

Bureau International des Poids et Mesures

# Consultative Committee for Thermometry (CCT)

Report of the 28th meeting  
(1 – 2 June 2017)  
to the International Committee for Weights and Measures



Comité international des poids et mesures

**LIST OF MEMBERS OF THE  
CONSULTATIVE COMMITTEE FOR THERMOMETRY**

as of 1 June 2017

**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.

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)**

Czech Metrology Institute [CMI], Prague.

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

## 1. **OPENING OF THE MEETING; APPOINTMENT OF THE RAPPOREUR; APPROVAL OF THE AGENDA**

The twenty-eighth meeting of the Consultative Committee for Thermometry (CCT) took place at the International Bureau of Weights and Measures (BIPM), Pavillon de Breteuil, Sèvres, on 1 and 2 June 2017.

The following were present:

M.G.A. Abdalla (NIS), Z. Ahmed (NIST), I. AlFaleh (SASO), J. Alves e Sousa (IPQ), M. Anagnostou (EMI), S. Bell (NPL), P. Bloembergen (NIM), J. Bojkovski (University of Ljubljana), J.D. Brionizio (INMETRO), N.P. Cele (NMISA), D. Del Campo Maldonado (CEM), Y. Duan (NIM / CIPM / President of the CCT), R. Feistel (Leibniz Institute for Baltic Sea Research), E.K. Ejigu (NMISA), B. Fellmuth (PTB), V.C. Femicola (INRIM), J.R. Filtz (LNE-Cnam), J. Fischer (PTB), R.M. Gavioso (INRIM), E. van der Ham (NMIA), M. Heinonen (MIKES), Y. Hermier (LNE-Cnam), J. Hollandt (PTB), W. Joung (KRISS), M. Kalemci (UME), S. Kondratev (VNIIM), T. Kopunec (SMU), A. Kowal (INTiBS), V.G. Kytin (VNIIFTRI), G. Machin (NPL), M. Matveyev (VNIIM), E. Mendez Lango (CENAM), A. Merlone (INRIM), C. Meyer (NIST), M.J.T. Milton (Director of the BIPM), T. Nakano (NMIJ/AIST), P. Pavlasek (SMU), J.V. Pearce (NPL), A. Peruzzi (VSL), A. Pokhodun (VNIIM), J. Qu (NIM), P.M.C. Rourke (NRC), C.A. Sanchez Morales (INM Colombia), N. Sasajima (NMIJ/AIST), P. Saunders (MSL), A. Shchipunov (VNIIFTRI), F. Sparasci (LNE-Cnam), R. Strnad (CMI), P.P.M. Steur (INRIM), A. Szmyrka-Grzebyk (INTiBS), A.D.W. Todd (NRC), M. Vinge (VNIIFTRI), L. Wang (A\*STAR), Y. Yamada (NMIJ/AIST), I. Yang (KRISS), H. Yoon (NIST), Z. Yuan (NIM), J.T. Zhang (NIM), D. Zvizdic (HMI).

Also present: J. Miles (BIPM), S. Picard (Executive Secretary of the CCT), N. Zviagin (Executive Secretary of the JCRB).

Excused: Y.G. Kim (KRISS), G.F. Strouse (NIST), D.R. White (MSL).

The President of the CCT, Dr Y. Duan opened the meeting and welcomed the participants. Dr Y. Duan noted that at all CCT criteria have been met for the redefinition of the kelvin, and that the 28th meeting of the CCT is an historic event focused on preparations for the redefinition. Drs P.M.C Rourke and A.D.W Todd (both NRC) were appointed *rappporteur*. The agenda of the meeting was approved with no changes or additions.

The Director of the BIPM, Dr M. Milton, welcomed the participants.

## 2. **CIPM Update**

Dr M. Milton, Director of the BIPM gave an update from the CIPM. This report included information relating to the revision of the *Mutual Recognition Agreement* (CIPM MRA) and clarification on Consultative Committee membership rules: Member States now have the right for one national laboratory charged with establishing national standards in the field to be an observer; international organizations will be considered “liaisons”, not members; and named individuals will be “guests” or “experts”, not members. He also gave information about the joint

CCM and CCU roadmap to 2018 where the CCM recommendation G1 is now accessible on the BIPM website. The redefinition will come into force on 20 May 2019. An updated *Mise en Pratique of the Realization of the Kelvin (MeP-K)* will be ready by 31 July 2017. The CCU has drafted a joint statement regarding the redefinition to which the CCT has contributed.

### 3. REPORT OF THE 27TH MEETING OF THE CCT 2014

The Executive Secretary of the CCT, Dr S. Picard (BIPM), recalled that the report of the 27th meeting of the CCT (2014) had been approved by all delegates by e-mail. The status of the actions which arose from the 26th meeting (see CCT/SUMM-2012rev) was as follows:

CCT27/A1: *The Chairs of the newly formed working and task groups will suggest candidates for membership to the CCT President for approval.*

Status: Complete.

CCT27/A2: *The Chairs of the newly formed working and task groups will draft terms of reference to be communicated to the CCT President for approval.*

Status: Complete.

CCT27/A3: **TG<sup>1</sup>-K** is to continue to draft successively the revision of the "Guide for Realization of the ITS-90" to be completed in **2015**, and submit the chapters to the CCT for advice and approval.

Status: Complete.

CCT27/A4: **TG-GoTh** is to make a limited revision of the uncertainty document on SPRTs (keeping the 2008 label) and continue the revision of the Guide to Secondary Thermometry (formerly Techniques for Approximating the ITS-90).

Status: The uncertainty document on SPRTs has been abandoned, but the Guide for the Realization of the ITS-90 supersedes it; preparation of the Guide to Secondary Thermometry is in progress.

CCT27/A5: **WG<sup>2</sup>-KC** will enlarge its membership and aim to involve members of all RMOs.

Status: Complete.

CCT27/A6: **All participants will deliver all data** (initial and final measurements) **by the end of 2014.**

Status: Complete.

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<sup>1</sup> Task group

<sup>2</sup> Working Group

CCT27/A7: *Six participants of the CCT-K9 will deliver initial data before **end of June 2014**, and all participants will deliver all data (initial and final measurements) by the end of 2014.*

Status: Complete.

CCT27/A8: *A Special Issue of Metrologia on the Boltzmann constant will be co-edited by D.R. White (MSL) and J. Fischer (PTB), working with around 20 groups of authors. It is to be published in **2015**.*

Status: Complete.

## **4. Redefinition of the kelvin**

### **4.1 Introduction**

The CCT President, Dr Y. Duan (NIM) noted the large contribution to this work from the participants.

### **4.2 Acoustic Gas Thermometry, Roberto Gavioso (INRIM)**

Dr R. Gavioso gave a presentation summarizing the history, milestones and current status of acoustic gas thermometry (AGT) [CCT/17-29].

### **4.3 Dielectric Constant Gas Thermometry, Bernd Fellmuth (PTB)**

Dr B. Fellmuth gave a presentation outlining the history and motivation for dielectric constant gas thermometry (DCGT), its fundamentals, difficulties and results [CCT/17-30].

Dr Y. Duan noted the important contribution that DCGT had made towards meeting the CCT criteria for redefinition because it is the second independent method with low uncertainties that was used to measure the Boltzmann constant.

### **4.4 Noise Thermometry, Jifeng Qu (NIM)**

Dr J. Qu gave a presentation outlining the use of Johnson noise thermometry (JNT) to determine the Boltzmann constant [CCT/17-31]. He discussed the difficulties, required accuracies and recent results.

#### 4.5 Report from TG-SI, Joachim Fischer (PTB)

Dr J. Fischer gave a presentation summarizing the Boltzmann constant determination work including the new results obtained in the past year from LNE-Cnam (AGT), NPL (AGT), INRIM (AGT), NIM (AGT), PTB (DCGT), NIM/NIST (JNT) and University of Naples (DBT) [CCT/17-28]. He noted that for the CCT, all the conditions for redefinition have been met.

