65 K to 1 K at LNE-Cnam” the comparison of ITS-90 and PLTS-2000 [CCT/20-70], emphasizing that the users of ITS-90 need to highly aware the difference between ITS-90 and our current knowledge especially in this low temperature range.

Dr A. Peruzzi asked about the distinction between PLTS-2000 and thermodynamic temperature in this temperature range. Dr C. Gaiser clarified that those two are surely different, but the uncertainty of PLST-2000 is about half of millikelvin while the deviation of ITS-90 from either PLTS-2000 or thermodynamic temperature is about 1.5 mK, and in future there will be more work on $T - T_{2000}$ as well as $T - T_{90}$ in this temperature range.

4 Report from WG-Hu, Stephanie Bell (NPL)

Dr S. Bell started her report [CCT/20-72] by reminding of the Terms of reference. The members have increased from 18 to 20 since the last meeting, where Dr H. Abe (NMIJ AIST) now contributes as Vice chair. The WG met at the TEMPMEKO (Chengdu, China) in June 2019 and via an online meeting in December 2020.

She presented a summary of the full set of key and supplementary comparisons of the CCT and the RMOs having progressed, and reached approval for some, from 2014 until end of 2020. Notably, the CCT-K6 was completed in 2015, covering dew point from -50 °C to +20 °C, with 10 participants. There are presently two subsequent comparisons linked to the CCT-K6 which are being completed. There is also CCT-K8, covering dew points from 30 °C to 95 °C, also 10 participants, for which the Draft A is in progress.

Dr S. Bell identified the need for a repeat of the CCT-K6, which should of course not clash with other humidity comparisons carried out by the CCT or by RMOs. In fact, the APMP is already carrying out a repeat, APMP.T-K6.2013, that is well advanced.

The WG has discussed how to reduce the work to carry out the comparison within a coherent time frame; how to reach a fast completion; to carry out linkage when a comparison is staggered in time and how to align key comparisons to the CMC humidity. In addition, it has been observed by the APMP but is relevant to all RMOs that the uncertainty analysis is presented using different formats and a non-uniform support. This makes the CMC review particularly difficult. Due to this, some CMCs have mistakenly been approved at RMO level; that approval later being reversed at inter-RMO review.

Further, the present review protocol forces dew-point comparisons to be at small intervals (many measured points) due to the protocol allowing only small ranges of interpolation or extrapolation from comparison values. For this reason, the WG-Hu has been asked by CCT WG-CMC to review and propose amendments to review protocols for the dew point and relative humidity.

Dr S. Bell mentioned a heavy work program that is going on humidity quantities, units, symbols, and realizations. Notably, the draft of a document on humidity terms and definitions is progressing, to become available on the CCT web. Former relative humidity definitions have been unsatisfactory and have previously been discussed in several review papers in *Metrologia*:

- Metrological challenges for measurements of key climatological observables: oceanic salinity and pH, and atmospheric humidity Part 1: overview R. Feistel et al, *Metrologia* 2016 53 pp. R1 – R11
- Defining relative humidity in terms of water activity Part 1: Definition R. Feistel et al, *Metrologia* 2017 54 pp. 566-576

Alternative definitions based on relative fugacity are under consideration, and the relative humidity and its association with SI is in preparation for publication in *Metrologia*.

The WG-Hu is also completing a guide on uncertainty in humidity realizations, led by Dr J. Lovell-Smith (MSL).

A guide on primary humidity realizations is presently being outlined.

The WG-Hu has had a collaborative workshop with IAPWS and the BIPM in 2018 (17th ICPWS, Prague, Czechia). Dr J. Lovell-Smith and Dr S. Bell are both active within the Humidity working group on the Joint Committee on Properties of Seawater.

The CCT WG-Hu has collaborated with the CCQM on trace moisture in gases, within a small overlap of measurement range via the CCQM-K116, where the results demonstrated satisfactory equivalence.

Dr Y. Duan thanked Dr S. Bell for her presentation and the work of the working group and invited for questions.

