

Bureau International des Poids et Mesures

# Consultative Committee for Thermometry (CCT)

Report of the 27th meeting  
(21–23 May 2014)  
to the International Committee for Weights and Measures



Note:

Following a decision made by the International Committee for Weights and Measures at its 92nd meeting in October 2003, Reports of meetings of Consultative Committees will henceforth be published only on the BIPM website in the form presented here.

Full bilingual printed versions in French and English will no longer appear.

Working documents for the meetings are listed at the end of each Report and those which the Consultative Committee decides are for public use are available also on the website.

M.J.T. Milton,  
Director of the BIPM

## LIST OF MEMBERS OF THE CONSULTATIVE COMMITTEE FOR THERMOMETRY

as of 21 May 2014

### President

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

### Executive Secretary (*ad interim*)

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.

Centre for Metrology and Accreditation [MIKES], Espoo.

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 [VSL], Delft.

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

**Official Observer(s)**

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

## CONTENT

- 1 Half day seminar on topics related to thermometry
- 2 Opening of the meeting; Appointment of the rapporteur; Approval of the agenda
- 3 Report of the 26th Meeting of the CCT 2012
- 4 Reports of the Working Groups
  - 4.1 CCT Working Group 1
    - 4.1.1 Task Group on the *MeP-K*
  - 4.2 CCT Working Group 2
  - 4.3 CCT Working Group 3
  - 4.4 CCT Working Group 4
    - 4.4.1 SI Task Group
  - 4.5 CCT Working Group 5
  - 4.6 CCT Working Group 6
  - 4.7 CCT Working Group 7
  - 4.8 CCT Working Group 8
  - 4.9 CCT Working Group 9
  - 4.10 Report of the Working Group on Strategy
- 5 Composition of the new Working Groups and Task Groups
- 6 CCT key comparisons
- 7 Regional Metrology Organizations
  - 7.1 JCRB matters
  - 7.2 AFRIMET report
  - 7.3 APMP report
  - 7.4 COOMET report
  - 7.5 EURAMET report
  - 7.6 SIM report
  - 7.7 *Résumé* on the InK project
  - 7.8 *Résumé* on the METefnet project
- 8 CCT membership
- 9 Recommendations to the CIPM
- 10 Reports from international meetings
- 11 Publications
- 12 Feedback on the new format of the CCT meeting
- 13 Date of next CCT meeting
- 14 Actions and decisions

## 1 HALF DAY SEMINAR ON TOPICS RELATED TO THERMOMETRY

The twenty-seventh meeting of the Consultative Committee for Thermometry began with a half day seminar on topics related to thermometry.

The following talks were presented:

Dr Walter Bich (INRiM) **Revision of the GUM: why and how?**<sup>1</sup>

*This talk was intended to explain why the GUM needs a revision and to show how it is being revised. The conceptual evolution was outlined, focusing on what will change from the viewpoint of the practitioner. The new procedures for (a) the evaluation of a standard uncertainty and (b) the construction of a coverage interval (or region) compare favourably with the current ones in terms of simplicity (the former) and generality (the latter); see CCT/14-38.*

Dr Rod White (MSL) **Bayesian uncertainty: pluses and minuses**

*This talk highlighted differences in the frequentist and Bayesian approaches to uncertainty and how these relate to measurement; see CCT/14-39.*

Dr Joachim Fischer (PTB) **Current status of the redefinition of the kelvin**

*The future definition of the kelvin will be based on a fixed numerical value of the Boltzmann constant. Measurements, progress to date, and future perspectives concerning the determination of the Boltzmann constant, using fundamentally different techniques, were reported; see CCT/14-40.*

Dr Dolores del Campo (CEM) **The European project “Novel Techniques for Traceable Temperature Dissemination”**

*In the frame of the European Metrology Research Programme the project Novel Techniques for Traceable Temperature Dissemination (NOTED) focuses on developing new techniques for improved traceability to the kelvin supporting wider and simpler dissemination to the users. The presentation summarized the main activities carried out in the project together with the most significant findings and developments up to now; see CCT/14-41.*

Dr Andrea Peruzzi (VSL) **Experimental determination of the isotopic correction constants for the triple point of water**

*Temperature measurements of ten triple point water cells containing water of different isotopic compositions were made. For each cell, the isotopic composition was analysed using optical feedback cavity enhanced absorption spectroscopy. New values of unprecedented accuracy for the isotopic correction constants were derived; see CCT/14-42.*

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<sup>1</sup> For a list of acronyms, [click here](#).

**Dr Martti Heinonen (MIKES) Joint work with the IAPWS**

*This presentation summarized the unsolved scientific problems related to the definition of relative humidity and outlined the progress so far. The future and the importance of collaborating beyond the metrology community were also discussed; see CCT/14-43.*

**Dr Andrea Merlone (INRiM) Thermal metrology for meteorology and climate**

*This talk reported the challenges and opportunities that have opened up in recent years for the thermal metrology community in establishing permanent and long-lasting cooperation with the climatology and meteorology communities. A general vision of the creation of ad hoc task groups, addressing several aspects of metrology for environmental sciences, was also discussed; see CCT/14-44.*

Dr Peter Thorne (Nansen Environmental and Remote Sensing Center)

**Dickensian climate metrology: The ghosts of meteorological observations past, present and future**

*At present, climate change is evidenced in factors which include retreating glaciers, increases in temperature and humidity and in rising sea-levels. It is important to know how the climate has changed and to monitor how it will change in the future with a high degree of confidence. Today, many of the measurements are far from perfect and most lack even cursory traceability. This talk concentrated on two case studies that benefit from substantial and sustained metrological input: The International Surface Temperature Initiative and the GCOS Reference Upper Air Network; see CCT/14-45.*

## **2 OPENING OF THE MEETING; APPOINTMENT OF THE RAPPORTEUR; APPROVAL OF THE AGENDA**

The twenty-seventh meeting of the Consultative Committee for Thermometry (CCT) took place at the International Bureau of Weights and Measures (BIPM), Pavillon de Breteuil, Sèvres, on 21 to 23 May 2014.

The following were present:

M. Arai (NMIJ/AIST), T. Baba (NMIJ/AIST), M. Batuello (INRiM), S. Bell (NPL), D. Del Campo (CEM), Y. Duan (President of the CCT), E. Ejigu (NMISA), B. Fellmuth (PTB), V. Fericola (INRiM), E. Filipe (IPQ), J. Fischer (PTB), E. van der Ham (NMIA), M. Heinonen (MIKES), Y. Hermier (LNE), K. Hill (NRC), J. Hollandt (PTB), M. Kalemci (UME), Y.-G. Kim (KRISS), S. Korostin (VNIIFTRI), G. Kytin (VNIIFTRI), G. Machin (NPL), M. Matveyev (VNIIM), E. Méndez-Lango (CENAM), A. Merlone (INRiM), M.J.T. Milton (Director of the BIPM), P. Pavlasek (SMU), J. Pearce (NPL), A. Peruzzi (VSL), A. Pokhodun (VNIIM), P. Rourke (NRC), N. Sokolov (VNIIM), P. Steur (INRiM),

G.F. Strouse (NIST), J. Tamba (NMIJ/AIST), A.D. Todd (NRC), R. Teixeira (INMETRO), M. Vinge (VNIIFTRI), L. Wang (A\*STAR), D.R. White (MSL), Y. Yamada (NMIJ/AIST), I. Yang (KRISS), H. Yoon (NIST), Z. Yuan (NIM), J. Zhang (NIM).

Observers: D. Zvizdić (HMI).

Invited by the President: W. Bich (INRiM), R. Feistel (Leibniz Institute for Baltic Sea Research), O. Robatto (LATU), R. Strnad (CMI), A. Szmyrka-Grzebyk (INTiBS), P. Thorne (Nansen Environmental and Remote Sensing Centre).

Also present: S. Picard (Executive Secretary of the CCT (*ad interim*)), C. Kuanbayev (Executive Secretary of the JCRB), C. Thomas (Coordinator of the BIPM KCDB).

The President of the CCT, Dr Y. Duan opened the meeting and welcomed the participants. Dr A. Peruzzi (VSL) was appointed *rapporteur*. The agenda of the meeting was approved with no changes or additions.

### 3 REPORT OF THE 26TH MEETING OF THE CCT 2012

The Executive Secretary of the CCT, Dr S. Picard, recalled that the report of the 26th meeting of the CCT (2012) 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:

CCT/A1: **WG1** is to complete the revision of “Supplementary information for the international temperature scale of 1990” before the next CCT meeting in **2014**.

Status: not completed.

CCT/A2. **WG1** is to complete the revision of the “Mise en pratique for the kelvin” in **2013** and subsequently submit it to the Consultative Committee for Units (CCU) for advice and to the CIPM for approval.

Status: Completed.

CCT/A3. **WG2** is to include radiation thermometry approximations to ITS-90 in the revised version of “Techniques for approximating the international temperature scale of 1990”.

Status: not completed.

CCT/A4. The **SI Task Group** will provide a document on the subject of the SI revision by **April 2013**.

Status: Completed.

CCT/A5. **WG5** will communicate information on thermal imagers to the International Electrotechnical Commission (IEC) committee.

Status: Completed.



CCT/A6. **WG6** will liaise with other bodies where there is a shared interest in moisture in materials, including the Consultative Committee for Amount of Substance (CCQM) and the World Meteorological Organization (WMO).

Status: Completed.

CCT/A7. **WG9** will develop a Calibration and Measurement Capability (CMC) review protocol to allow appropriate Key and Supplementary Comparisons of thermal conductivity of insulating materials, thermal diffusivity of dense materials, and normal spectral emissivity of solids.

Status: not completed.

CCT/A8. The **Working Group on Strategy** will produce a CCT strategic plan, based on the input of all CCT WGs by **March 2013**.

Status: Completed.

## 4 REPORTS OF THE WORKING GROUPS

### 4.1 CCT Working Group 1: Defining fixed points and interpolating equations of the ITS-90 and the dissemination of the kelvin

Dr B. Fellmuth presented the report of the activities of Working Group 1 (CCT/14-24).

He summarized the progress in the revision of the *Supplementary Information for the ITS-90 (SInf)* since the previous CCT meeting in 2012:

- Six parts of the *SInf* were revised: *Forewords and Contents*, *Introduction*, Section 2.2 *Triple point of Water*, Section 2.5 *Metal Fixed Points for Radiation Thermometry*, Chapter 4 *Interpolating Constant-Volume Gas Thermometry* and Chapter 6 *Radiation Thermometry*.
- Drafts were prepared for two parts: Section 2.1 *Influence of Impurities* and Chapter 5 *Platinum Resistance Thermometry*.
- Outlines were agreed for the remaining three parts: Section 2.3 *Cryogenic Fixed Points*, Section 2.4 *Metal Fixed Points for Contact Thermometry* and Chapter 3 *Vapour Pressure Scales and Pressure Measurements*.

The revised parts were posted on the BIPM website; for the non-revised parts the BIPM website still contains a link to the original version of the *SInf*.

A detailed plan for the revision of the remaining parts was agreed, including the distribution of tasks among the WG members. It is now expected that the revision of the *SInf* will be completed by the end of 2014 and the final formatting and harmonization of the parts will take place in the first half of 2015.

Dr B. Fellmuth clarified that some appendices of Section 2.1, particularly Appendix 2 *Distribution Coefficients and Liquidus-Line Slopes*, require the collation and evaluation of data from different sources (evaluation of binary phase diagrams, doping experiments and

thermodynamic calculations) that are only partially available from the present literature. As consequence, the completion of such appendices will require a few years.