#### 4.6 Report from TG-K (*MeP* only), Bernd Fellmuth (PTB)

Dr B. Fellmuth presented an overview of the revision to the *MeP-K*, the effects of the redefinition, and the criteria for inclusion of a technique in the *MeP-K* [CCT/17-32].

### 5. CCT Strategy

#### 5.1 Report from the Working Group on Strategic Planning

Dr S. Picard gave a report from the WG-SP, which is chaired by the CCT President, Dr Y. Duan [CCT/17-43]. She indicated that the *MeP-K* is to be communicated to the CCU for their meeting in September 2017 and that the appendices will be completed by December 2017.

Dr S. Picard gave feedback from the WG and TG chairs, and an overview of the CIPM MRA review and KCDB.

She reviewed the TGs and WGs that have proposed updates to their Terms of Reference and Tasks. It was noted that Dr J. Fischer will step down from his role as chair of WG-CTh and Dr C. Gaiser (PTB) was nominated to replace him.

It was proposed that TG-Env be changed into a working group to allow it to make the long-term plans and commitments required by other bodies.

Dr J. Fischer was invited by Dr Y. Duan to coordinate the revision of the CCT's Strategic Plan, to be completed by December 2017. This document is to be updated every four years, to align with the timing of CGPM meetings.

There were requests to close TG-SI, TG-K, and TG-SMFPC, as their tasks have been completed.

The TG-NCTh-CMC and TG-NCTh-HTFPU under WG-NCTh will continue until December 2017.

The creation of a new TG on photonic thermometry was proposed.

#### 5.2 Discussion

Dr Y. Duan noted that it is time to revise the CCT's Strategic Plan. He invited Dr J. Fischer to coordinate this revision with the members of WG-SP. Dr Y. Duan commented that it should prioritize the main tasks and focus for the future and he suggested that the requirements of industry and environmental bodies should be taken into consideration.

Dr Z. Ahmed (NIST) outlined some of the aspects of photonic thermometry and noted that primary and relative measurements are possible and that commercial products are already

available. He expressed the desire that industry should not out-pace the CCT. Dr Y. Duan invited Dr Z. Ahmed to submit some references about photonic thermometry.

Dr H. Yoon (NIST) noted the existence of a EURAMET proposal for research into photonic and quantum correlation thermometers, and ongoing work in this area at several NMIs.

Dr A. Peruzzi (INRIM) asked for an explanation of the physical principle. Dr Z. Ahmed explained that there are a number of techniques, for example in the index of refraction and changes in the optical resonances in a Bragg grating or ring resonator revealed by a mode-locked laser.

Dr Y. Hermier (LNE-Cnam) indicated that LNE has plans for work in this area but considering the early state of this research field wondered whether a CCT TG was the most appropriate forum to discuss this research, particularly if the TG activities involved only exchanging information. Dr H. Yoon mentioned that commercial fibre grating thermometers are already available: companies are buying these thermometers then asking NIST how to calibrate them.

Dr M. Heinonen (MIKES) expressed support for the formation of the TG and indicated that MIKES was also working in this area but wondered what the specific tasks of the proposed TG should be. Dr Y. Hermier requested clarification about the real goal of the proposed TG, and wondered whether there are enough NMI experts for real progress toward the goal.

Dr V. Fericola (INRIM) suggested that a forum was needed to monitor new technologies.

Dr Y. Duan invited Drs Z. Ahmed and H. Yoon to prepare a brief presentation and to draft the terms of reference and tasks for the proposed TG ready for the second day of the meeting.

## 6. Recommendation from the CCT

### 6.1 Recommendation T1 from TG-SI (CCT/17-16)

This draft recommendation [CCT/17-16], issued by the task group for the SI, is a follow-up from the 2014 recommendation adding that now that the conditions for redefinition have been met and the *MeP-K* is complete, the CCT recommends that the CIPM bring to the attention of CODATA the new data for adjustment and recommends the use of eight digits for the Boltzmann constant to redefine the kelvin.

Dr M. Milton commented that the recommendation should include a statement that the temperature of the triple point of water (TPW) will be 273.16 K at the time of redefinition. He suggested a simple, explicit statement indicating that the criteria for redefinition have been met and to reword the second item under 'recommends' to reflect that CODATA meets before the CIPM.

Dr I. Yang (KRISS) asked about the number of zeros after 273.16. Dr J Fischer indicated that the number will not be specified and Dr M. Milton noted that future primary thermometry measurements of the TPW to reduce the uncertainty of the TPW could change the number of digits. Dr Y. Duan noted that people can measure the thermodynamic temperature of their own TPW cells. Dr M. Milton said that the TPW temperature of 273.16 K is cited in many textbooks and must not change through the redefinition.



## 6.2 Recommendation T2

The draft recommendation CCT T2 was presented by Dr G. Machin (NPL) and was intended to encourage NMIs to continue their work after redefinition and to take advantage of the redefinition and *MeP-K* to realize  $T$  and  $T_{90}$ .

Dr P. Steur (INRIM) asked whether the CCT endorses multiple laboratory scales. Dr G. Machin replied that different methods for realizing temperature are endorsed but not different scales.

Dr M. Milton asked what action the CIPM should take based on this resolution and recommended that this recommendation be combined with Recommendation T1. Dr M. Milton noted that this is a good initiative since after redefinition all NMIs can get involved in primary thermometry. Dr A. Merlone (INRIM) noted that combining T1 and T2 reduces duplication of background information. Dr G. Machin and Dr J. Fischer agreed to revise and combine T1 and T2. See Section 12 below for further discussion of the resulting single combined recommendation (called T1).

## 7. Revision of the CIPM MRA

Dr S. Picard (KCDB coordinator) presented the upcoming revision to the KCDB. The revision is based on the 2016 recommendations issued by the [Working Group on the Implementation and Operation of the CIPM MRA](#) (as a follow up to CGPM resolution R5 2014). Some of these recommendations concern:

- Better consistency in CMCs and uncertainty expressions;
- Results of KCs and SCs should be interpreted as widely as possible;
- CMCs should cover as many services as technically justified, so that CMCs become representative rather than comprehensive;
- CCs and NMIs are encouraged to use uncertainty equations and matrices;
- Revise the KCDB web interface and search;
- Risk-based approach on CMC review (CCT has done this);
- More training and guidance material; and
- Web-based tool for complete CMC submission and review, with tracking.

The set of specifications for the KCDB 2.0 is presently the subject of a call for tenders.

Dr S. Picard outlined the new features of the KCDB 2.0 including:

- Improved searching
  - Search for measurands and uncertainty ranges;
  - Improved thesaurus.
- Web-based CMC submission with:
  - Risk-based evaluation included;
  - Support for intra- and inter-RMO review;
  - Batch submissions replaced by one-by-one submission;
  - Broad-scope CMCs to be considered.
- User friendly web support
- Possibility to track comparisons in real time
  - using a web-form that prompt pilots for updates every six months.

Dr S. Picard noted that a time slot to convert to KCDB 2.0 will need to be determined in order to minimize disruption to CMCs being added or changed.

Dr Y. Duan noted that the new features will better serve the users of the KCDB.

## 8. Comparisons

### 8.1 Report from WG-KC, Andrea Peruzzi (VSL)

Dr A. Peruzzi presented the activities of the WG-KC since the 2014 CCT meeting [CCT/17-40 and 58]. He reviewed the terms of reference and tasks for the WG and proposed the removal of Task 3 (“advising the pilot laboratory about the preparation of a comparison status document”) and to modify Task 4 to read “review and comment on supplementary comparison Draft B reports and Technical Protocols on request”.

He discouraged consulting the WG-KC only at the last stage of comparisons.

Dr A. Peruzzi acknowledged Mr K. Hill’s (NRC) work in the past, which substantially increased the efficiency of the WG, and all members thanked him for his contribution. He added that since 2014 the WG membership has been expanded to include four new members.