During Dr S. Bell's presentation, she mentioned the International Symposium on Humidity and Moisture (ISHM) which was originally agreed to be held jointly with TEMPMEKO in 2023. Dr M. Sadli (LNE-LCM/Cnam) commented that the next TEMPMEKO planned to be in France, is compromised due to the Covid-19 crisis but a decision is still to be taken. Dr H. Yoon informed about the International Temperature Symposium 10 in 2023 and suggested that scheduling conflicts be avoided. Dr S. Bell noted that if the ISHM would be difficult to hold face-to-face, an online event would be organized.

Dr I. Yang (KRISS) referred to the bilateral comparison CCT-K6.1 and asked if the bilateral comparison indeed needs an RMO review, or if they could be reviewed directly by the CCT. Dr S. Bell said that it is not mandatory to go via the RMO as this particular comparison covers participants from two RMOs, but that it is possible.

Dr A. Merlone (INRIM) asked about progress on soil moisture and references. Dr S. Bell indicated the WG-Hu do not work directly on soil moisture. Dr A. Merlone suggested to form a group on soil moisture within the WG-Hu and bring this up to the Strategic Planning.

Dr S. Bell asked for the possibility to start a new comparison, a repeat of CCT-K6.

Dr Y. Duan suggested to discuss this issue at the WG-SP meeting.

5 AOB

Dr A. Peruzzi (NRC) announced that the Technical Protocol for CCT-K7.2021 has recently been approved by the CCT WG-KC and the measurements are presently being prepared, planned to start in April 2021.

Dr S. Picard indicated the amendment of CMC service 2.2.2 has been approved unanimously and the associated service list will be updated on the CCT web. She also informed that the Minutes of CCT Session 1 and 2 had been approved and will as such become the basis for the CCT report to the CIPM. She asked the delegates to submit the comments, if any, for the Minutes of CCT Session 3 before the deadline for approval of the Minutes.

Dr Y Duan noted that the “Guidelines of CCT comparisons” has been approved unanimously and will be uploaded as a guidance document on the web.

Dr Y. Duan recalled the request for member status made by NSC IM (Ukraine) and observer status made by CSM (Hong Kong, China). Based on feedback from the CCT delegates he concluded that the CCT discourage a full member status for NSC IM (Ukraine) but instead encouraged NSC IM to become an Official observer while increasing their research activity. The CCT supported SCL (Hong Kong, China) to become an official observer. Dr Y. Duan will forward these recommendations to the CIPM for their consideration at their next meeting in March 2021.

Dr S. Picard informed that the updated guidance and policy documents of BIPM, on subjects such as key comparisons and CMCs, have been approved and uploaded on the BIPM webpage.

6 Scientific presentation, G. Machin (NPL)

Dr G Machin presented “Realising the redefined kelvin – a EURAMET perspective” [CCT/20-73].

After Dr G. Machin’s presentation, Dr Y. Duan thanked for the talk and invited for questions and comments.

Dr F. Sparasci (LNE-LCM/Cnam) highlighted the part on “improvement of the ITS-90 to extend its lifetime” in Dr G. Machin’s talk, and pointed out that such an approach could be included in the CCT recommendation. Dr G. Machin responded that he and Dr C. Gaiser together will find a way to add this point to the draft CCT recommendation.

Dr M. Heinonen (MIKES) commented that even primary realizations still need to demonstrate the traceability of the measurement.

Dr H. Yoon pointed out the wording of “life extension” of the ITS-90, suggesting more positive wordings be used. He also highlighted that there exist commercial systems, especially in the low temperature range, in which primary thermometry such as noise thermometry is incorporated, and thus no additional calibration is required. Dr M. Heinonen responded that the traceability requires demonstration of correct uncertainty assessment and the level of uncertainty concerned matters.

Dr C. Gaiser commented on the magnetic field flux thermometer, which is already used as a relative primary thermometer, and that PTB is working on an absolute primary thermometer using the same technique. He commented that they have traceability in both cases.

7 Actions and Decisions

The following actions were identified during the session:

Actions:

- CCT29/A1. TG-GoTh and WG-CTh to update the appendix on SMFPC in the Guide to the ITS-90 to include considerations on uncertainty assessment using worst case deviation using SMFPCs.
- CCT29/A2. WG-CMC to consider revising the relevant CMC review protocols to take into account new information and outcome of the discussion on the realization of ITS-90 using SMFPCs.

*Dr I Yang, Rapporteur
February 2021*