#### 4.1.1 Task Group on the MeP-K: Amended version of the MeP-K

Dr B. Fellmuth explained that, although the BIPM website still posts the present version of the *MeP-K* (2011), a new version of the *MeP-K* was prepared by this Task Group and approved by the CCT in May 2013. This second version is currently posted on the restricted area of the BIPM website and will be moved to the open-access area only after the redefinition of the kelvin. With respect to the original version, the *MeP-K* was amended along the following lines:

- the document was rearranged into five sections including scope and introduction;
- the explicit-constant definition of the kelvin was briefly explained;
- a nomenclature for defining important terms was included (Section 3);
- the criteria for the inclusion of primary thermometry methods in the *MeP-K* were defined;
- a brief description of two primary thermometry methods, namely acoustic gas thermometry (Section 4.1) and radiometric thermometry (Section 4.2) was included.

The inclusion of further primary thermometry methods in the *MeP-K*, e.g. other gas-thermometry methods, seems possible until the redefinition of the kelvin.

He emphasized that at present an endorsement of multiple methods for the realization of the base unit kelvin does not exist.

Dr S. Picard expressed her gratitude to Dr B. Fellmuth for the amount of work performed by WG1 and her hope for a broader distribution of the work among the users. Dr B. Fellmuth clarified that a workshop and a publication on the *MeP-K* are being prepared for the wider thermometry community.

Dr C. Thomas noted that, after the redefinition of the kelvin, the *MeP-K* will become a formal part of the SI brochure.

## 4.2 CCT Working Group 2: Secondary contact thermometry

Dr A. Merlone recalled the changes that have been made to the terms of reference (ToR) of Working Group 2 during the past six years. From 2008 to 2010, the concerns of WG2 were limited to secondary contact thermometry, mainly the revision of the *Techniques for Approximating the ITS-90*. In 2012 the ToR of the WG2 were broadened by including the task of monitoring the needs of the users of secondary thermometers. In 2013, the WG2 met during the TEMPMEKO 2013 Symposium and, having received relevant feedback from the climate community users, decided to propose to the CCT the creation of a new Task Group on climate. Dr P. Thorne, Nansen Environmental and Remote Sensing Centre (NERSC), recognized as a leading representative of the climate community, was invited to attend this CCT meeting as an observer and had given a presentation at the CCT Workshop that preceded the CCT meeting.

Dr A. Merlone pointed out that the acquisition of a broader vision for the goals of this WG did not prevent the WG from making substantial progress on the revision of the *Guide on Secondary*

*Thermometry* (new title of the *Techniques for Approximating the ITS-90*). Some chapters of the *Guide* were uploaded onto the restricted area of the BIPM website (for example, *Specialized Fixed Points above 0 °C*), other chapters are in progress.

Dr S. Picard asked whether the two documents already uploaded on the restricted area of the BIPM website needed to be approved by the CCT before making them publicly available. Dr D.R. White clarified that one of the documents needs formal approval by the CCT.

Dr B. Fellmuth advised that, on the BIPM website, the *Guide on Secondary Thermometry* should not be placed together with the *MeP-K*. There should be a clear distinction between the two, given the fact that the *MeP-K* is a prescriptive document, while the *Guide on Secondary Thermometry* is not.

### 4.3 CCT Working Group 3: Uncertainties in contact thermometry

Dr D.R. White presented the report of the activities of Working Group 3 (CCT/14-36). After recalling the ToR of WG3, Dr D.R. White explained that, in the past, the WG3 focused on the revision of the uncertainty guide on SPRTs (CCT/08-19rev, *Uncertainties in the Realization of the SPRT Subranges of the ITS-90*) and the preparation of an uncertainty guide for noble-metal thermocouples. Other activities of the WG3 included the development of a guide on sealed metal fixed-point cells, the uncertainty in the extrapolation of long-stem SPRT calibration to liquid nitrogen temperatures, a better understanding of the non-uniqueness in the SPRT sub-ranges of the ITS-90 and a watch on the development of the GUM revision.

Several modifications of membership occurred during the term: Dr Fernicola (INRiM) replaced Dr F. Pavese as INRiM representative (Dr F. Pavese stayed on as an independent expert), Dr M. Kalemci (UME) replaced Dr A. Kartal Dogan, Dr R. Morice (LNE-CNAM) resigned and Dr J. Pearce (NPL) joined the group. To assist with preparation of the uncertainty guide for noble metal thermocouples, the WG co-opted several expert members: Dr F. Jahan (NMIA), Dr F. Edler (PTB), Dr K. Garrity (NIST) and Dr H. Ogura (NMIJ).

Dr D.R. White explained that the review of the uncertainty guide on SPRTs (CCT/08-19rev) was prompted by a letter from Ms. S. Gaita (Romania). The letter from Ms S. Gaita was accompanied by two supporting documents: the first discussed the method by which the uncertainty is propagated in the guide and the second listed a number of errors in the guide. At the same time, as WG1 was abstracting some parts from CCT/08-19rev during the preparation of a revised chapter of the *SInf*, it became evident that a number of sections of the CCT/08-19rev were out of date. For both reasons, WG3 decided to review the document that had been completed. With respect to Ms S. Gaita's first document on methods for propagating uncertainty, Dr D.R. White clarified that the method suggested by Ms S. Gaita is mathematically equivalent to that used in CCT/08-19rev. As for the errors identified in Ms S. Gaita's second document, they can be classified into three main groups: i) typographical errors, ii) errors of omission and iii) failure to provide an explicit statement of the measurement model. The first two groups of errors were minor and easy to correct, the third group was due to a deliberate decision by WG3 to avoid complexity.

The revision of the guide identified several areas requiring major revisions or additions including, among others, the isotope effects of neon, the interface curvature in metal fixed points, update isotopic correction constants for water triple point, update information on non-

uniqueness, self-heating correction and use of Allan variance to investigate resistance bridge performance.

Dr D.R. White explained that the revision would be deliberately kept to a minimum and carried out quickly. This would ensure that there would be no confusion between the revised document and the revision of the *Supplementary Information for the ITS-90* under preparation by the WG1. As a consequence, the guide will still reflect the knowledge at the time it was prepared (2008) and, for this reason, still retain the Working Document number CCT/08-19rev. A full revision of the guide will be performed in the future, after the SPRT chapter of the *Supplementary Information* has been published.

He also announced that the WG started the development of an uncertainty guide for noble-metal thermocouples, prompted by concerns raised by Dr Ballico (NMIA). The guide will also address the less well-known and controversial aspects of thermocouple calibrations, such as the calibration state, hysteresis and inhomogeneities.

WG7 asked WG3 to give advice on the uncertainty to be assigned to sealed metal freezing point cells used for long-stem SPRTs because, after sealing the cells, the pressure is unknown. WG3 agrees to give advice to the CCT on this issue after further discussions.

Dr D.R. White recalled the document on the GUM revision that he submitted in the last CCT meeting. This document was sent to the JCGM, but he received no feedback.

Dr B. Fellmuth emphasized that the revised *SInf* should replace all CCT documents on the realization of the ITS-90.

#### 4.4 CCT Working Group 4: Thermodynamic temperature determinations and extension of the ITS-90 to lower temperatures

Dr J. Fischer presented the report of the activities of Working Group 4 (CCT/14-19).

Dr J. Fischer recalled that the 2010 WG4 review of thermodynamic measurements revealed unexplained inconsistencies between the uncertainties claimed in specific data sets and consensus estimates of  $T - T_{90}$  and summarized the new results published since 2010.

At low temperatures, from 25 K to 255 K, there are inconsistencies between Constant Volume Gas Thermometry (CVGT) and Acoustic Gas Thermometry (AGT), with AGT of a smaller uncertainty than CVGT. New results have been published since 2010 by the NMIJ/AIST (CVGT) and the PTB (Dielectric Constant Gas Thermometry, DCGT). The DCGT results of the PTB up to 36 K do not confirm the negative values of  $T - T_{90}$  obtained by AGT.

At increasing temperatures, CVGT and AGT are the only methods available and at high temperatures only Spectral Radiation Thermometry (SRT) is of use, Johnson Noise Thermometry (JNT) having a high uncertainty. New results have been published by the NIST/NIM (JNT) from 693 K to 800 K, NMIA (SRT) at the gold point (1337 K), INRiM (SRT) and the NPL/LNE (SRT) at the copper point (1358 K).

Dr J. Fischer noted that many new developments and extension or repetition experiments are foreseen for the coming year that justifies the continuation of the work of the WG4. Since 2010, only a few experiments produced valid results for consideration in the WG4 and the recent measurements are insufficient to resolve the weaknesses identified by the WG4.

Dr G. Machin added that the copper point temperature will be re-determined soon by eight different institutes and that the NIST and the NPL will jointly re-determine the tin, zinc, aluminium and silver points.

Dr M. Heinonen observed that work is also underway at ultra-low temperature ( $T < 1$  K) and Dr G. Machin clarified that such work will be reported in a separate presentation.

Dr Y. Duan noted with pleasure that more and more NMIs are getting involved in thermodynamic temperature determinations.

#### 4.4.1 SI Task Group: Redefinition of the kelvin

Dr J. Fischer presented the report of the activities of the CCT Task Group on the SI (CCT/14-20).

He summarized the progress of the Boltzmann constant experiments. He recalled that, at the moment, the smallest standard uncertainty in the determination of the Boltzmann constant had been achieved by the NPL in 2013 using AGT ( $0.7 \times 10^{-6}$ ) and that there is a discrepancy between the NPL 2013 result and the LNE 2011 results. While the NPL experiment has concluded, the LNE continues to work with two AGT experiments in parallel (using two spheres, BCU3 and BCU4). At present the LNE has obtained insufficient agreement among the acoustic modes of BCU4, probably due to a dead space volume between the two hemispheres (the LNE uses a tenth of the torque on the screws compared to other institutes). The AGT experiment at the INRiM is currently investigating the impurity content in the helium gas in collaboration with the PTB. The NIM/NIST AGT experiment resulted in a considerable reduction in the inconsistency among modes and is successfully continuing with the two-cylinder approach. The DCGT experiment at the PTB is on the way to achieving a  $2 \times 10^{-6}$  uncertainty. The uncertainties of the NIST and NIM JNT experiments are currently dominated by statistical uncertainties in the order of  $10 \times 10^{-6}$  to  $20 \times 10^{-6}$ . The NMIJ is developing a brand new JNT experiment. Doppler Broadening Thermometry (DBT): the University Paris North calculated a type B uncertainty of  $2.3 \times 10^{-6}$  but this is based on a line shape model at very low pressure that gives rise to significant type A uncertainties due to signal-to-noise issues. The DBT experiment of the University of Naples achieved an experimental uncertainty of  $24 \times 10^{-6}$ , which is the lowest obtained so far for this technique.

According to the CCT recommendation T2 (2010) to the CIPM a relative standard uncertainty of the order of  $1 \times 10^{-6}$  should be obtained before proceeding to the redefinition of the kelvin, based on measurements applying at least two fundamentally different methods of primary thermometry.

In the 2013 CODATA interim adjustment, without considering correlations, the weight of the NPL AGT 2013 experiment was 59 %, while the PTB DCGT 2013 experiment (being an independent method with respect to AGT) was only weighted by 2 %.

Based on the status as of May 2014, CODATA could recommend a new value with a relative uncertainty of the order of  $0.5 \times 10^{-6}$ . However, there is a small possibility that the next CODATA adjustment could lead to the exclusion of the PTB DCGT result because of the 1 % weight cut-off criterion. In this case, the CCT conditions of at least two fundamentally different methods would not be fulfilled and another method with sufficiently low uncertainty would be required.

For the AGT Boltzmann experiments using argon, the largest uncertainty arises from the determination of the relative argon isotopic abundances. As the NPL and LNE AGT experiments disagree, at least one of the institutes has underestimated its uncertainty. The argon problem is presently under thorough investigation at the LNE, where acoustic comparison experiments are performed with different gases, and at the KRISS using mass spectrometry. If this discrepancy cannot be resolved, CODATA may enlarge the uncertainties of AGT experiments with argon.

Dr J. Fischer recommended that the CCT takes control of the process, presently in the hands of CODATA.