Dr A. Peruzzi gave statistics on the number of comparisons since May 2014:

- 50 comparisons that were treated;
- 18 approved comparisons;
- 2 declared abandoned;
- 27 new comparisons initiated (two from GULFMET);
- 25 “silent comparisons” - no communication since May 2014.

There are presently a total of 111 thermometry comparisons in the KCDB, of which 36 were approved between 1999 and 2014.

Dr A. Peruzzi noted that there is no requirement to ‘freeze in’ historical practices that may be obsolete in new KCs (for example, new RMO-level KCs). The WG will consider this and not require exact copying of a previous protocol as long as the linking is not affected (for example, the link between the RMO KC to the preceding CIPM KC).

Dr A. Peruzzi introduced the new Protocol and Report templates that follow the requirements of document [CIPM-MRA-D-05](#) and noted that they may be of use to other CCs. Dr M. Heinonen commented that the templates are very useful.

Dr A. Peruzzi discussed the sustainability of maintaining three reviewers per document, given the increased workload: three reviewers is still a good approach, but can drop down to two reviewers for e.g. supplementary comparisons.

Dr A. Peruzzi showed a list of so-called “silent comparisons” for which there has been no communication from the pilot in three years. Dr S. Picard noted that for the CCT-level comparisons in this list, the pilots have been contacted. The WG-KC chair agreed to follow up with the RMOs and send the CCT President an update (see CCT28/A4). Dr M. Milton commented that the focus should be on a plan to complete the comparisons, not just whether they are “silent” or not. He highlighted that NMI directors do not want comparisons to take

longer than five years and that there is a risk that the JCRB/CIPM may cancel very long-running comparisons. He asked that the WG supports the CCT president by updating him about these comparisons.

Dr M. Milton asked about the review of SCs specifically related to CCT SCs. Dr A. Peruzzi agreed that these should be reviewed as if they were CCT KCs. Dr M. Milton suggested to not change the ToR and to encourage the review of SCs by the WG-KC.

## 8.2 Reported comparisons since the 2014 meeting

Dr H. Yoon gave an update on the [CCT-K9](#) comparison piloted by NIST. He noted that there is a pre-Draft A report with tentative KCRVs but there are unexplained drifts in some of the thermometers.

Dr A. Peruzzi noted that in the pre-Draft report not only the measurements performed by the institutes before sending the SPRT to the pilot are used for the analysis but also the measurements made when the SPRT has been returned. The “return measurements” were not used for the [CCT-K3](#) comparison and their inclusion is not described by the protocol. Dr H. Yoon agreed to convey this to the team at NIST.

Dr S. Picard asked about the time-line for completion and Dr H. Yoon indicated that comments on the pre-Draft A are required from the participants by the end of June 2017, Draft A will be distributed to participants by the end of August 2017, and Draft B will be completed by the end of October 2017. Dr Y. Duan noted that CCT-K9 has already been in progress for six years, and that some comparisons have already exceeded 10 years, so time-lines for comparison completion are needed.

Dr S. Bell (NPL) gave an update on the [CCT-K8](#) comparison, noting that things are going well. The original one-loop format was changed to two-loops and intermediate checks indicate that the travelling instrument drift is acceptable. She mentioned that the instruments needed to be overhauled by the manufacturer but a Draft A was likely to be available by the end of 2017, and that the comparison should be completed before the next CCT meeting.

## 8.3 Future comparison proposals

Dr Y. Duan invited proposals for new comparisons. Dr A. Peruzzi suggested repeating [CCT-K7](#) (Comparison of water triple point cells). Dr M. Kalemci (UME) suggested repeating [CCT-K4](#) (Comparison of local realizations of Aluminum and Silver freezing-point temperatures). Dr P.P.M. Steur suggested repeating [CCT-K2](#) (Realizations of the ITS-90 from 13.8 K to 273.16 K).

Dr Y. Duan suggested that the matter be discussed during the next coffee break and a decision be made later in the meeting (see 11.1 Report from WG-CTh). It was decided that CCT-K7 was the highest priority and NMIs should consider piloting with a start date in 2018-2019. It was noted that there was limited interest in CCT-K4 and that the CCT should not consider a repeat of CCT-K2 for at least five years. Dr J. Fischer mentioned that it is hard to agree to do more until the final results of CCT-K9 are known, and Dr B. Fellmuth noted that a comparison of cryogenic fixed points was done in 2012 and there is very little interest in repeating CCT-K2 now.

## 9. Regional Metrology Organizations (RMOs)

### 9.1 Report from CCT Working Group for Calibration and Measurement Capabilities (CCT WG-CMC), Dr J. Bojkovski (University of Ljubljana)

Dr J. Bojkovski presented the work of the WG-CMC since the last CCT meeting [CCT/17-45]. He noted that Mr G. Strouse (NIST) had stepped down as chair at the meeting of the WG in Zakopane (Poland) and Dr J. Bojkovski had accepted the task. Dr J. Bojkovski noted that it takes too much time for the reviews to complete final decisions and that there have been some issues with Quality System chairs not submitting the approvals for laboratories' quality systems.

Dr J. Bojkovski mentioned the review of the CMC review protocol for radiation thermometry by the TG-NCTh-CMC and asked that RMOs review the protocol. There was a comment by Mr Y. Yamada, the TG-NCTh-CMC chair that the protocol is still being finalized by the TG and should not be reviewed by the RMOs until it is complete. Dr J. Bojkovski also discussed the new CMC review protocol for thermophysical properties.

Dr J. Bojkovski outlined the need for harmonization of inter-RMO reviews as there are different interpretations by different RMOs. The RMOs should be stricter when preparing information for review and each RMO should prepare a list of interpretations.

Dr J. Bojkovski indicated that the next meeting of the WG would be held in conjunction with the TEMPMEKO/Tempbeijing conference in China in 2019.

Dr M. Milton mentioned that all CCs are encouraged to use a risk-based approach to CMCs, and that the CCT is taking a lead in this area.

### 9.2 Report from the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB), Nikita Zviagin

The JCRB Executive Secretary, Mr N. Zviagin reported on behalf of the JCRB [CCT/17-56]. The JCRB meets every six months and he reported on some of the completed initiatives such as the joint metrology school and METAS project, the 2016 Capacity Building and Knowledge Transfer "leaders of tomorrow" project, the BIPM-GULFMET TC workshop, and the BIPM-EURAMET TC leadership course. He reminded the CCT that the CIPM MRA documents are available on the website and mentioned a modification to D-04 and an update to the reference to ISO Guide 17034.

Mr N. Zviagin noted that CMC reviews can be viewed using the guest logon.

Mr N. Zviagin gave some statistics on thermometry CMCs:

- All CMC sets since May 2014: 146, nine in thermometry
- Average time for reviews 72 days, median 61 days (good compared to other CCs)
- 12 KCs and 11 SCs incomplete and older than five years.

## 9.3 Reports from regional organizations

### 9.3.1 AFRIMETS

Dr E. Ejigu (NMISA) presented an update of the activities of AFRIMETS [CCT/17-37]. He gave an overview of the capabilities of the labs in AFRIMETS, and noted the challenges within AFRIMETS due to language barriers. Dr E. Ejigu presented the four comparisons currently under way and the four that are planned. He gave an overview of the training and capacity development and CMC submission activities in the RMO.

### 9.3.2 APMP

Dr W. Li (A\*STAR) presented an overview of APMP and outlined its structure and recent activities [CCT/17-39]. She described the meetings and workshops organized by APMP and a project aimed at developing countries in the region. It was noted that APMP requires that all KCs and SCs are reviewed by both the RMO and CCT-WG-KC. Dr W. Li reported on the status of APMP comparisons and peer reviews. She introduced two ideas being discussed in APMP related to combining peer reviews and intra-RMO review and the possibility of a paid comparison. Dr H. Yoon asked what a paid comparison was and expressed concerns that labs might keep paying to repeat comparisons if they found the first result unsatisfactory. Dr W. Li responded that the APMP is developing guidelines and the issues will be brought up at a future JCRB meeting.

### 9.3.3 COOMET

Prof. A. Pokhodun (VNIIM) reported on the activities, members and comparisons under way within COOMET [CCT/17-34]. He also gave an overview of the CMC situation in COOMET.

### 9.3.4 EURAMET

Prof. G. Machin (NPL) presented an overview of the structure, meetings and workshops held since 2014 within EURAMET [CCT/17-36]. He outlined the InK project [CCT/17-26] to improve primary thermometry between 1 mK and 3000 K, and the EMPRESS project to improve industrial and process temperature sensors. Prof. G. Machin then outlined the plans for 2018 which included: a new TC-T chair, Dr D. del Campo (CEM); the InK2 project (ending May 2019); preparations for EMPRESS 2; a workshop for the redefined kelvin; a summer school in 2018 for next generation thermal metrologists within the EURAMET region; and revising the EURAMET roadmaps.

### 9.3.5 GULFMET

Dr M. Anagnostou (EMI) listed the current Member States of GULFMET (Kingdom of Bahrain, State of Kuwait, Sultanate of Oman, State of Qatar, Kingdom of Saudi Arabia, United Arab Emirates, and Republic of Yemen) and noted that the GULFMET TC-T was established in November 2015 [CCT/17-38]. He outlined the main tasks, noted that the TC-T has a WG for review of CMCs and outlined the capabilities of EMI (United Arab Emirates) and SASO (Kingdom of Saudi Arabia). Dr M. Anagnostou listed the comparisons under way in GULFMET.

### 9.3.6 SIM

Dr E. Mendez (CENAM) presented the activities of the SIM TC-T and noted that there had been a change in the chair since May 2014 [CCT/17-35]. He mentioned that there had been a meeting in September 2016 and outlined the running and planned comparisons. Dr E. Mendez outlined the CMCs submitted and under review and the training activities within SIM.

## 9.4 Résumé on collaborations

This section was intended to discuss the EURAMET InK project, but since Prof. G. Machin presented this during the EURAMET report, no further discussion was necessary.

## 10. Report from Working Groups and Task Groups

### 10.1 Report from CCT Working Group for Contact Thermometry (CCT WG-CTh)

Dr J. Fischer reported on the activities of WG-CTh since May 2014 [CCT/17-44 and 57], and noted that a subgroup for Supplementary Material for  $T-T_{90}$  had been formed (chaired by Dr M. de Podesta). In relation to the working document “Towards ITS-XX”, Dr J. Fischer mentioned that the WG-CTh felt that a new temperature scale was not needed at this time. Dr J. Fischer noted that contact thermometry activities had previously been split between WG-CTh and TG-K; with the present proposal to close TG-K, ongoing contact thermometry work will reside within WG-CTh.

Dr J. Fischer followed up on discussions from the previous day of the 28th CCT meeting regarding key comparisons:

- [CCT-K2](#) should not be repeated within the next five years; refer to the recent star intercomparison of cryogenic fixed points.
- Links to [CCT-K4](#) can be accommodated via bilateral comparisons.
- Repeating [CCT-K7](#) is the highest priority, and NMIs should consider piloting this comparison, to start in 2018-2019. This comparison should take advantage of the new TPW isotopic corrections.

Dr J. Fischer reported on the current status of  $T-T_{90}$ . He gave an overview of the current status and noted that its last update was in 2011, giving an outline of new measurements carried out since 2011 and planned measurements. Dr J. Fischer highlighted the paucity of data from 40 K to 80 K. New results show no change in the slope at the triple point of water. He suggested waiting for Ink2 for values above 500 K.

Dr J. Fischer gave an overview of problems with PLTS-2000 and of the new activities in that range.

## 10.2 Report from CCT Working Group for Non-Contact Thermometry (CCT WG-NCTh)

Prof. G. Machin reported on the activities of the WG and described proposed changes to the ToRs to include the review and reporting of  $T-T_{90}$  [CCT/17-21 and 42]. He also gave an overview of membership changes, meetings since May 2014 and the documents produced. He reported on the TGs within the WG and gave an update on the [CCT-K10](#) comparison, indicating that the measurements were expected to be completed by April 2018 and a Draft A completed by the end of 2018. Prof. G. Machin suggested that a WG meeting and a half-day workshop on InGaAs detectors be held in conjunction with the IMEKO World Congress in September 2018.

There was a comment from Dr B. Fellmuth to ensure that the update to the ToRs uses the new nomenclature for the Guide for Thermometry.

### 10.2.1 Report from CCT Task Group for Non-Contact Thermometry CMCs (CCT TG-NCTh-CMC)

Mr Y. Yamada presented the work of the task group to revise the radiation thermometry CMC review document to include a new class of services for disseminating  $T$  and ITS-90 by high-temperature fixed points. He said that it will utilize the CCT  $T-T_{90}$  recommended values and showed a revised “classification of services”. He outlined a CMC review protocol for radiation thermometry thermodynamic temperature dissemination in three forms:

- Absolute  $T$  measurements
- Relative  $T$  measurements
- Conversion from  $T_{90}$  to  $T$  using the CCT correction function.

### 10.2.2 Report from CCT Task Group for Non-Contact Thermometry HTFP Uncertainties (CCT TG-NCTh-HTFPU)

Dr A. Todd reported on the status of the activities of the TG to compile a list of the uncertainty components related to high temperature fixed points. He indicated that the values arrived at by this task group will feed into the TG-NCTh-CMC and to the work of Dr P. Saunders’ TG to develop a document relating to high temperature thermodynamic temperature measurement. Dr A. Todd indicated that a revised document would be distributed to the TG-HTFPU by the end of June 2017.

### 10.3 Report from CCT Working Group for Humidity (CCT WG-Hu)

Dr S. Bell presented a report from WG-Hu and noted that there were no changes to the ToR, but a reference to [CCT-K8](#) was added to the tasks [CCT/17-41]. She noted that the membership was stable at 18 and gave an update on humidity comparisons. She also mentioned that WG-Hu is considering how to reduce the effort required for KCs (reviewing frequency and speed of completion), and considering the linkage between comparisons that are staggered in time. Dr S. Bell brought forward an issue with definitions in humidity especially with the ambiguity of existing relative humidity definitions; WG-Hu is looking into a new definition based on relative fugacity.

Dr S. Bell noted that relative humidity is not mentioned in the SI Brochure. She acknowledged the contribution of the International Association for the Properties of Water and Steam (IAPWS) in the WG and mentioned that the next International Symposium on Humidity and Moisture (ISHM) event is under discussion.

Dr M. Milton commented that the SI brochure has a section that deals with non-SI units but to have the unit for relative humidity included, a strong historical case would be required for CIPM approval (as is being considered for the bar and mmHg). Dr H. Yoon suggested that the non-uniqueness of the definition of relative humidity should be resolved before adding it to the SI brochure. Dr S. Bell commented that the symbol for relative humidity could be defined in the SI brochure before the problems related to the relative humidity definition are resolved. Dr M. Milton replied that the SI deals with quantities, not only symbols, but if the CCT works to deal with the non-uniqueness of the definition and then makes a recommendation to the CIPM, relative humidity might cross the threshold of CIPM interest. Dr M. Milton suggested that the unit for relative humidity could be defined by ISO. Dr Y. Duan agreed to raise the issue with the CIPM but this action will require a preferred definition to be agreed by the CCT/WG-Hu. Dr M. Milton noted that it is important to be careful that the unit does not specify the quantity: the reactive power unit “var” should be considered as a cautionary example, since it is widely used but was rejected for inclusion in the SI brochure.