For this and other reasons, Dr J. Fischer suggested that a new recommendation to the CIPM was drafted, discussed at the appropriate agenda point (cf. Recommendations to the CIPM).

#### 4.5 CCT Working Group 5: Radiation Thermometry

Dr G. Machin presented the report of the activities of Working Group 5 (CCT/14-18). Dr G. Machin reminded the CCT of the ToR, tasks, membership and the meetings of WG5. A workshop on primary radiometric temperature determinations was held in October 2012 at the INRiM; the presentations are available on the restricted access webpages of the CCT-WG5. Dr G. Machin listed the documents produced and which are under development by the WG5: the text for the high temperature section of the *MeP-K* was completed and incorporated in the new *MeP-K*, the text for the *Slmf* above the silver point was finalized and the text for *Guide on Secondary Thermometry* (formerly *Approximating Techniques for the ITS-90*) is under preparation.

With respect to the high temperature fixed point (HTFP) research, Dr G. Machin informed the CCT that this work is now being performed within the European Metrology Research Programme (EMRP) project entitled “Implementing the new Kelvin”. Four of each type of selected HTFPs (Co-C, Pt-C and Re-C) are being circulated to eight different NMIs that will independently determine thermodynamic temperature. The Cu point is also being determined at the same time.

Dr G. Machin summarized the progress in the organization of a new Key Comparison (KC) above the silver point. The need for such KC was already clear at the previous CCT meeting in 2012, but at that time no agreement was reached between the RMOs on how to proceed. After intensive discussions, with helpful intervention by the CCT president, WG5 is now able to launch a new KC in summer 2014. The new comparison will have a collapsed star architecture, will be coordinated by the NPL and will cover the temperature range from the silver point to around 2800 °C. The participants are the CEM, KRISS, LNE-CNAM, NIM, NIST, NMIJ, NPL, NRC, PTB and the VNIIM. The travelling standards will be two radiation thermometers and one transfer standard copper point. Additionally, HTFPs will be circulated but will not be a formal part of the KC. Dr G. Machin outlined the time schedule of the comparison: the final discussions on the comparison protocol (second draft) took place during the WG5 meeting of 19 May 2014, so the protocol can now be finalized and submitted to WG7 for approval. The measurements will start by autumn 2014 and will finish by 2016, with completion scheduled for 2018.

Dr Y. Duan expressed his satisfaction for WG5 having developed such a high level KC.

#### 4.6 CCT Working Group 6: Humidity measurements

Dr S. Bell presented the report of the activities of Working Group 6 (CCT/14-30).

After recalling the ToR of the group, Dr S. Bell summarized the progress achieved in the two humidity KCs: the draft B of CCT-K6 (dewpoint from  $-50\text{ }^{\circ}\text{C}$  to  $20\text{ }^{\circ}\text{C}$ ) had been approved by all participants and CCT-K8 (dewpoint from  $30\text{ }^{\circ}\text{C}$  to  $95\text{ }^{\circ}\text{C}$ ) will start later in 2014. Next steps are: the finalization of the CCT-K6 report and its submission to WG7 for approval, the completion of CCT-K8 protocol and the start of its measurements, and the linkage between these two KCs and the corresponding RMO comparisons.

With respect to strategic planning of future key and supplementary comparisons, Dr S. Bell indicated that the WG6 agreed to proceed with planning a comparison in the low range at their meeting held earlier in the week. Although it will probably not be a KC, the alignment of its protocol with APMP.T-S13 is taken into account.

Dr S. Bell outlined the progress of the WG6 in the clarification of humidity quantities, units and symbols. A landmark paper on relative humidity quantities and definitions, in collaboration with International Association for the Properties of Water and Steam (IAPWS), is being prepared and will be published in *Metrologia*. Dr S. Bell welcomed the offer of continuous support from the IAPWS, which may lead to the development of new humidity reference functions from the *TEOS-10* thermodynamic formulation. The group will approach the CCU with a proposal to consider relative humidity in the SI brochure.

Work on the uncertainty in humidity document is progressing slowly but more concisely. A humidity uncertainty workshop is under consideration. The IAPWS showed interest in developing full uncertainty approaches for the *TEOS-10* thermodynamic formulation.

Concerning interactions with the CCQM, two WG6 members are due to participate in the CCQM-K116 comparison of trace moisture in gases and moisture in materials. Within the framework of the EMRP project METefnet, there is interaction between the humidity and CCQM communities in the area of moisture in materials.

Dr S. Bell announced that a possible host for the next International Symposium on Humidity and Moisture (ISHM) has come forward.

An active collaboration between the WG6, IAPWS and World Meteorological Organization (WMO) is ongoing: three WG6 members attended the joint IAPWS and BIPM workshop in September 2013. Two WG6 members joined the IAPWS WG on Thermophysical Properties of Water and Steam. Dr Thorne from the WMO is also collaborating with the CCT.

Dr Y. Duan asked why the planned comparison in the low humidity range is not a KC. Dr S. Bell replied that a KC would need to comply with more formal requirements; a non-KC would be more flexible and its offspring comparisons would not be obliged to linkage. Dr Y. Duan observed that it would generate RMO comparisons, while it would be preferable to have linkage between the RMO comparisons. Dr M. Heinonen clarified that there is a practical problem: when trace moisture is measured with a chilled mirror hygrometer, the comparison measurements require years. He is not convinced that there should be a linkage in every humidity range, because the workload would be too heavy. Dr Y. Duan reiterated that, although there is no need for many KCs, RMO KCs should be linked to the parent CCT KC, as required by the CIPM MRA. Dr M. Heinonen observed that, in the field of trace moisture, not many NMIs around the world have the capability to participate in such a comparison. Dr Y. Duan

suggested that, when running a RMO KC, participants from other RMOs can be invited and included, which will help in establishing the linkage between different RMOs.

Dr S. Picard asked whether the completion of CCT-K6 will launch the linking of the corresponding RMO KCs. Dr S. Bell replied that linkage is a RMO responsibility and not a CCT KC responsibility.

#### 4.7 CCT Working Group 7: Key comparisons

Mr K. Hill presented the report of the activities of Working Group 7 (CCT/14-21).

Mr K. Hill presented an overview of the thermometry comparisons in the KCDB. A total of 93 comparisons are listed in the KCDB, 28 of them approved prior to the previous CCT meeting of May 2012, 13 approved since May 2012; 27 of these requested WG7 action (e.g. protocol review, report review) since May 2012 and 25 did not solicit any WG7 action since May 2012.

Concerning the membership of the group, Mr K. Hill reminded that initially the members of the WG were the pilots of ongoing KCs. Over time, many of the past comparison pilots are no longer delegates of the CCT. Further, the workload has increased so that recruitment of additional members is of high priority. For this reason Dr K. Hill recommended that WG7 should be allowed to significantly increase its membership.

Mr K. Hill reiterated that the tasks of the group are 1) to review the initial protocol and its subsequent iterations until WG7 approval and 2) to review the Draft B report (once agreed by the participants) and its revisions until WG7 approves its publication. Often there are long delays between subsequent versions of the report and the responsibility for these delays must be borne by the pilot and the participants. Comparisons are typically carried out over many years, even though it would be in the best interests of all involved to ensure they conclude as fast as possible to maximize their relevance.

Mr K. Hill recommended the comparison pilots to consult the document CIPM MRA-D-05, which provides a checklist of items that should be included in the protocol. Because the document is less prescriptive regarding the content of the comparison report, Dr Ballico prepared supplementary checklists to be used as guidelines for both protocols and reports (CCT/12-25).

Some important prescriptions of the CIPM MRA-D-05 document were recalled: only CIPM KCs result in a key comparison reference value (KCRV); for an RMO KC the method for determining the KCRV is part of the protocol and is agreed by the CC or by the appropriate WG delegated by the CC; the RMO KC protocol must include the method in which the results will be linked to the corresponding KCRV; RMO KCs are open to participation of NMIs of other regions; the protocol should include a list of the principal components of the uncertainty budget.

Mr K. Hill encouraged the incorporation of the uncertainty guides prepared by the various WGs in the comparison protocols, particularly the SPRT uncertainty guide CCT/08-19rev. Pilots are also encouraged to regularly monitor the status of their comparisons in the KCDB and to update the information when necessary by completing the appropriate form located in the JCRB area of the BIPM website:

[http://www.bipm.org/utis/common/documents/jcrb/registration\\_and\\_progress\\_form.pdf](http://www.bipm.org/utis/common/documents/jcrb/registration_and_progress_form.pdf).

Dr S. Picard asked whether any action should be taken on the comparisons that appeared to be “abandoned”, but Mr K. Hill replied that it is not clear who should take action.



Dr E. Filipe lamented that some RMOs still have difficulties in understanding the difference between traceability and comparison. For example, they wish to use the results of a bilateral comparison as a calibration. Is this something for the WG7 to clarify? Mr K. Hill pointed out that a comparison is a proficiency test and does not provide traceability, but WG7 is only concerned with the report. Dr H. Yoon asked whether the CCT should have the same approach as the Consultative Committee for Photometry and Radiometry (CCPR), where participation in a KC is not allowed if the laboratory does not have an independent realization. Mr K. Hill replied that within the CCT this is not explicitly treated, we do not make sure that the realizations are independent.

Dr M. Milton informed that the long delays in reporting KCs is a major concern for the JCRB, which is currently dealing with this issue. Dr K. Hill recommended finding a mechanism to avoid delays within the CCT, rather than having the JCRB solve it.

Dr Y. Duan reminded the CCT that Mr K. Hill is resigning from WG7 and thanked Mr K. Hill for his valuable contribution to the CCT over the years and asked him to say a few words. Mr K. Hill recalled the exciting times during which the ITS-90 was built up and acknowledged that the interaction with the CCT members always stimulated his scientific research.

#### 4.8 CCT Working Group 8: CMCs

Mr G. Strouse presented the report of the activities of Working Group 8 (CCT/14-23).

He summarized the activities of the group since the last CCT Meeting 2012: in 2012 three RMO CMC submissions (from the APMP and the EURAMET) were published; in 2013 nine RMO CMC submissions (from all RMOs) were published and a talk was given by Dr A. Peruzzi at the JCRB Workshop on *CMC Review Best Practice* and in 2014; eight RMO CMC submissions (from the APMP, COOMET, EURAMET and the SIM) were published.

Mr G. Strouse expressed his satisfaction for the active contribution of all RMOs and thanked Dr C. Kuabayev, Executive Secretary of the JCRB, for his collaboration in the publication of the CMCs in the KCDB.

An overview was given of the CMCs approved over the last two years in terms of the number of countries per RMO: a total of 586 CMCs were approved for 49 different countries, of which one from was from AFRIMETS, 12 from APMP, six from COOMET, 26 from EURAMET and four from SIM. To date more than 2300 CMCs were published from 56 different countries, of which one was from AFRIMETS, 12 from APMP, five from COOMET, 28 from EURAMET and 10 from SIM.

As for the country representation within each RMO, Mr G. Strouse noted that in AFRIMETS 2 % of the countries are represented, in APMP 50 %, in COOMET 25 %, in EURAMET 76 % and in SIM 29 %.

Mr G. Strouse outlined the highlights of the WG8 meeting: each RMO gave a short presentation (the corresponding report can be found on the BIPM website). Three RMO CMCs submissions (APMP, COOMET and EURAMET) were approved. Prompted by the APMP, the harmonization of KCDB nomenclature was initiated during the meeting (limited to service categories for primary thermometry). Three new review protocols are under development: the WG9 protocol for thermal diffusivity was submitted to WG8, which requested additional

editing; the WG9 protocol for thermal conductivity is being planned; and a protocol for air temperature is under consideration.

Mr G. Strouse thanked Dr C. Thomas for her valuable contribution to the WG8.