### 10.4 Report from CCT Task Group for the Realization of the Kelvin (CCT TG-K)

Dr B. Fellmuth noted the tasks of the TG are complete and the TG should be closed and thanked the members for their contributions [CCT/17-10 and 48]. The activities of the TG are summarized in CCT/17-10. He outlined the changes to the documents *Guide to the Realization of the ITS-90* and the *MeP-K*. Dr B. Fellmuth commented that appendices 2, 3, and 4 to section 2.1 of the Guide need to be revised by the WG-CTh and that an appendix to section 2.4 of the Guide based on the report from the TG-SMFPC should be prepared. He gave an overview of the new chapter 3 of the Guide dealing with vapour pressure scales and pressure measurements.

Dr B. Fellmuth noted that Chapter 5 of the Guide has been updated and that it was a huge job. He suggested that the CCT/08-19-rev document be moved to the restricted area of the BIPM CCT website because it is obsolete and the latest version of the material is contained in the Guide.



Dr B. Fellmuth gave an overview of the status of the Guide and noted that all documents were approved by the CCT since there were no comments. Dr Y. Duan noted the achievements of the TG.

### 10.5 CCT Task Group for Environment (CCT TG-Env)

Dr A. Merlone presented the work of the TG and noted that a number of the Essential Climate Variables (ECVs) defined by the World Meteorological Organization (WMO) are related to temperature and humidity [CCT/17-49]. He noted the members of the TG and its involvement with other international bodies. Dr A. Merlone (INRIM) gave an overview of the laboratory and field work that is ongoing in this area and the different projects and joint meetings. He suggested a discussion to improve the VIM definition of *traceability* and invited comments from interested parties. Dr Merlone asked the CCT WG-SP to include a statement related to climate in its revision of the strategic planning document.

Dr Y. Duan noted that this is an important topic and encouraged others to contribute to climate measurements. He requested that those who attended the TG meeting formally join the TG. Dr M. Milton cautioned against making people partners if they are not associated with an NMI. Dr A. Merlone noted that the WMO has signed the CIPM MRA. Dr M. Milton replied that it should be confirmed that Prof. P. Thorne has formal designation from the WMO.

### 10.6 Report from CCT Task Group for Thermophysical Quantities (CCT TG-ThQ)

Dr J.-R. Filtz (LNE-Cnam) reported on the membership and meetings since 2014, and reviewed and reported changes to the ToRs as suggested by WG-SP [CCT/17-47]. He reviewed the comparisons that are under way and planned. He noted that questionnaires to collect the capabilities, range, interest, grand challenge drivers and detailed needs of NMIs will be circulated within TG-ThQ in three areas: thermal expansion coefficient (prepared by Mr S. Kondratev of VNIIM), calorific value (prepared by Dr E. Korchagina of VNIIM), and heat flux density (prepared by Dr H. Yoon of NIST). Prof. G. Machin asked that the heat flux density questionnaire be sent to the entire CCT and not just the TG-ThQ. Dr S. Picard asked whether the proposed comparisons will be Key Comparisons, Supplementary Comparisons or Pilot Studies. Dr J.-R. Filtz replied that this was under discussion within the TG. Dr Y. Duan noted that there has been some growth in the area of chemistry for thermometry.

### 10.7 Report from CCT Task Group for Guides on Thermometry (CCT TG-GoTh)

Dr D. del Campo (CEM) reported on behalf of the chair of TG-GoTh (Dr D.R. White (MSL)) and reviewed the membership, ToRs, and tasks [CCT/17-22 and 46]. She outlined the progress since May 2014, including the Guides for specialized fixed points and two thermocouple guides. Dr D. del Campo described the results of the last meeting held in Zakopane (Poland). She gave an overview of the guides and their status:

- Thermistor Thermometry: last edition August 2014;
- Specialized Fixed Points above 0 °C: online shortly;

- Thermocouple Thermometry: interrupted by urgent requests for a guide covering reference thermocouples to support international comparisons and accreditation of thermocouple calibration capabilities. Finally two guides will be issued: General thermocouple thermometry and reference thermocouple thermometry.
- Industrial Platinum Resistance Thermometry: after the publication of the Fixed Point guide this will become a priority.
- Calibration Media: after the publication of the thermocouple guide this will become a priority.
- Radiation Thermometry: waiting for the completion of the primary radiometry uncertainties guide by the CCT WG-NCTh.

Dr D. del Campo discussed the list of temperatures and uncertainties for secondary fixed points and noted that the web-based database and the protocol for the inclusion of new fixed points or fixed point temperatures is to be determined. She described the review of CCT/08-19 and indicated that some revisions were made but further revision should be left until the *Supplementary Information* has been published. She indicated that a full revision should be considered but that this task should be undertaken by the WG-CTh.

Dr B. Fellmuth commented that all work on CCT/08-19 is to be stopped since all the necessary information is contained in Chapter 5 of the Guide. Dr B. Fellmuth noted that Dr D.R. White, who is both the chair of TG-GoTh and a co-author of Chapter 5 of the Guide, had agreed to stop work on CCT/08-19. He also commented that for the list of secondary fixed points, the TG should consider new methods for combining results which have differences larger than the uncertainty. Dr D. del Campo agreed and indicated this will be included in the protocol. Dr B. Fellmuth suggested that work could be modelled on the previous approach of Dr R.E. Bedford.

Dr J. Hollandt (PTB) mentioned that WG-NCTh has already prepared a number of documents related to radiation thermometry and Prof. G. Machin indicated that the current guides are to be updated by WG-NCTh.

## 10.8 Report from TG-SMFPC

Dr B. Fellmuth reported that the main result of the TG is that sealed cells should be compared to open cells and the report will be added to the *Guide* as an appendix of Section 2.4. He indicated that the work of the TG is complete and the TG should be closed.

## 11. Recommendations to the International Committee for Weights and Measures (CIPM)

### 11.1 Recommendation CCT T1: On a new definition of the kelvin (CCT/17-27)

Dr J. Fischer and Prof. G. Machin amended the earlier version of CCT recommendation T1 from Section 6.1 and combined it with CCT recommendation T2 from Section 6.2 to make a new CCT recommendation T1.

Dr H. Yoon noted that if in the future someone compares an SPRT in a triple point of water (TPW) cell with an acoustic gas thermometer, the determined TPW thermodynamic temperature could be different to 273.16 K, so he suggested that “273.16 K” should not be in the definition.

Dr M. Heinonen commented that in the new definition, the temperature of the TPW has some uncertainty, but now “273.16 K” is listed without uncertainty because only two digits of precision are written. Dr J. Fischer cautioned against making the recommendation too complicated.

Dr P. Saunders (MSL) noted that the ITS-90 temperature  $T_{90}$  of the TPW and the thermodynamic temperature  $T$  of the TPW might diverge. Dr B. Fellmuth replied that it is the task of WG-CTh to evaluate  $T - T_{90}$ , so if warranted, the WG could at some point come to a consensus agreement that  $T_{90}$  deviates from  $T$  at the TPW. Dr M. Milton noted that after re-definition the temperature of the TPW becomes a variable in CODATA fitting, but CODATA has agreed that at re-definition the value 273.16 K will be used. He suggested that the recommendation be clarified to say that the TPW temperature will be 273.16 K at the time of re-definition.

Dr F. Sparasci (LNE-Cnam) noted that the official ITS-90 documents contain the old definition of the kelvin, and may confuse people when comparing to the new formal definition of the kelvin; he suggested that this situation should be remedied. Dr B. Fellmuth pointed out that the new *MeP-K* says that both  $T_{90}$  and  $T$  can be used. Dr A. Peruzzi suggested that the CCT make a statement that the pre-redefinition  $T_{90}$  and  $T$  were two quantities with the same unit, but that they will no longer have the same unit after re-definition. Dr I. Yang said that the CCT may not need to worry too much about this issue right now, because both definitions correspond as long as TPW is still 273.16 K. Dr J. Fischer acknowledged that in light of the above comments the original ITS-90 text cannot be used in full after the re-definition of the kelvin. Prof. G. Machin noted that since old scientific papers (such as the ITS-90 publication) are unmodifiable records, he suggested that the CCT add some clarifying text to the BIPM website, although this is unlikely to make any practical difference. Dr F. Sparasci and Dr J. Fischer supported the suggestion to add clarifying text to the BIPM website. Dr Y. Duan and Dr B. Fellmuth suggested adding a statement to the *MeP-K* saying that the section of ITS-90 containing the old definition of the kelvin is no longer valid.