Mr G. Strouse recalled that guest access to the WG8 Discussion Forum is possible and that all CMC review protocols developed by WG8 are available via open access on the BIPM website. WG8 CMCs review protocols are reached outside the RMOs community, for example in US they are used by accredited laboratories to understand the uncertainties and to test whether they can achieve accreditation.

Mr G. Strouse listed the recent and future changes in WG8 membership due to changes in RMO TC-T chairmanship: Dr E. Ejigu recently replaced Dr H. Liedberg at AFRIMETS; Dr G. Machin will replace Dr A. Peruzzi in June 2014 at EURAMET; and Dr Y.-G. Kim will finish his mandate in 2015 at the APMP.

Dr S. Picard asked if any information was available on the economic impact of the KCDB. Mr G. Strouse did not possess such information.

Dr Y. Hermier asked if any feedback was available on the 'pop-in' survey on the KCDB conducted by the BIPM. Dr C. Thomas confirmed that a survey was conducted for a period of two months and the results were reported in the JCRB report.

#### **4.9 CCT Working Group 9: Thermophysical Properties**

Dr T. Baba presented the report of the activities of Working Group 9 (CCT/14-30).

He recalled the ToR and the membership of the WG9. The new ToR corresponds to the former with the addition of developing and maintaining an effective liaison with the international materials science community, including the Versailles Project on Advanced Materials and Standards (VAMAS).

Dr T. Baba summarized the meeting of the group since 2005, and recalled the evolution of the three pilot studies (CCT-P01 on thermal conductivity of insulating materials, CCT-P02 on thermal diffusivity of dense materials and CCT-P03 on normal spectral emissivity of solids). After discussion at the CCT meeting 2012, it was agreed that these pilot studies could be registered as supplementary comparisons with the goal of supporting the submission of CMCs for the participating NMIs and the nomenclature of the three pilot studies was changed in CCT-S2, CCT-S3 and CCT-S1, respectively.

The technical protocol of CCT-S1 was agreed by WG9 in the meeting of 20 May 2014 and will be submitted to WG7 for approval. At the same time, the Draft A report is being circulated among the participants. The CMC review protocol of infrared spectral normal emissivity is in preparation.

Based on the experience gained in CCT-S2, the APMP initiated an additional supplementary comparison on thermal conductivity (APMP.T-S10). The technical protocol was approved by WG7, the specimens are being prepared by the pilot and the measurements will start soon.

The APMP initiated an additional supplementary comparison on thermal diffusivity (APMP.T-S9), similar to CCT-S3 (thermal diffusivity of isotropic graphite with laser flash method) and Dr T. Baba showed its detailed schedule (Draft B scheduled for January 2015).

Dr T. Baba, after 9 years of chairmanship, resigned from the WG9 and recommended Dr J.-R. Filtz as the new chairperson. Dr Y. Duan thanked Dr T. Baba for his contribution as chairperson of the WG9 and invited Dr J.-R. Filtz to make a short speech to the CCT plenary. Dr J.R. Filtz thanked Dr T. Baba for his dedicated work, outlined his background in the field of thermophysical properties of materials and anticipated his short-term and long-term vision for the WG9. In the short term the ToR and tasks of the WG should be revised and formulated in terms of research activities and comparisons. In the long term the visibility of the group and the link between thermometry, humidity and thermo-physical properties of materials should be enhanced.

#### 4.10 Report of the WG on Strategy and revised structure of the CCT Working Groups

Mr G. Strouse indicated that the meeting of the WG on Strategy was dedicated to discussing the proposal, presented by the president of the CCT (CCT/14/06), for a revised structure of the CCT Working Groups.

Mr G. Strouse summarized the background and the most relevant aspects of this proposal. The NMI directors encouraged the CCs to increase their efficiency by reducing the membership and the overall number of WG/TGs, while maintaining the essential benefits produced. The driving force behind such a request seems to be cost saving.

In the revised structure, a Working Group is defined as being established for continuous tasks required by the CCT or covers a mature field with a demonstrated long-term basis with an objective-oriented activity and must be approved by the CIPM. A Task Group is established for an interest group with one or several objectives limited in time and/or by achievement. Tasks groups are to be approved by the CCT. A Forum is established when there is an interest for a broader exchange or when there is a wish to reach a wider audience.

Mr G. Strouse presented the modality to enforce the revised structure of WGs and TGs: first all WGs and TGs are dissolved and reformed into new WGs and TGs. The chair of each new WG/TG will be proposed by the CCT president and voted by the plenary CCT. For each new WG/TG, each NMI delegate will be asked to express an interest to become a member and, if yes, to indicate the name of the NMI expert that will represent the NMI in the WG/TG. After the meeting, the CCT president and the chairperson will decide the membership on the basis of the NMI's expression of interest.

After asking for remaining questions/comments/objections, Dr Y. Duan declared the revised structure approved by the plenary CCT.

Dr G. Strouse listed the new WG/TGs and how they originated from old WG/TGs:

- TG-K, resulted from merging WG1 and TG-*MeP*;
- TG-GoTh, resulted from merging WG2 and WG3;
- WG-CTh, reformation of WG4;
- WG-NCTh, reformation of WG5;
- WG-Humidity, reformation of WG6;
- WG-KC, reformation of WG7;
- WG-CMC, reformation of WG8;
- TG-ThQ, reformation of WG9;

- TG-SI, reformation of TG-SI;
- TG-Env, new task group;
- WG-SP, reformation of WG-S.

Dr Y. Duan expressed his gratitude to all those who have contributed to the dissolved WGs and TGs over the years and invited Dr M. Milton to say a few words about the motivation for the requested reform. Dr M. Milton commented that in 2011 the CIPM was challenged to look at its governance, the CCs and the CIPM MRA. With respect to the CIPM MRA, he indicated that the decision to revise the CIPM MRA will be announced at the CGPM in November 2014. With respect to governance of the CIPM, Dr M. Milton commented that all 18 members of CIPM will resign in connection with the GCPM and members will be elected in November 2014. In line with the intention of running open, transparent and accountable processes, the CCs were asked to reform their structure. The emphasis is to look at resources and efficiency as well as creating opportunities for new activities within the CCT. Also, beside the CCT, other CCs prepared proposals for revised structure and the CCT proposal is in line with the other proposals. This process of rationalization is not unusual for these times, in which special attention must be devoted to resources.

Dr Y. Duan thanked Dr S. Picard for preparing the document CCT/14-06.

Mr G. Strouse asked whether there is a clear indication on the reduction of the number of members of the WGs and TGs. Dr M. Milton replied that there is no strict rule and there are two opposing pressures: on one side there is the tendency of the NMI directors to have only one person per meeting, on the other side the Metre Convention is expanding; every year there are new Member States and the number of Member States represented in the CCs will therefore certainly increase.

Dr S. Bell asked if co-opted members, which do not come from NMIs, are still accepted. Dr M. Milton replied that, on the contrary, more stakeholder involvement is desired.

There was some discussion on the modality of applying for membership: should the director or a superior from the NMI apply for the membership? Should a form be used for applying for membership? Dr Y. Duan clarified that these points would be specified in the session of the meeting in which the applications for membership will be collected (following day).

## **5 COMPOSITIONS OF NEW WORKING GROUPS AND TASK GROUPS**

For each newly formed WG and TG, the CCT president proposed a chairperson and asked for a formal vote by the CCT plenary. All proposed chairpersons were unanimously approved by the CCT plenary.

For each new WG and TG, the CCT delegates were asked to express the interest of their respective NMI in becoming a member and to nominate the corresponding expert.

**TG-K:**

Chairperson: Dr B. Fellmuth

Interest in becoming a member: NIST (G. Strouse), NRC (K. Hill), UME (M. Kalemci), VNIIM (A. Pokhodun), NIM (J. Sun), KRISS (W. Joung), VSL (A. Peruzzi), NPL (J. Pearce), LNE (F. Sparasci), NMIJ (T. Nakano), INRiM (P. Steur), CENAM (E. Mendez)

**TG-GoTh:**

Chairperson: Dr R. White

Interest in becoming a member: NIST (W. Tew), UME (M. Kalemci), VNIIM (A. Ivanova), NIM (J. Sun), CEM (D. Del Campo), NMIA (F. Jahan), KRISS (Y.G. Kim), PTB (F. Edler), NPL (J. Pearce), MIKES (M. Heinonen), NMIJ (J. Tamba), IPQ (E. Filipe), INRiM (L. Iacomini), CENAM (E. Mendez), SMU (S. Duris)

**WG-CTh:**

Chairperson: Dr J. Fischer

Interest in becoming a member: NIST (M. Moldover), NRC (P. Rourke), VNIIM (A. Pokhodun), NIM (J. Zhang), KRISS (I. Yang), NPL (M. De Podesta), LNE (L. Pitre), NMIJ (K. Yamazawa), VNIIFTRI (G. Kytin), INRiM (P. Steur), INMETRO (R. Teixeira), MSL (D. R. White)

Co-opted member: R. Rusby (NPL)

**TG-SI:**

Chairperson: Dr J. Fischer

Interest in becoming a member: NIST (M. Moldover), NRC (P. Rourke), VNIIM (A. Pokhodun), NIM (J. Zhang), MSL (R. White), KRISS (I. Yang), NPL (G. Machin), NMIJ (K. Yamazawa), LNE (L. Pitre), INRiM (R. Gavioso)

Observers: S. Picard and Y. Duan

**WG-NCTh:**

Chairperson: Dr G. Machin

Interest in becoming a member: NIST (H. Yoon), NRC (A. Todd), UME (A. Diril), VNIIM (M. Matveyev), NMIA (E. van der Ham), NIM (Z. Yuan), NMISA (E. Ejigu), CEM (M.J. Martín), MSL (P. Saunders), KRISS (Y.-G. Kim), PTB (J. Hollandt), VSL (E. Vuelban), LNE (M. Sadli), NMIJ (Y. Yamada), A\*STAR (L. Wang), INRiM (F. Girard), INMETRO (R. Teixeira), CENAM (D. Cardenas)

Co-opted members: K. Anhalt (PTB), H. Mc Evoy (NPL)

**WG-Hu:**

Chairperson: Dr S. Bell

Interest in becoming a member: NIST (C. Meyer), UME (S. Aytekin), NMISA (R. Mnguni), INTA (R. Benyon), MSL (J. Lovell-Smith), KRISS (Choi), PTB (N. Böse), VSL (R. Bosma), MIKES (M. Heinonen), LNE (E. Georgin), NMIJ (H. Abe), VNIIM (M. Vinge), INRiM (V. Fericola), A\*STAR (L. Wang), CENAM (L. Lira-Cortes)

Co-opted member: R. Feistel (Leibniz Institute for Baltic Sea Research)

**WG-KC:**

Chairperson: Dr A. Peruzzi

Interest in becoming a member: G. Strouse (NIST), S. Bell (NPL), R. Rusby (NPL), H. McEvoy (NPL), A. Todd (NRC), K. Hill (NRC), S. Rudtsch (PTB), R. Benyon (INTA), Y. Yamada (NMIJ), R. White (MSL); RMO TC-T chairpersons are invited as observers

**WG-CMC:**

Chairperson: Mr G. Strouse

Members: RMO TC-T chairpersons, i.e. AFRIMET (E. Ejigu), APMP (Y.G. Kim), COOMET (A. Pokhodun), EURAMET (G. Machin), SIM (O. Robatto)

**WG-ThQ:**

Chairperson: Mr J.-R. Filtz

Interest in becoming a member: NIST (L. Hanssen), VNIIM (N. Sokolov), NIM (J. Zhang), KRISS (Kwon), PTB (J. Hollandt), NPL (C. Stacey), LNE (B. Hay), NMIJ (N. Yamada), INRiM (F. Girard), CENAM (Lira)

**TG-Env:**

Chairperson: Dr A. Merlone

Interest in becoming a member: NIST (G. Strouse), UME (M. Kalemci), NMIA (E. van der Ham), NIM (J. Zhang), NMISA (E. Ejigu), CEM (C. Garcia), KRISS (Y.G. Kim), PTB (C. Monte), NPL (M. de Podesta), MIKES (M. Heinonen), LNE (F. Sparasci), NMIJ (J. Tamba), SMU (P. Pavlacek)

Co-opted members: P. Thorne (NERSC), R. Feistel (Leibniz Institute for Baltic Sea Research), CCPR president, a representative of the WG-Hu

**WG-SP:** Chairperson: Dr Y. Duan (CCT President)

Working Group and Task Group chairpersons, i.e.