Dr A. Merlone asked if it was worth changing the symbol for the Boltzmann constant back to  $k_B$  from  $k$ , since it could be confused with other common scientific uses of the lower case  $k$  symbol. Dr J. Fischer replied that the draft SI Brochure currently uses  $k$  without subscript B as the symbol of the Boltzmann constant.

Dr D. Zvizdic (FSB) suggested that the CCT should propose that values of ITS-90 will continue to be used until there is a new resolution to change them. Dr B. Fellmuth replied that this is not necessary because the redefinition of the kelvin does not change the ITS.

The CCT approved the recommendation CCT T1.

## 12. CCT memberships and WG memberships

### 12.1 WG and TG Memberships

Dr Y. Duan motioned that Dr C. Gaiser become chair of WG-CTh. There were no objections and so the motion was approved.

Dr Duan suggested that TG-Env becomes WG-Env chaired by Dr A. Merlone. There were no objections and the motion was approved. However, it will need CIPM approval. Dr Y. Duan noted that now is the time to emphasize monitoring climate change.

Dr Y. Duan invited Dr Z. Ahmed to give a presentation on photonic thermometry [CCT/17-33]. Dr Z. Ahmed indicated that he wished to broaden the scope of earlier-proposed new TG to include other kinds of new temperature sensors. He then outlined the main photonic thermometry techniques including fibre-Bragg gratings, Whispering Gallery Mode Resonator (WGMR), ring resonators, Fabry-Perot cavities and photonic crystal cavities.

Dr J.-R. Filtz (LNE) commented that the Consultative Committee for Photometry and Radiometry (CCPR) had a workshop and a former TG on fibre-optic sensors, and invited Dr Z. Ahmed to keep in touch with CCPR colleagues.

Dr W. Joung (KRISS) asked about the temperature range and Dr Z. Ahmed replied that it is limited by the materials used.

Dr W. Joung asked what the time-limited TG goal would be. Dr H. Yoon replied that the Terms of Reference (ToR) and tasks of the TG would be decided later. Dr J. Fischer said that it is important that the CCT sees the ToR.

Dr V. Fericola suggested that emerging technologies such as nanoscale thermometers should be considered in the TG. He suggested that the TG survey all emerging thermometry technologies and report at the next CCT meeting. Dr H. Yoon agreed that the previously-proposed ToR for the TG were too narrow, and that a broader scope can be appropriate so as not to exclude participants, then at the next CCT meeting it is possible to change direction.

Prof. G. Machin commented that the definition in the presentation is narrow and the term “non-radiative” should be considered. He suggested that the TG be formed within WG-CTh.

Dr W. Li supported the suggestion of a broader scope, but also noted that it should include humidity. Dr Y. Duan commented that this would imply that the TG should not be under WG-CTh. Prof. G. Machin suggested that it should be a separate TG that is reviewed at the next CCT meeting. Dr P. Steur commented that the technique is more like secondary thermometry and falls under the area previously handled by WG2 (WG2 and WG3 were closed at the 27th meeting of the CCT, and their tasks transferred to TG-GoTh). Dr J. Fischer commented that the main applications are for contact temperature measurements so the TG should exist under WG-CTh, but that humidity could still be included in the TG.

Dr A. Merlone noted that TG-Env needed clear ToR, but if WG-CTh already has ToR that are broad enough to cover this new TG, then the TG can be included in that WG and develop clearer ToR in time for the next CCT meeting.

Dr Y. Duan commented that it was nice to see new measurement technology and that the CCT should have a feedback system to monitor development of new techniques. He suggested that this be a new TG within WG-CTh, and that the scope be broadened to cover new measurement technologies in all of contact thermometry. The next CCT meeting can then decide if there is a specific area to focus on.

Dr W. Li suggested that one member of WG-Hu join this TG.

Dr S. Picard noted that if the new TG was created within WG-CTh, no change to the WG-CTh ToR would be required, and Dr Y. Duan said that the ToR for the new TG would not be needed at the ongoing meeting.

Dr V. Fericola asked whether the new TG is approved by the CCT or WG-CTh. Dr Y. Duan and Dr S. Picard clarified that the new TG would report to WG-CTh. Dr J. Fischer (outgoing chair of WG-CTh) said that he would bring the TG proposal forward to Dr C. Gaiser (incoming chair of WG-CTh) and follow it for six months, with Dr Z. Ahmed chairing the TG.

Dr F. Sparasci mentioned that it would be good to see the goal for the proposed TG at the present CCT meeting. Dr J. Bojkovski suggested that the new TG be named for Emerging Technologies (WG-CTh-TG-ET).

Dr Z. Ahmed proposed ToRs for the TG: “Identify, study and advise the CCT on matters related to the areas of emergent technologies” with a task to “review the field and report to the CCT” detailing various emergent technologies, benefits, user population, *etc.* Dr H. Yoon commented that it could include, for example, better JNT and other technologies not yet imagined. He hoped that after approximately six months, champions would emerge for each of the new types of thermometers identified and that in three years the report will act as a “radar” for new techniques and a course of action could be decided at the next CCT meeting.

Dr V. Fericola asked that the sentence about dissemination be removed, and to remove the reference to wavelength.

Dr J. Fischer commented that the ToRs and tasks fit into the scope of WG-CTh.

The CCT agreed that the TG-ET should be formed under WG-CTh and approved Dr Z. Ahmed as chair. By a show of hands, the following NMIs expressed interest in joining the TG:

- NMIA (Australia);
- NIST (USA);
- NMISA (South Africa);
- VNIIM (Russia);
- CENAM (Mexico);
- CEM (Spain);
- NMIJ (Japan);
- PTB (Germany);
- INRIM (Italy);
- NIM (China);
- NPL (UK);
- VSL (Netherlands);
- LNE-Cnam (France);
- MIKES (Finland);
- UME (Turkey);
- A\*STAR (Singapore).

## 12.2 CCT membership

Dr Y. Duan invited Dr R. Strnad (CMI) to give a presentation to support the application of CMI (Czech Republic) for membership of the CCT. Dr R. Strnad presented the capabilities and research at CMI in the areas of contact thermometry, non-contact thermometry, humidity (in air

and in other gases) and thermal quantities [CCT/17-24 and 25]. During his presentation he noted the CMCs of CMI.

Dr A. Peruzzi asked if their work in high pressure humidity has been published. Dr Strnad indicated that it has not been since it represented a capability.

After the presentation, Dr Y. Duan asked all the participants to leave the meeting room except for the delegates. The CCT discussed the application and noted the rapid progression and investment, and the breadth of published papers. The CCT took the unanimous decision to propose to CIPM the acceptance of CMI as a Member of CCT.

### **13. Reports from international meetings**

Dr Y. Duan noted that the planning for the joint TEMPMEKO/Tempbeijing conference in 2019 has started and that the organizers are considering holding the conference in either Chengdu or Beijing.

Dr M. Milton reminded participants of the BIPM workshop on Quantum Metrology to be held on 28-29 September 2017. He noted that it is now fully subscribed and that it will be the largest workshop the BIPM has held.

### **14. Publications**

There was no discussion under this topic

### **15. Other Items**

Dr Y. Duan noted that this meeting would be the last CCT meeting for Drs J. Fischer, B. Fellmuth and P. Steur and thanked them on behalf of the CCT for their contributions.

### **16. Date of next meeting**

Dr Y. Duan suggested that the next meeting of the CCT be held in April or March of 2020. Dr M. Milton noted that March, April and May 2020 might be a busy period at the BIPM. It was concluded that the next CCT meeting would be held in 2020, with the exact date to be determined.