G. Strouse (NIST) for WG-CMC, J.Fischer (PTB) for WG-CTh and TG-SI, S. Bell (NPL) for WG-Hu, A. Peruzzi (VSL) for WG-KC, G. Machin (NPL) for WG-NCTh, A. Merlone (INRiM) for TG-Env, D.R. White (MSL) for TG-GoTh, B. Fellmuth (PTB) for TG-K, J.-R. Filtz (LNE) for TG-ThQ; RMO TC-T chairpersons are invited as observers

## 6 CCT KEY COMPARISONS

Dr S. Picard introduced this session which was dedicated to the progress of CCT KCs since last CCT meeting in 2012 and asked Mr K. Hill whether any KC reports had been received since the last meeting; Mr K. Hill replied negatively.

Dr S. Picard then proceeded with asking the pilots of all on-going comparisons to briefly summarize the status of the respective comparison.

For CCT-K1.1, Mr G. Strouse commented that the pilot was waiting for a participant to deliver his data. After the data are received by the pilot (expected to happen in summer 2014), the comparison will move forward.

For CCT-K2.2, Dr P. Steur announced that NIM would receive the equipment in 2015 and expects a completion of the measurement by the beginning of 2016.

For CCT-K2.5, Mr K. Hill commented that data from INRiM were expected to be delivered within one year.

For CCT-K6, Dr S. Bell gave a presentation.

Dr S. Bell recalled the scope, the mechanism and the participants of this comparison. The second version of Draft A Report (2013) was agreed by all participants and partially presented at TEMPMEKO2013. The Draft B Report, in which the KCRV was revised at two temperatures by excluding agreed outliers, is currently in the process of agreement by the participants.

Dr S. Bell explained the root cause for the long duration (2001-2014) of this comparison: many travelling standards broke down and repairs were necessary due to old instruments with a consequent increase in extra pilot checks. Although no sign of discontinuity in the performance of the travelling standards was observed, the long-term stability of the instrument remained a concern due to the long duration and some ambiguity in the drift data. The duration of CCT-K6 is also a concern for linking to other comparisons and for the next repeat cycle of comparisons.

The overall summary graph of the results was displayed and Dr S. Bell pointed out that the reporting also covers how the instruments drift, the outliers and the KCRV were considered. With respect to the outliers and the KCRV, the KCRV was recalculated at two temperatures excluding the two outlying results. The impact of including/excluding the outliers from the KCRV calculation was not relevant. The outlying results have a credible explanation and action was taken to increase the corresponding CMC uncertainty.

Dr S. Bell finished by anticipating the next steps to be taken: Draft B report to be submitted to WG7 for approval and RMO extension comparisons to be linked to the KCRV.

For CCT-K6.1, Dr S. Bell conveyed the message from the pilot Dr J. Lowell-Smith that, due to technical problems in the interpretation of the results, the comparison is currently only at the stage of preparing the Draft A Report.

For CCT-K8, Dr S. Bell presented some slides prepared by the pilot Dr R. Benyon, who sincerely apologized for the delay in making progress in this comparison. The NIST acts as co-pilot with support from the E+E. The MBW delivered four PRTs that have been extensively tested by the INTA and sent to the NIST for temperature calibration prior to final integration in the chilled mirror hygrometers. Dr S. Bell also recalled the main aspects of the protocol, the

participants and the circulation scheme. As for the time line of the comparison, the start of the measurements is scheduled for September 2014 and the end for January 2017.

For CCT-K9, Mr G. Strouse informed that many participants had not yet delivered the final data (CENAM, INMETRO, INRiM, INTI, LNE, NIM, NMIA, NMISA and NRC) and some of the participants had not even delivered the initial data (CENAM, INTI, LNE, NIM, NMIA, and NRC). Moreover, two participants had had accidents with their SPRTs.

Mr G. Strouse set a deadline for the delivery of all data by the end of 2014. There was some discussion on what should be done if not all the participants deliver their data by the end of 2014, but no final decision was taken. Mr G. Strouse invited the participants to write to him after they return to their laboratories and inform him of the date they will deliver the data.

Dr Y. Duan proposed to ask the delegates of the six countries that did not deliver the initial data to clarify why, and when they expect to deliver the initial data. The NIM replied that their final data are available but it was not clear to them that they had to deliver the initial data separately and in advance of the final data. The LNE and the NMIA noted that a problem with communication of data was due to change of staff. All six participants (CENAM, INTI, LNE, NIM, NMIA, and NRC) agreed to deliver the initial data within one month.

Dr T. Baba summarized the progress of the three CCT SCs: for CCT-S1, the protocol was agreed by all participants and will be sent immediately to WG7 for approval, for CCT-S2, the pilot is LNE and Dr Hermier agreed on asking Dr Hay to inform Dr Baba on the status of the comparison, for CCT-S3, piloted by NMIJ, the measurements were completed and Draft A is being prepared.

Dr S. Picard asked whether new CCT KCs were being planned.

Dr G. Machin announced that a new KC on radiation thermometry was initiated with the name CCT-K10.

Dr Y. Hermier announced that the regional EURAMET extension of CCT-K9, namely EURAMET.T-K9, had been initiated.

## **7 REGIONAL METROLOGY ORGANIZATIONS**

### **7.1 JCRB matters**

The Executive Secretary of the JCRB, Mr C. Kuanbayev, reported on the activities of the JCRB since the last CCT Meeting.

Mr C. Kuanbayev commented on the CIPM MRA documents on the BIPM website,

<http://www.bipm.org/en/cipm-mra/documents/> and announced that a new tool is available at

<http://www.bipm.org/jsp/en/JCRBOutcomes.jsp>, where all resolutions, recommendations and actions of the JCRB can be found and searched by meeting, by topic and by search term.

Mr C. Kuanbayev highlighted the main outcomes of the JCRB: resolution 30/1 on the new deadlines for the RMOs to indicate the intention to review (3 weeks), to submit the review report



and to approve CMCs (3 weeks), recommendation 30/1 in which the JCRB encouraged the CCs and the RMOs to use the BIPM web forum and to consider increased use of the “fast track”, recommendation 30/2 to reduce, where possible, duplication resulting from RMO reviewing the same CMCs in interregional review and recommendation 30/3 to the RMO for paying greater attention to the appropriate guidelines during the intra-RMO review.

Mr C. Kuanbayev informed the CCT of the new form available for updating information on KC/SCs (action 31/1). The form can be downloaded, filled in or updated and uploaded back. He also mentioned that the JCRB asked the RMOs to prepare a list of the benefits and the successes of the CIPM MRA (action 32/5) and to contribute to the future revision of the CIPM MRA (action 32/6).

Some statistics on the Database were presented: the average time from posting a CMC to its publication decreased significantly from 132 days (from 2001 to December 2012) to 107 days (from January to July 2013) to 76 days (from August 2013 to February 2014). For “fast track” the average time is only 17 days.

Dr C. Thomas gave a short presentation on the ‘pop-in’ questionnaire for visitors to Appendix B and Appendix C of the KCDB, which was run for approximately two months at the beginning of 2014. The goal of this exercise was to understand who visits the KCDB. A total of 642 responses were collected (BIPM was excluded from the results of the questionnaire), 62.9 % were from NMIs, 7.2 % from DIs and 14.8 % from accredited bodies and calibration and testing laboratories. Dr M. Milton was pleasantly surprised with the relevance of last percentage. Dr Y. Duan wondered why NMIs access the KCDB so frequently (62.9 %). Dr M. Milton replied that he himself accesses the KCDB frequently because it is a convenient repository for KC reports. Dr V. Fericola shared statistics performed at INRiM according to which there is a factor of 200 between the number of CMCs and the number of accredited laboratories certificates. Dr P. Steur asked whether the low level of access from industrial and commercial companies is disappointing, Dr M. Milton commented that on the contrary the percentage was surprisingly high.

## 7.2 AFRIMET report

Dr E. Ejigu presented the report on the activities of AFRIMETS over the past two years.

Dr E. Ejigu recalled that AFRIMETS is organized into six sub-RMOs (MAGMET, NEWMET, EAMET, SADC MET, CEMAC MET and SOAMET). The last two do not have member countries, so only four are active.

The capabilities and the comparisons conducted by the AFRIMETS members were summarized. The comparison AFRIMETS.T-S1 on industrial PRTs started in March 2008; its Draft B Report was reviewed by WG7 and the comments are currently being addressed. AFRIMETS.T-S2 on industrial PRTs started in May 2012 but it was suspended during the circulation of the travelling standard. AFRIMETS.T-S3, also on industrial PRTs, started in May 2012 and it is currently being circulated. Some comparisons are being conducted at the sub-RMO level: there are the EAMET comparisons on industrial PRTs and on thermocouples; MAGMET comparisons on SPRTs and fixed points; SADC MET comparisons on PRTs, thermocouples and electrical simulations.

Dr E. Ejigu outlined the future plans of the AFRIMETS TC-T to: encourage the AFRIMETS countries to become CCT members; build capacity through training workshops/seminars/courses; establish laboratory attachment/internships; share equipment and facilities; and improve accreditation/peer review. There are plans to start new comparisons on noble metal thermocouples, electrical simulations, radiation thermometers, SPRTs at fixed points, liquid in glass thermometers and temperature indicators.

Dr E. Ejigu emphasized the constraints of the AFRIMETS region: the lack of sufficient funds, the capacity gap in traceability maintenance and the small number of TC-T members.

Dr M. Milton congratulated Dr E. Ejigu for the AFRIMETS activities and asked whether AFRIMETS has one TC-T for each Sub-RMO. Dr E. Ejigu replied that that is the case.

Mr K. Hill asked whether Dr E. Ejigu had any information on the progress of AFRIMETS.T-S4 comparison between Slovenia and South-Africa, but Dr E. Ejigu did not.

### 7.3 APMP report

Dr Y.-G. Kim presented the report of the activities of the APMP in the past two years (CCT/14-27).

Dr Y.-G. Kim illustrated the structure of the APMP TC-T. There are five WGs which are mainly concerned with CMC reviews: WG on SPRTs and Fixed Points; WG on radiation thermometry; WG on industrial thermometers; WG on humidity; and WG on thermo-physical quantities.

Several APMP meetings/workshops were organized in 2013: one workshop on radiation thermometry was held in May in Japan, as a preparatory step for the APMP KC on radiation thermometry. The APMP mid-year meeting was held in June 2013 in Sri Lanka and the APMP TC-T Meeting was held in December 2013 in Taiwan. The review of the RMO CMCs takes place once per year with a deadline for submission at the end of July and with the reviews performed in association with the TC-T meeting. The CIPM MRA-D-04 document is followed strictly in the reviews.

Dr Y.-G. Kim summarized the main outcomes of the last APMP TC-T meeting: the reviewers for SCL (Hong Kong (China)) and KIM-LIPI (Indonesia) were approved, the regional extension of the new radiation thermometry comparison CCT-K10 was agreed and several new regional comparisons were approved (KC on silver point, KC on SPRTs from argon to zinc, SC for thermocouples up to 1500 °C and SC for ear thermometers). A resolution was approved on the delay of comparisons: in case of KC/SC delay without a valid reason, if the delay is longer than indicated in the protocol, the restriction specified in the protocol will be applied and the participant is given a restriction in participation in other comparisons until the problem is solved. The TC-T holds a satellite workshop every year just before the APMP meeting. In 2014 the subject of the workshop is “Meteorological measurements of temperature and humidity”.

Dr Y.-G. Kim announced the APMP events in 2014. The APMP mid-year meeting will be held in June in Indonesia. On 19-20 September an APMP workshop will be held in the Republic of Korea on “Meteorological measurements of temperature and humidity in APMP region” where the APMP TC-T meeting will also take place (21 to 26 September).

The main issues related to the planned APMP comparisons (APMP.T-K4.2, repetition of APMP.T-K6, because APMP.T-K6 was conducted a long time ago and APMP.T-K9) were

outlined as well as the on-going APMP comparisons (APMP.T-S7, APMP.T-S8, APMP.T-S10, APMP.T-S11 and APMP.T-S12).

Dr G. Machin asked whether the APMP has a procedure for approving reviewers and Dr Y.-G. Kim replied positively.

Dr H. Yoon expressed his concern on having had a preparatory workshop for the APMP comparison on radiation thermometry, because this could jeopardize the independency of individual realizations. Dr Y. Yamada explained that the workshop was mainly intended to teach how to handle the circulated fixed points in order to minimize the risk of breakage.

#### **7.4 COOMET report**

Dr A. Pokhodun presented a report on the activities of COOMET TC1.10 during the last two years (CCT/14-22).

Dr A. Pokhodun showed how the attendance of the COOMET TC1.10 meeting had grown since its creation in 2001; only four countries attended the first meeting in 2001 while 13 countries attended last meeting in 2014.

Some intrinsic difficulties of the committee were pointed out: Russia is the only CCT member in COOMET, so all regional key comparisons must be piloted by Russia with a consequent heavy workload. The large distances between the NMIs concerned represent additional logistic issues in running comparisons.

Dr A. Pokhodun listed the COOMET comparisons that were completed and that are in progress, and showed the dynamics of the development of the COOMET measuring capabilities in time: only Russia and the BelGIM (Belarus) had CMCs in 2009. In 2010 the NSC IM (Ukraine) had published CMCs, and in 2013 the KazInMetr (Kazakhstan), INIMET (Cuba) and the INSM (Moldova) published CMCs, the GEOSTM (Georgia) was added to the group in 2014.

He indicated that the review of inter- and intra-RMO CMCs is performed in the COOMET according to the WG8 review protocols and the COOMET document COOMET-R/GM/7:2006.

Dr A. Pokhodun mentioned two COOMET projects intended to support the CIPM MRA: COOMET 594/RU/13 (a training workshop on calibration of platinum resistance thermometers) and COOMET 633/KG/14 (on calibration of resistance thermometers).

Dr Y. Duan commented that, as there is only one CCT member in COOMET, the linkage of regional comparisons to the corresponding CCT comparisons could not be as robust as for other RMOs. Dr J. Fischer informed that the PTB takes part in some of the COOMET comparisons which mitigates this problem.

#### **7.5 EURAMET report**

Dr A. Peruzzi presented the report of the activities of the EURAMET over the last two years (CCT/14-15).

Dr A. Peruzzi recalled that the EURAMET TC-T is involved in three technical areas: thermometry, humidity and thermo-physical quantities. The TC is organized into four Working Groups: 1) the WG on CMC Review, which performs inter- and intra-RMO CMC reviews,

2) the WG on Strategy, which generates and updates the technical roadmaps and supports and coordinates the participation of the TC-T in the joint EURAMET/EU research programmes, 3) the WG on Best Practice, which supports assessments and improve measurement procedures and 4) the WG on Thermo-physical Quantities of Materials.

He listed the regional comparisons that were completed since the last CCT meeting, the comparisons that are currently in an advanced stage (measurements completed) and the comparisons that were initiated recently. Among the last ones, Dr A. Peruzzi emphasized the decision taken by EURAMET of initiating the regional extension of CCT-K9, without waiting for the conclusion of CCT-K9.

The intra-RMO CMC review process within EURAMET was described: it is a cyclic process with a one year period, the NMI contact persons are required to submit new or modified CMC entries by the end of February, the CMC Review group must respond by the end of May with acceptance or with request of additional supporting information and the contact persons must submit, if required, additional supporting information by the end of June.

Dr A. Peruzzi summarized the batches of EURAMET CMCs published in the KCDB since May 2012: two batches were published in 2012, three batches in 2013 and two batches in 2014 for a total of 333 published CMCs. Two new batches were approved in the last WG8 meeting and will be soon published in the KCDB.

The activities of the EURAMET TC-T were dominated by two consecutive metrology research programmes in the past years, jointly funded by the EU and a large majority of EURAMET countries. The most recent programme, the EMPIR, will last from 2014 to 2024.

Dr A. Peruzzi pointed out that the engagement of the EURAMET TC-T community in such programmes was coordinated by the Strategy WG through a web-based share-point. He also emphasized that, because of the relevant EU funding received by the NMI/DIs through such programmes, the national metrology programmes are becoming strongly linked to such EURAMET/EU joint programmes, so much so that, beyond the base maintenance of the facilities, only residual funding and resources remain available for more traditional activities like KC/SCs.

Finally Dr A. Peruzzi indicated that, as part of a larger process undertaken by the EURAMET metrology TCs to guide the direction of metrology research of the EURAMET NMI/DIs over the next decade, the EURAMET TC-T generated and periodically updates technical roadmaps for Thermometry, Humidity and Moisture and Thermophysical Quantities of Materials. These three roadmaps were presented at the TEMPMEKO 2013 symposium and the corresponding papers will be published in the *International Journal of Thermophysics*.

Dr E. Van der Ham asked whether there is a mechanism for non-EURAMET NMIs to express an interest in participating in joint research projects of the EMPIR programme. Dr A. Peruzzi replied that unfortunately at the moment there is no such mechanism.

Dr Y.-G. Kim asked how the CMC review work is distributed among the members of the CMC Review WG. Dr A. Peruzzi replied that, for each group of services, there are two experts in the field among the members of the CMC Review WG to whom the review is assigned.

## 7.6 SIM report

Ms O. Robatto presented the report of the activities of SIM MWG 3 (Metrology Working Group of Thermometry) over the last two years (CCT/14-25).

Ms O. Robatto summarized the SIM comparisons in progress, the comparisons approved and published in the KCDB and the proposed comparisons that are marked as planned in the KCDB. She reminded the CCT that currently ten SIM members have CMCs published in the KCDB and that a SIM member, Colombia, recently became Member State of the BIPM.

Ms O. Robatto mentioned other SIM activities like the NIST Guest Research Program, which allowed the internship of two SIM researchers at NIST in 2012 and the three-week long Thermometry Workshop held at the CENAM in 2013. The meeting of SIM Metrology was held at the NIST in October 2013, hosting 53 students from 29 SIM countries.

Concerning future SIM activities, Ms O. Robatto informed the CCT on the forthcoming SIM MWG3, which is planned to coincide with the *Simposio de Metrologia 2014* that will be held at CENAM in October 2014.

## 7.7 Résumé on the InK project

Dr G. Machin outlined the objectives of the European Metrology Research Project *Implementing the new Kelvin (InK)*. This project aims at a step change in primary thermometry from 0.9 mK to 3000 K by developing and demonstrating primary thermometry methods that could challenge and supplant the defined scales at high (>1300 K) and low (<1K) temperatures, by determining  $T-T_{90}$  values with the world's lowest uncertainties (<1 mK) between approximately 1 K and 933 K, and by determining new  $T-T_{2000}$  values addressing the discrepancy in the background data of the PLTS-2000.

Dr G. Machin informed the CCT that the project includes nine EU partners, four unfunded non-EU partners, three research excellence grants and five collaborators, runs from October 2012 to September 2015 and is structured in four work packages (WPs).

The activities of the four WPs were outlined: WP1 is dedicated to the assignment of thermodynamic temperatures to HTFPs above 1000 °C (Re-C, Pt-C, Co-C and Cu); WP2 aims to assess two different methods for the dissemination of thermodynamic temperature above 1000 °C (a relative primary one, with *a priori* calibrated HTFPs, and an absolute primary one, based on absolute radiometry). The objective of WP3 is to provide improved estimates of  $T-T_{90}$  through determinations via multiple primary thermometry methods (acoustic, dielectric constant, refractive index, electrical noise and lower temperature radiometry). The WP4 aims at: the development of primary thermometers for the direct realization of the kelvin below 1 K; providing new and improved thermometers to disseminate  $T$  at very low temperatures; and undertaking low uncertainty primary thermometry to resolve discrepancies in the background data of the PLTS-2000.

Finally Dr G. Machin announced that the InK project was awarded an international scientific meeting at the Royal Society's Kavli Royal Society International Centre, Chicheley Hall, UK, on 18-19 May 2015 with possible publication in a special edition of the *Philosophical Transactions of the Royal Society*.

## 7.8 **Résumé on the METefnet project**

Dr S. Bell gave an introduction to the European Metrology Research Project *Metrology for Moisture in Materials, METefnet*. This project aims at developing unambiguous principles, methods and equipment for establishing and disseminating SI traceability to measurements of moisture in solids.

She pointed out that mass loss on drying is recognized as the ultimate reference for moisture content in solids but moisture content values are distorted by other volatiles and varying binding of water. Moreover, in measurements of moisture in solids, uncertainties are often unknown and means to establish traceability links are insufficient or missing.

Dr S. Bell outlined the objectives of this project: to establish the principles of SI traceability for moisture measurements, to develop primary NMI realizations for water mass fraction and amount fraction, to develop transfer standard instruments to enable dissemination from primary realizations, to develop methods for calibrating surface moisture meters and to develop methods for estimating uncertainty. The target materials are pharmaceuticals, foodstuffs, polymers and wood products.

The CCT was given details of the project partners and potential collaborators.

Dr S. Bell clarified the reasons for the interest of humidity scientists in such objectives: though composition by mass or amount of substance is chemistry, as industries ultimately seek on-line physical measurements of moisture, this concerns air humidity. In fact, for most applied air humidity measurements, the real interest is moisture in materials, and air humidity and material moisture content are closely inter-related (water activity).

The metrology issues that are dealt with in the project were summarized: different methods measure different things (water or moisture, free water, capillary water, bound water, ...), sample handling, reference methods for mass loss on drying, heating and weighing does not reliably evaluate water fraction, certified reference materials give traceability of water fraction but they are limited and narrowly applicable. Both physical and chemical metrology are needed and a mature metrology infrastructure, which requires NMI standards, key comparisons, CMCs, commercial laboratory accreditations and traceable calibrations, is not yet in place for this field.

Dr S. Bell announced that the CCQM formed a task group on grain moisture with input from CCT WG6. This originated from the request of some CCQM members for a KC and CMCs on grain moisture. A non-key comparison was planned with UNIIM providing a report on methods and uncertainty to support the comparison. The CCQM objected that the measurand is method-dependent. METefnet hopefully will improve this situation. The International Organization of Legal Metrology (OIML) oversees legal metrology aspects of moisture in grain.

Dr M. Milton asked whether moisture in grain is addressed in the project and Dr S. Bell replied that there is no plan to do that. Dr M. Milton then asked for the reason for the projects interest in grain moisture. Dr M. Heinonen (coordinator of this project) clarified that most of the measurement methods are very much matrix dependent and a universal reference is very difficult to find, so at the moment the project is focused on specific industrial interests such as pharmaceuticals and foodstuffs.

Mr K. Hill asked whether the project also addresses moisture in gas. Dr S. Bell replied that, although this specific project does not deal with moisture in gas, other EMRP projects addressed

moisture in gas, such as the EMRP project on energy gases, focused on methane, and a new EMRP project focused on biogases.