Dr Y. Duan thanked all the attendees and invited Dr M. Milton to make his closing comments. Dr M. Milton thanked Dr S. Picard for organizing the meeting and Dr Y. Duan for successfully chairing the meeting.

Dr Y. Duan thanked all BIPM staff and all attendees for their contributions and closed the meeting.

## 17. Actions and Decisions

The actions and decisions taken at the meeting were identified for posting on the CCT web page with minimum delay.

### Actions

- CCT28/A1. T. Herman (NIST) will send CCT-K9 Draft B to participants by October 2017.
- CCT28/A2. B. Fellmuth (PTB) will address the final version of the *Mise en Pratique* to the CCU for their September 2017 meeting, and appendices by December 2017.
- CCT28/A3. WG-SP shall provide the first revision of the CCT Strategic Planning document by Dec-2017 (coordinated by J. Fischer (PTB)).
- CCT28/A4. WG-KC will update the CCT President on silent comparisons and plans for their completion by October 2017.
- CCT28/A5. J. Fischer will draft a statement to clarify the relationship between the ITS-90 and the kelvin that will be posted on the BIPM web.
- CCT28/A6. B. Fellmuth will add a sentence to the *MeP-K* to clarify the relationship between the ITS-90 and the kelvin.
- CCT28/A7. S. Picard will move the CCT/08-19-rev document to the restricted area of the BIPM CCT web site.
- CCT28/A8. WG-SP to add a statement related to climate in its revision of the CCT Strategic Planning Document.
- CCT28/A9. WG-CTh Chair will draft ToR and tasks for the TG-CTh-ET (Emerging technologies) and suggest members to the CCT president.

### Decisions

- CCT28/D1. The CCT President will forward the CCT recommendation T1 (2017) to the CIPM.
- CCT28/D2. J. Fischer will co-ordinate the revision of the strategic planning document.
- CCT28/D3. The CCT President will recommend the CIPM to attribute member status of the CCT to the CMI (Czech Republic).
- CCT28/D4. TG-SI is closed.
- CCT28/D5. TG-K is closed.
- CCT28/D6. TG-SMFPC is closed.
- CCT28/D7. The Task Group on Emerging technologies (TG-CTh-ET) is created under CCT-WG-CTh and chaired by Z. Ahmed.
- CCT28/D8. CCT President will recommend to the CIPM that C. Gaiser becomes Chair of CCT-WG-CTh.
- CCT28/D9. CCT president will recommend to the CIPM that CCT-TG-Env becomes CCT-WG-Env chaired by A. Merlone.
- CCT28/D10. Next meeting will be held at the BIPM in March or April 2020.

*Dr A.D.W. Todd and Dr P.M.C. Rourke, Rapporteurs*

*June 2017*

## RECOMMANDATION DU COMITÉ CONSULTATIF DE THERMOMÉTRIE PRÉSENTÉES AU COMITÉ INTERNATIONAL DES POIDS ET MESURES

### RECOMMANDATION T 1 (2017)

#### Pour une nouvelle définition du kelvin en 2018

Le Comité consultatif de thermométrie (CCT), à sa 28<sup>e</sup> session en 2017,

##### *rappelant*

- le rapport « *Report to the CIPM on the implications of changing the definition of the base unit kelvin* » qu'il a présenté au CIPM en 2007,
- la recommandation CCT T 2 (2010) « *Considérations sur une nouvelle définition du kelvin* » qu'il a présentée au CIPM en 2010,
- la recommandation CCT T 1 (2014) « *Sur une nouvelle définition du kelvin* » qu'il a présentée au CIPM en 2014,

##### *accueillant favorablement*

- la Résolution 1 (2011) de la CGPM « *Sur l'éventuelle révision à venir du Système international d'unités, le SI* » selon laquelle, une fois le SI révisé, l'unité de température sera reliée à la constante de Boltzmann,
- la Recommandation CCU U 1 (2013) « *Sur la révision du Système international d'unités, le SI* », soumise par le CCU au CIPM,

##### *notant*

- que les expériences telles que la thermométrie acoustique à gaz, la thermométrie à gaz par mesure de la constante diélectrique, la thermométrie à bruit de Johnson, la thermométrie par mesure de l'élargissement Doppler, constituent des voies fondamentalement distinctes pour déterminer la valeur de la constante de Boltzmann  $k$ ,
- que, dans son ajustement de 2014 des constantes fondamentales, la CODATA a recommandé une valeur de  $k$  avec une incertitude-type relative de  $5,7 \times 10^{-7}$ ,
- qu'une fois le kelvin redéfini, une incertitude-type relative de  $5,7 \times 10^{-7}$  pour  $k$  correspondra à une incertitude-type d'environ 0,16 mK de la température du point triple de l'eau,
- que la température du point triple de l'eau sera de 273,16 K au moment de la redéfinition du kelvin,

##### *considérant*

- les discussions qui se sont tenues lors des 26<sup>e</sup>, 27<sup>e</sup> et 28<sup>e</sup> réunions du CCT en 2012, 2014 et 2017,
- les récents progrès significatifs des expériences entreprises afin de déterminer la valeur de la constante de Boltzmann, l'objectif étant d'accroître la confiance vis-à-vis de la valeur obtenue en 2014, tel que l'a recommandé le sous-groupe de travail du CCT sur le SI lors de ses réunions de 2014, 2015 et 2017,
- la détermination de la valeur de  $k$  qui se fonde désormais sur trois méthodes fondamentalement distinctes qui permettent d'obtenir, chacune, au moins un résultat présentant une incertitude-type relative inférieure à  $3 \times 10^{-6}$ ,



- le fait que toutes les exigences du CCT concernant la nouvelle définition du kelvin sont désormais remplies,
- les progrès des expériences qui ont permis d'établir une mise en pratique de la nouvelle définition du kelvin, dont la portée a été étendue afin de couvrir les mesures directes de la température thermodynamique une fois que le kelvin aura été redéfini,

***recommande***

- au CIPM de finaliser les redéfinitions des unités en convenant de fixer les valeurs des constantes physiques fondamentales à partir desquelles une valeur numérique fixée de la constante de Boltzmann comportant 8 chiffres sera adoptée pour la redéfinition du kelvin,
- aux laboratoires nationaux de métrologie des États Membres de tirer pleinement parti des possibilités qu'offrent la redéfinition du kelvin et la mise en pratique de la définition du kelvin concernant la réalisation et la dissémination de la température thermodynamique.

## RECOMMENDATIONS OF THE CONSULTATIVE COMMITTEE FOR THERMOMETRY SUBMITTED TO THE INTERNATIONAL COMMITTEE FOR WEIGHTS AND MEASURES

### RECOMMENDATION T 1 (2017)

#### For a new definition of the kelvin in 2018

The Consultative Committee for Thermometry (CCT), at its 28th meeting in 2017,

#### *recalling*

- the CCT Report to the CIPM in 2007, “Report to the CIPM on the implications of changing the definition of the base unit kelvin”,
- the CCT Recommendation to the CIPM in 2010, “Considerations for a new definition of the kelvin”, CCT T 2 (2010),
- the CCT Recommendation to the CIPM in 2014, “On a new definition of the kelvin”, CCT T 1 (2014),

#### *welcoming*

- the Resolution 1 (2011) of the CGPM, “On the possible future revision of the International System of Units, the SI” which, when accomplished, will link the unit of temperature to the Boltzmann constant,
- the CCU Recommendation to the CIPM, “Revision of the International System of Units, the SI”, CCU U 1 (2013),

#### *noting that*

- experiments such as acoustic gas thermometry, dielectric constant gas thermometry, Johnson noise thermometry, and Doppler broadening thermometry represent fundamentally different methods to determine the Boltzmann constant  $k$ ,
- the CODATA recommended a value for  $k$  with a relative standard uncertainty equal to 5.7 parts in  $10^7$  in its 2014 adjustment of fundamental constants,
- a relative standard uncertainty in  $k$  of 5.7 parts in  $10^7$  would correspond to a standard uncertainty of about 0.16 mK of the temperature of the triple point of water after the redefinition,
- the temperature of the triple point of water will be 273.16 K at the time of the redefinition of the kelvin,