## 8 CCT MEMBERSHIPS

Dr Y. Duan recalled on the rules for CCT membership that are described in CIPM-D-01 document. More specifically Dr Y. Duan made reference to the following part of the CIPM document:

*“Membership of a CC is open to institution of Member States of the BIPM that are recognized internationally as most expert in the field. This normally requires that they:*

- *Be national laboratories charged with establishing national standards in the field;*
- *Be active in research and have a record of recent publications in research journal of international repute;*
- *Have demonstrated competence by a record of participation in international comparisons organized either by the CC, the BIPM or a regional metrology organization;”*

Dr Y. Duan invited Dr A. Szmyrka-Grzebyk to make a presentation on behalf of the INTiBS (Poland) to support its application for membership of the CCT.

Dr A. Szmyrka-Grzebyk clarified that in Poland two laboratories maintain the national standards for temperature: the GUM, which maintains the national standards for the high temperature range from  $-189.3442\text{ }^{\circ}\text{C}$  to  $961.78\text{ }^{\circ}\text{C}$  with long-stem SPRTs, and the INTiBS which maintains the national standards for the low temperature range from  $13.8033\text{ K}$  to  $273.16\text{ K}$  with capsule SPRTs.

Dr A. Szmyrka-Grzebyk presented a short review of the research interests of the INTiBS, summarized the history of the laboratory of temperature standards of the INTiBS, which dates back to 1966, and recalled the main achievements of the laboratory.

Dr Y. Duan invited Dr R. Strnad to make a presentation to support the application for membership of the CCT by the CMI (Czech Republic). Dr R. Strnad presented the temperature measurement capabilities of the laboratory: for contact thermometry, fixed point calibrations from Ar to Pt and calibrations by comparison from  $-80\text{ }^{\circ}\text{C}$  to  $1800\text{ }^{\circ}\text{C}$  and, for non-contact thermometry, fixed point calibrations at In, Sn, Al and Cu and calibrations by comparisons from  $-30\text{ }^{\circ}\text{C}$  to  $1800\text{ }^{\circ}\text{C}$ . Concerning future plans, Dr R. Strnad anticipated that CMI intends to work on eutectic fixed points (Fe-C, Co-C and Ni-C) and the required know-how will be acquired through a EMRP Researcher of Excellence Grant whose research was performed at the NPL.

Dr R. Strnad also presented the humidity measurement capabilities of the laboratory and its capabilities in the measurement of thermo-physical quantities.

Dr Y. Duan invited Dr D. Zvizdić to present the application on behalf of HMI (Croatia). Dr D. Zvizdić clarified that, as HMI applied became an observer of the CCT in 2012, he only

considered it appropriate to present the activities performed in the past two years to support the request for a full membership of the CCT.

Dr D. Zvizdić recalled the organizational structure of the HMI, and outlined the research activities performed by HMI/FBS-LPM in the past two years.

The original concept of multi-entrance fixed points (MEFPs) was introduced by the HMI/FBS-LPM in 2005, and is meant to be used in comparison calibrations as they allow improved gradients and stability without the need to use high-purity materials, pressure control and primary furnaces and baths. In the first mercury MEFPs thermal gradients decreased from 6 mK to 0.5 mK with respect to the traditional solid equalizing block. In the tin-filled MEFP, grey cast iron was used to manufacture the cell and a maximum temperature difference obtained between borings was 2 mK. In the Zn MEFP, the maximum differences between the temperatures measured inside the re-entrant tubes were 0.4 mK to 3 mK.

Another research line of the HMI/FBS-LPM is the investigation of hysteresis of thin film PRTs in the range 100 °C to 600 °C. Particularly the representativeness of the hysteresis measured in one thermometer for other thermometers of the same type and manufacturer was investigated.

Further, numerical modeling of transient heat transfer in zinc fixed point cells and the influence of fluid velocity on self-heating errors in platinum resistance thermometry are investigated.

In the field of humidity, the HMI/FBS-LPM developed a primary low range dew-point generator and the performances of this generator were evidenced in a bilateral comparison with the MIKES. With the same dew-point generator, an investigation of the efficiency in two different thermal environments was performed.

After the presentations, the CCT President asked all participants, except for the CCT member delegates, to leave the meeting room, and invited comments. An extended discussion followed on each application and the CCT took a unanimous decision on the requested memberships.

The CCT was well aware of the INTiBS as a renowned institute, and recognized the solid competences of Prof. A. Szmyrka-Grzebyk. However, the CCT perceived limited capacity and resources of the INTiBS and therefore preferred to keep a watching brief on its evolution in research and capacity. For this reason, the CCT did not recommend a CCT observer or membership of the INTiBS.

The CCT noted positively the evolution of the HMI/FSB-LPM and its objectives in research. Nevertheless, the CCT preferred to follow the progress of the HMI/FSB-LPM research and capacity. For this reason, the CCT did not recommend full CCT membership of the HMI. Nevertheless, the CCT encouraged the HMI/FSB-LPM to actively take part in one of its working groups.

The CCT positively noted the CMI involvement and capacity in metrology and research and supported an observer status. As a consequence, the CCT President Dr Y. Duan declared to the delegates that he will recommend the CIPM to accept observer status for the CMI. The interested institutes were later informed of the CCT decision.



## 9 RECOMMENDATIONS TO THE CIPM

Dr J. Fischer explained that the recommendation T2 (2010) required updating and clarification and presented a first draft proposal for the recommendation T1 (2014) to the CIPM *On a new definition of the kelvin*.

In this proposal, the CCT recommends the CIPM to ask CODATA to adjust the values of the fundamental physical constants from which a fixed and robust numerical value of the Boltzmann constant  $k$  will be adopted when a number of conditions have been met. He clarified that a final condition set in the draft was meant to free a relevant amount of resources, currently concentrated on the determination of the Boltzmann constant, for future important thermometry activities, namely thermodynamic measurements.

An intense discussion followed on whether or not further developments should be discouraged.

Dr J. Fischer admitted that there was no unanimous agreement on the last condition and suggested it be removed from the recommendation.

Dr G. Machin proposed to replace the last condition with an encouragement to work on thermodynamic realizations.

Dr Y. Duan finally proposed the creation of a small task group to re-draft the recommendation in the evening and present it to the CCT plenary the following day. Dr J. Fischer, Dr G. Machin, Mr K. Hill, Dr P. Steur, Mr G. Strouse and Dr J. Zhang agreed to prepare a revised draft for the following day.

The following day, Dr J. Fischer noted that the task group had decided to remove the last condition and to leave unchanged the first two conditions. After including a few more editorial changes proposed by Dr M. Milton and Dr C. Thomas, Dr Y. Duan asked for a formal CCT vote on this recommendation, which was unanimously approved (see p. 36 of this report).

Dr G. Machin suggested preparing a separate recommendation to the CIPM to encourage the NMIs to work on thermodynamic temperature determinations. Dr M. Milton informed that it must be prepared during the CCT meeting, as a recommendation to the CIPM must be voted on by the CCT.

Dr C. Thomas suggested formulating it as a declaration rather than a recommendation, because the CCT request is directed to the NMIs and DIs to work on thermodynamic realizations.

Dr Y. Duan proposed Dr G. Machin to prepare a suitable declaration to be added to the CCT report (see p. 39 of this report).

## 10 REPORTS FROM INTERNATIONAL MEETINGS

Dr E. Filipe gave a short report on the TEMPMEKO 2013 conference, which was held in Funchal (Portugal) in October 2013. The conference was attended by 310 delegates from 43 different countries, and by 15 international instrumentation manufactures. Dr D.R. White

chaired the international programme committee. The proceedings of the conference will appear as several special issues of the *International Journal of Thermophysics*.

## 11 PUBLICATIONS

Dr S. Picard encouraged the NMIs to send their bibliographies (or the link to their bibliographies) for the BIPM website.

Dr D.R. White has been asked to organize and edit a special issue of *Metrologia* on the Boltzmann constant for which Dr J. Fischer will be co-editor. At a meeting of CCT-WG4/TG-SI, all of the various groups known to be involved in Boltzmann constant measurements were invited to contribute and a total of 18 papers have been planned for inclusion. The deadline for submissions is December 2014, with publication scheduled for 2015.

Dr G. Machin added that the international scientific meeting at the Royal Society (May 2015) will produce proceedings.

## 12 FEEDBACK ON THE NEW FORMAT OF THE CCT MEETING

Dr S. Picard asked for feedback on the new format of the CCT meeting. Dr G. Machin particularly appreciated the innovation of the RMO presentations. Dr E. Van der Ham enjoyed the workshop and the RMO presentations.

## 13 DATE OF NEXT CCT MEETING

Dr Y. Duan reminded that the CCT meeting is usually held once every two years but, as the 26th CGPM is likely to be held in 2018, he proposed holding the 28th CCT meeting in May 2017, to allow the final discussion on the redefinition of the Kelvin during the meeting, to which the CCT agreed. Dr Y. Duan noted that the WGs and TGs will have the opportunity to meet during the TEMPMEKO 2016 symposium in Poland.

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 her preparatory work on the reorganization of the WGs and TGs, and Dr Y. Duan for successfully chairing the meeting.

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

## 14 ACTIONS AND DECISIONS

The actions and decisions taken at the meeting were identified to be posted on the CCT web page with minimum delay.

### Actions:

- CCT27/A1. The Chairs of the newly formed working and task groups will suggest candidates for membership to the CCT President for approval.
- 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.
- CCT27/A3. **TG-K** is to continue to draft successively the revision of the “*Supplementary Information on ITS-90*” to be completed in **2015**, and submit the chapters to the CCT for advice and approval.
- 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 *Guide to Secondary Thermometry* (formerly *Techniques for Approximating the ITS-90*).
- CCT27/A5. **WG-KC** will enlarge its membership and aim to involve members of all RMOs.
- CCT27/A6. **All participants will deliver all data** (initial and final measurements) **by the end of 2014**.
- CCT27/A7. Six participants of the CCT-K9 will deliver initial data before **end of June 2014**.
- 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**.

### Decisions:

- CCT27/D1. The CCT President will recommend the CIPM to attribute observer status of the CCT to the CMI (Czech Republic).
- CCT27/D2. Dr K. Hill (NRC) stepped down as chairman of the WG7.
- CCT27/D3. Dr T. Baba (NMIJ/AIST) stepped down as chairman of the WG9.
- CCT27/D4. The establishment of the following Working Groups was approved by the CCT:
  - CCT Working Group for Contact Thermometry (CCT WG-CTh)
  - CCT Working Group for Non-Contact Thermometry (CCT WG-NCTh)
  - CCT Working Group for Humidity (CCT WG-Hu)
  - CCT Working Group for Key Comparisons (CCT WG-KC)
  - CCT Working Group for Calibration and Measurement Capabilities (CCT WG-CMC)
  - CCT Working Group for Strategic Planning (CCT WG-SP)

- CCT27/D5. The establishment of the following Task Groups was approved by the CCT:
- CCT Task Group for the Realization of the Kelvin (CCT TG-K)
  - CCT Task Group on Guides on Thermometry (CCT TG-GoTh)
  - CCT Task Group for Thermophysical Quantities (CCT TG-ThQ)
  - CCT Task Group for Environmental Questions linked to Thermometry (CCT TG-Env)
- CCT27/D6. The Task Group on SI (TG-SI) is to be maintained, with a reviewed membership.
- CCT27/D7. The following appointments of Chairs for the CCT WGs were approved by the CCT:
- |              |                   |
|--------------|-------------------|
| CCT WG-CTh:  | J. Fischer (PTB)  |
| CCT WG-NCTh: | G. Machin (NPL)   |
| CCT WG-Hu:   | S. Bell (NPL)     |
| CCT WG-KC:   | A. Peruzzi (VSL)  |
| CCT WG-CMC:  | G. Strouse (NIST) |
| CCT WG-SP:   | Y. Duan (NIM)     |
- CCT27/D8. The following appointments of Chairs for the CCT TGs were approved by the CCT:
- |              |                    |
|--------------|--------------------|
| CCT TG-K:    | B. Fellmuth (PTB)  |
| CCT TG-GoTh: | D. R. White (MSL)  |
| CCT TG-ThQ:  | J.-R. Filtz (LNE)  |
| CCT TG-Env:  | A. Merlone (INRiM) |
- CCT27/D9. Dr J. Fischer (PTB) was appointed to continue to chair the TG-SI.
- CCT27/D10. A CCT recommendation was drafted on the conditions for fixing the Boltzmann constant, to be addressed to the CIPM.
- CCT27/D11. It was decided to draft a Declaration to emphasize the need for new determinations of thermodynamic temperature to anticipate the implementation of the realization of the new definition of the kelvin, ultimately resulting in a revised temperature scale. It will be incorporated in the CCT minutes and in the next version of the Strategic Planning document.

Dr A. Peruzzi, *Rapporteur*  
May 2014

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

**RECOMMENDATION T 1 (2014)**

**On a new definition of the kelvin**

The Consultative Committee for Thermometry (CCT)

*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);

*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);

*recognizing*

the need to confirm and clarify Recommendation CCT T 2 (2010) in the light of Resolution 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  $9.1 \times 10^{-7}$  in its 2010 adjustment of fundamental constants, however based on only one experimental method;
- a relative standard uncertainty in  $k$  of  $9.1 \times 10^{-7}$  would correspond to a standard uncertainty of about 0.25 mK of the temperature of the triple point of water after the redefinition;

*considering*

- the discussions held at the 26th and 27th meetings of the CCT in 2012 and 2014;
- the considerable progress recently achieved in experimental determinations of the Boltzmann constant to improve confidence in the 2010 value, as reported at the CCT “Task Group on the SI” meetings held in 2013 and 2014;

- that additional results are anticipated before the end of 2015;
- that experimental progress has allowed the development of a *mise en pratique* for the new definition of the kelvin, which has been extended to cover direct measurement of thermodynamic temperature after the new definition of the kelvin;

*recommends*

- that the CIPM request the CODATA to adjust the values of the fundamental physical constants, from which a fixed numerical value of the Boltzmann constant will be adopted, when the following two conditions are met:
  1. the relative standard uncertainty of the adjusted value of  $k$  is less than  $1 \times 10^{-6}$ ;
  2. the determination of  $k$  is based on at least two fundamentally different methods, of which at least one result for each shall have a relative standard uncertainty less than  $3 \times 10^{-6}$ .

## DECLARATION OF THE CONSULTATIVE COMMITTEE FOR THERMOMETRY OF ITS 27TH MEETING

### Requirement for new determinations of thermodynamic temperature

Thermodynamic temperature,  $T$ , is the basic physical quantity to which all measurements of temperature should ultimately be referred.

The CCT observes that:

- the International Temperature Scale of 1990, ITS-90 has been in place for 24 years and has inherent weaknesses, including known discrepancies from  $T$ ;
- the Provisional Low-Temperature Scale of 2000, PLTS-2000, remains provisional with currently no resolution of its inherent discrepancy of ~6 % at the lowest temperatures;
- experiments to determine the Boltzmann constant,  $k$ , will draw to a close with the unit redefinition.

For these reasons, the CCT encourages NMIs to conduct significant experiments for the determination of thermodynamic temperature, to ensure that the SI unit *kelvin* is realized and disseminated in an optimum way in the coming decades.

In particular new thermodynamic temperature determinations are required to support:

- In the short term: the introduction and implementation of the *mise en pratique* for the definition of the kelvin (*MeP-K*) through determining robust, reliable values of  $T-T_{90}$  and  $T-T_{2000}$ .
- In the medium term: facilitate direct dissemination of the redefined kelvin through developing robust and reliable methodologies to disseminate  $T$ , particularly at the extremes of temperature  $>1300$  K and  $<1$  K.
- In the long term: generate the background data required for a new unified temperature scale of improved thermodynamic consistency compared to the currently defined scales.

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

Open Working Documents of the CCT can be accessed from the BIPM website:

<http://www.bipm.org/cc/AllowedDocuments.jsp?cc=CCT>.

All working documents, including those restricted to Committee members can be accessed on the CCT restricted access website:

<http://www.bipm.org/cc/CCT/Restricted/WorkingDocuments.jsp>.

CCT/14-1	CCT Draft Agenda, Y. Duan, 3 pp.
CCT/14-2	EMRP Progress report: Project Implementing the New Kelvin (InK), G. Machin, 6 pp.
CCT/14-3	<a href="#">TG-SI Report to the CCT 8 May 2013, J. Fischer, 6 pp.</a>
CCT/14-4	Strategic Document for Rolling Programme Development from 2013-2015 – CCT, J. Fischer, 19 pp.
CCT/14-5	Strategic Document for Rolling Programme Development from 2013-2015 – CCT, J. Fischer, A. Henson, S. Picard, 1 pp.
CCT/14-6	<a href="#">Proposal for a Revised Structure of WGs within the CCT, Y. Duan, 4 pp.</a>
CCT/14-7	Support for 16.1: Report on thermometry activities at the INTiBS, Poland, A. Szmyrka-Grzebyk, 3 pp.
CCT/14-8	Support for 16.1: Bibliography of INTiBS, Poland, March 2014, A. Szmyrka-Grzebyk, 4 pp.
CCT/14-9	Improvement of the relative gas humidity unit (GET 151-86), M. A. Vinge, 2 pp.
CCT/14-10	Support for 16.3: Bibliography of HMI/FBS-LPM, Croatia, March 2014, D. Zvizdić, 3 pp.
CCT/14-11	Support for 16.3: List of comparisons, HMI/FBS-LPM Croatia, D. Zvizdić, 1 pp.
CCT/14-12	Support for 16.3: CMCs in Thermometry HMI/FBS-LPM Croatia, D. Zvizdić, 2 pp.
CCT/14-14	<a href="#">Half-day workshop: Abstracts, 5 pp.</a>
CCT/14-15	<a href="#">EURAMET TC-T Report 2014, A. Peruzzi, 3 pp.</a>
CCT/14-16	Support for 16.2: Report on thermometry activities at the CMI, Czech Republic, R. Strnad, 7 pp.
CCT/14-17	Protocol for high temperature key comparison - v4, H. McEvoy, 32 pp.
CCT/14-18	<a href="#">WG5 Activity Report 2012-2014, G. Machin, 8 pp.</a>
CCT/14-19	<a href="#">WG4 Activity Report 2012-2014, J. Fischer, 7 pp.</a>
CCT/14-20	<a href="#">TG-SI Activity Report 2012-2014, J. Fischer, 6 pp.</a>
CCT/14-21	<a href="#">WG7 Activity Report 2012-2014, K. Hill, 8 pp.</a>
CCT/14-22	<a href="#">COOMET TC-T Report 2014, A. Pokhodun, 7 pp.</a>
CCT/14-23	<a href="#">WG8 Activity Report 2012-2014, G. Strouse, 3 pp.</a>
CCT/14-24	<a href="#">WG1 Activity Report 2012-2014, B. Fellmuth, 3 pp.</a>
CCT/14-25	<a href="#">SIM TC-T Report 2014, O. Robatto, 4 pp.</a>
CCT/14-26	Guide on Secondary Thermometry: Specialized Fixed Points above 0 C, F. Edler, J. Pearce and D.R. White, 32 pp.



- CCT/14-27 [APMP TC-T Report 2014, Y. G. Kim, 22 pp.](#)
- CCT/14-28 NMI Reports: CEM 2014, D. del Campo, 10 pp.
- CCT/14-29 Guide on Secondary Thermometry: Thermocouple Thermometry, H. Liedberg / F. Edler / D.R. White, 27 pp.
- CCT/14-30 [WG6 Activity Report 2012-2014 - revised version, S. Bell, 4 pp.](#)
- CCT/14-31 NMI Reports: INRiM 2014, V. Fericola, 8 pp.
- CCT/14-32 Measurement of the molar mass of argon using the mass spectrometer at KRISS, I. Yang and J.S. Kim, 6 pp.
- CCT/14-33 Reanalysis of Possible Effects due to Gold-plating on the Thermal Expansion of Copper in Constant-volume Gas Thermometry at Low Temperatures, O. Tamura and P.P.M. Steur, 5 pp.
- CCT/14-34 On: Revised Structure of Working Groups within the CCT, J.-R. Filtz, 2 pp.
- CCT/14-35 Further confirmation of the value  $T_{90}(\text{Ne-22})$  ?  $T_{90}(\text{Ne-20})$  at INRiM, P.P.M. Steur and F. Pavese, 3 pp.
- CCT/14-36 [WG3 Activity Report 2012-2014, D.R. White, 4 pp.](#)
- CCT/14-37 [Who visits the BIPM key comparison database?, C. Thomas, 7 pp.](#)
- CCT/14-38 [Revision of the GUM: why and how? W. Bich, 25 pp.](#)
- CCT/14-39 [Bayesian Uncertainty: pluses and minuses, D.R. White, 18 pp.](#)
- CCT/14-40 Current status of the redefinition of the kelvin, J. Fischer, 26 pp.
- CCT/14-41 [The European Project? Novel techniques for traceable temperature dissemination?, D. del Campo, 26 pp.](#)
- CCT/14-42 [Experimental Determination of the Isotopic Correction Constants for the Triple Point of Water, A. Peruzzi, 24 pp.](#)
- CCT/14-43 [Joint work with the IAPWS; M. Heinonen, 12 pp.](#)
- CCT/14-44 [Thermal Metrology for Meteorology and Climate, A. Merlone, 58 pp.](#)
- CCT/14-45 [Dickensian climate metrology: The ghosts of meteorological observations past, present and future, P. Thorne, 30 pp.](#)
- CCT/14-46 Request for membership: Presentation of the INTiBS, Poland, A. Szmyrka-Grzebyk, 26 pp.
- CCT/14-47 Request for membership: Presentation of the CMI, Czech Republic, R. Strnad, 15 pp.
- CCT/14-48 Request for membership: Presentation of the HMI/FSB-LPM, Croatia, D. Zvizdić, 55 pp.
- CCT/14-49 [RMO Presentation: AFRIMETS, E. Ejigu, 15 pp.](#)
- CCT/14-50 [RMO Presentation: APMP, Y.-G. Kim, 22 pp.](#)
- CCT/14-51 [RMO Presentation: COOMET, A. Pokhodun, 27 pp.](#)
- CCT/14-52 [RMO Presentation: EURAMET, A. Peruzzi, 14 pp.](#)
- CCT/14-53 [RMO Presentation: SIM, O. Robatto, 15 pp.](#)
- CCT/14-54 [JCRB Report to the CCT 2012-1014, C. Kuanbayev, 11 pp.](#)
- CCT/14-55 WG1 – presentation, B. Fellmuth, 12 pp.
- CCT/14-56 WG4 – presentation, J. Fischer, 15 pp.
- CCT/14-57 WG5 – presentation, G. Machin, 13 pp.

CCT/14-58	WG6 – presentation, S. Bell, 10 pp.
CCT/14-59	WG7 – presentation, K. Hill, 26 pp.
CCT/14-60	WG8 – presentation, G. Strouse, 8 pp.
CCT/14-61	WG9 – presentation, T. Baba, 54 pp.
CCT/14-62	WGS – presentation, G. Strouse, 14 pp.
CCT/14-63	TG-SI – presentation, J. Fischer, 27 pp.
CCT/14-64	<a href="#">Progress report on CCT-K6, S. Bell, 19 pp.</a>
CCT/14-65	<a href="#">Progress report on CCT-K8, R. Benyon, 10 pp.</a>
CCT/14-66	<a href="#">Progress report on CCT-K9, G. Strouse, 1 pp.</a>
CCT/14-67	Presentation on EMRP METefnet, S. Bell, 12 pp.
CCT/14-68	Presentation on EMRP InK, G. Machin, 18 pp.
CCT/14-69	WG and TG Membership, G. Strouse, 2 pp.
CCT/14-70	NMI Reports: MIKES 2014, M. Heinonen, 8 pp.