#### *considering*

- the discussions held at the 26th, 27th, and 28th meetings of the CCT in 2012, 2014 and 2017,

- the considerable progress recently achieved in experimental determinations of the Boltzmann constant to improve confidence in the 2014 value, as reported at the CCT “Task Group on the SI” meetings held in 2014, 2015, and 2017,
- that the determination of  $k$  is now based on three fundamentally different methods, of which at least one result for each has a relative standard uncertainty less than 3 parts in  $10^6$ ,
- that all requirements of CCT for the new definition of the kelvin have been fulfilled,
- that experimental progress has allowed the development of a *mise en pratique* for the realization of the kelvin, which has been extended to cover direct measurement of thermodynamic temperature after the redefinition of the kelvin,

***recommends***

- that the CIPM finalizes the unit redefinitions through agreeing to fix the values of the fundamental physical constants, from which a fixed numerical value of the Boltzmann constant with eight digits will be adopted for the redefinition of the kelvin,
- that Member State NMIs take full advantage of the opportunities for the realization and dissemination of thermodynamic temperature afforded by the kelvin redefinition and the *mise en pratique* for the definition of the kelvin.

**APPENDIX T1: Working documents submitted to the CCT at its 27th meeting**

<b>CCT/17-01</b>	CCT 2017 Draft Agenda	Y. Duan
<a href="#"><u>CCT/17-02</u></a>	Declaration of CCT WG-NCTh concerning the realization of thermodynamic temperature	G. Machin et al.
<a href="#"><u>CCT/17-03</u></a>	Report on MMC 2016	A. Merlone
<b>CCT/17-04</b>	Mise en Pratique of the Realization of the Kelvin	B. Fellmuth et al.
<a href="#"><u>CCT/17-05</u></a>	Guide to ITS-90 TPW 2017	A. Peruzzi et al.
<a href="#"><u>CCT/17-06</u></a>	New Isotopic Correction Coefficients and Equations	A. Peruzzi and H.A.J Meijer
<a href="#"><u>CCT/17-07</u></a>	Technical Annex for ITS-90	CCT
<b>CCT/17-08</b>	2.1 Fixed Points - Influence of Impurities APPENDIX 2: Distribution coefficients...	B. Fellmuth et al.
<a href="#"><u>CCT/17-09</u></a>	On choosing the number of digits...	J. Fischer
<a href="#"><u>CCT/17-10</u></a>	Report from the Task Group for the Realization of the Kelvin (TG-K)	B. Fellmuth
<b>CCT/17-11</b>	Guide to ITS-90 : Vapour Pressure Scales and Pressure Measurements	B. Fellmuth et al.
<a href="#"><u>CCT/17-12</u></a>	MeP: Electronic Temperature measurement by Johnson Noise Thermometry	S. P. Benz et al.
<a href="#"><u>CCT/17-13</u></a>	MeP: Low-temperature Johnson Noise Thermometry	J. Engert and A. Kirste
<b>CCT/17-14</b>	MeP: Refractive Index gas Thermometry	P. Rourke et al.
<a href="#"><u>CCT/17-15</u></a>	Report from the Task Group for the SI (TG-SI)	J. Fischer
<b>CCT/17-16</b>	Draft Recommendation CCT T1: On a new definition of the kelvin	WG-CTh and TG-SI
<b>CCT/17-17</b>	Towards ITS-XX	R. White and P. Rourke
<b>CCT/17-18</b>	The ITS-90 after definition of neon isotopic reference composition	F. Pavese et al.
<a href="#"><u>CCT/17-19</u></a>	Report from the Task Group for Thermophysical Quantities (TG-ThQ)	J.-R. Filtz
<a href="#"><u>CCT/17-20</u></a>	Report from the Task Group for Sealed Metal Freezing Point Cells	R. White
<a href="#"><u>CCT/17-21</u></a>	Report from the Working Group for Non-Contact Thermometry (WG-NCTh)	G. Machin
<a href="#"><u>CCT/17-22</u></a>	Report from the Task Group for Guides on Thermometry (TG-GoTh)	R. White
<a href="#"><u>CCT/17-23</u></a>	Report from TC-T SIM	E. Mendez
<a href="#"><u>CCT/17-24</u></a>	CMI presentation for CCT member status request	R. Strnad
<a href="#"><u>CCT/17-25</u></a>	CMI support document with bibliography for CCT member status request	R. Strnad
<a href="#"><u>CCT/17-26</u></a>	Overview and progress report for CCT on InK2	G. Machin

<a href="#">CCT/17-27</a>	Recommendation CCT T1: On a new definition of the kelvin	CCT
<a href="#">CCT/17-28</a>	Redefinition of the kelvin: The Boltzmann project	J. Fischer
<a href="#">CCT/17-29</a>	Redefinition of the kelvin: Acoustic Gas Thermometry	R. Gavioso
<a href="#">CCT/17-30</a>	Redefinition of the kelvin: Dielectric Constant Gas Thermometry	B. Fellmuth
<a href="#">CCT/17-31</a>	Redefinition of the kelvin: Johnson Noise Thermometry	J. Qu
<a href="#">CCT/17-32</a>	The kelvin redefinition and the MeP-K	B. Fellmuth et al.
<a href="#">CCT/17-33</a>	Photonic Thermometry	Z. Ahmed
<a href="#">CCT/17-34</a>	COOMET TC-T Report	A.I. Pokhodun
<a href="#">CCT/17-35</a>	SIM TC-T Presentation	E. Mendez
<a href="#">CCT/17-36</a>	EURAMET TC-T Presentation	G. Machin
<a href="#">CCT/17-37</a>	AFRIMETS TC-T Presentation	E. Ejigu
<a href="#">CCT/17-38</a>	GULFMET TC-T Presentation	M. Anagnostou
<a href="#">CCT/17-39</a>	APMP TC-T Presentation	W. Li
<a href="#">CCT/17-40</a>	CCT WG-KC Presentation	A. Peruzzi
<a href="#">CCT/17-41</a>	CCT WG-Hu Presentation	S. Bell
<a href="#">CCT/17-42</a>	CCT WG-NCTh Presentation	G. Machin
<a href="#">CCT/17-43</a>	CCT WG-SP Presentation	Y. Duan
<a href="#">CCT/17-44</a>	CCT WG-CTh Presentation	J. Fischer
<a href="#">CCT/17-45</a>	CCT WG-CMC Presentation	J. Bojkovski
<a href="#">CCT/17-46</a>	CCT TG-GoTh Presentation	R. White and D. del Campo
<a href="#">CCT/17-47</a>	CCT TG-ThQ Presentation	J.-R. Filtz
<a href="#">CCT/17-48</a>	CCT TG-K Presentation	B. Fellmuth
<a href="#">CCT/17-49</a>	CCT TG-Env Presentation	A. Merlone
<a href="#">CCT/17-50</a>	CCT TG-NCTh-CMC Presentation	Y. Yamada
<a href="#">CCT/17-51</a>	CCT TG-NCTh-HTFPC Presentation	A. Todd
<a href="#">CCT/17-52</a>	Report from the CIPM	M. Milton
<a href="#">CCT/17-53</a>	Report on the revision of the KCDB	S. Picard
<a href="#">CCT/17-54</a>	Draft recommendation : On the realisation of the redefined kelvin	G. Machin
<a href="#">CCT/17-55</a>	Report on progress of CCT-K8	R. Benyon
<a href="#">CCT/17-56</a>	JCRB Report to the CCT	N. Zviagin
<a href="#">CCT/17-57</a>	Report from the Working Group for Contact Thermometry (WG-CTh)	J. Fischer
<a href="#">CCT/17-58</a>	Report from the Working Group for Key Comparisons (WG-KC)	A. Peruzzi