**Bureau International des Poids et Mesures**

# Consultative Committee for Thermometry (CCT)

Report of the 31st meeting
(16-17 May 2024)
to the International Committee for Weights and Measures


Comité international des poids et mesures

# LIST OF MEMBERS of the Consultative Committee for Thermometry
**as of 16 May 2024**

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D. del Campo Maldonado, member of the International Committee for Weights and Measures

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

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

Laboratoire National de Métrologie et d'Essais [LNE], Paris.

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

National Institute of Metrological Research/Istituto Nazionale di Ricerca Metrologica [INRIM], Turin.

National Institute of Metrology [NIM], Beijing.

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

National Measurement Institute of Australia [NMIA], Lindfield.

National Metrology Centre, Agency for Science, Technology and Research [NMC, A*STAR], Singapore.

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 /TÜBITAK Ulusal Metroloji Enstitüsü [UME], Gebze-Kocaeli.

National Physical Laboratory [NPL], Teddington.

National Research Council of Canada [NRC], Ottawa.

Norwegian Metrology Service/Justervesenet [JV], Kjeller.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

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

Dutch Metrology Institute [VSL], Delft.

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

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

**Official Observer(s)**

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

National Scientific Centre "Institute of Metrology" [NSC IM], Kharkiv.

Saudi Standards, Metrology and Quality Organization/National Measurement and Calibration Center, [SASO-NMCC], Riyadh

Institute of Low Temperature and Structure Research/Instytut Niskich Temperatur i Badañ Strukturalnych [INTiBS)], Varsovia

Kazakhstan Institute of Standardization and Metrology [RSE KazStandard], Astana

Bundesamt für Eich- und Vermessungswesen [BEV], Vienna

SCL – Standards and Calibration Laboratory, Wan Chai

Servicio Ecuatoriano de Normalización [INEN)], Quito

Instituto Nacional de Metrología de Colombia (INM Colombia), Bogotá

## Opening of the meeting

The Consultative Committee for Thermometry (CCT) held its thirty-first meeting at the International Bureau of Weights and Measures headquarters (BIPM), at Sèvres, and on-line, on 16 and 17 May 2024.

The following attended:

Members: M. Akoshima (NMIJ/AIST), K. Anhalt (PTB), S. Bell (NPL), R.A. Bergerud (JV), R. Caballero Santos (CEM), V. Cabral (IPQ), D. Cardenas-Garcia (CENAM), D. del Campo Madonado (CCT President, CEM / CIPM), E.K. Ejigu (NMISA), L. Eusébio (IPQ), Y. Fan (NMC, A*STAR), X. Feng (NIM), V. Fernicola (INRIM), J. Ferreira (IPQ), V. Fuksov (VNIIM), C. Gaiser (PTB), R. Gavioso (INRIM), B. Hay (LNE), F. Jahan (NMIA), S. Janssens (MSL), M. Kalemci (UME), Y.-G. Kim (KRISS), L. Knazovicka (CMI), S. Kondratiev (VNIIM), T. Kopunec (SMU), V.G. Kytin (VNIIFTRI), S.-W. Lee (KRISS), W. Lei (NMIA), X. Lu (NIM), G. Machin (NPL), M.I. Maniur (SMU), J.M. Mantilla (CEM), M.-J. Martín Hernández (CEM), E. Martines-Lopez (CENAM), B. Mascarenhas Lozano (INMETRO), A. Merlone (INRIM), C. Meyer (NIST), M.J.T. Milton (Director of the BIPM), R. Mokhutsoane (NMISA), R. Moretz Sohn (INMETRO), T. Nakano (NMIJ/AIST), H. Nasibli (UME), A. Oldershaw (NRC), A.A. Falnes Olsen (JV), M. Panman (VSL), P. Pavlasek (SMU), J. Pearce (NPL), A. Peruzzi (NRC), A. Rakonjac (MSL), P. Rourke (NRC), M. Sadli (LNE-LCM/CNAM), N. Sasajima (NMIJ/AIST), P. Saunders (MSL), A Shchipunov (VNIIFTRI), F. Sparasci (LNE), R. Strnad (CMI), S. Tabandeh (MIKES), W. Tew (NIST), E. van der Ham (NMIA), M. Vinge (VNIIFTRI), L. Wang (A*STAR), I. Yang (KRISS), S. Ye (NMC, A*STAR), H. Yoon (NIST).

Observers: K.W. Chen (SCL), H.S. Lam (SCL), R. Pushchyn (NSC IM), D. Zvizdic (FSB-LPM).

Representatives of Institutes from Member States invited to attend as Observers: N.M. Alqahtani (SASO-NMCC), A. Kowal (INTiBS), W.D. Paucar Quinteros (INEN), C. Sanchez (INM Colombia), A. Zhumagali (RSE “KazStandard”), C. Hofstätter-Mohler (BEV).

Guests: H. Abe (NMIJ/AIST), Z. Ahmed (NIST), N. Al Dawood (SASO-NMCC), R. Benyon Puig (INTA), J. Bojkovski (MIRS/UL-FE/LMK), J.-R. Filtz (LNE), J. Gust (Fluke Corporation), A. Todd (NRC).

Also present: I. Ahmed (JCRB Executive Secretary, BIPM), S. Maniguet (KCDB Coordinator, BIPM), F. Meynadier (BIPM), J.R. Miles (BIPM), S. Solve (CCT Executive Secretary, BIPM).

## 1. Welcome by the CCT President, Dr D. del Campo, and the Director of the BIPM

The president of the CCT, Dr D. del Campo, opened the session by welcoming the participants, including those online and gave the floor to Dr M. Milton, the Director of the BIPM. He formally welcomed the participants to the first in-person meeting of the CCT since the COVID-19 pandemic.

Dr M. Milton noted that this was the first CCT meeting for the new president of the CCT, Dr D. del Campo, and the new executive secretary, Dr S. Solve. He welcomed the president and the executive secretary of the CCT and stressed the fact that both were familiar with the field of thermometry.

Dr D. del Campo expressed her joy of being back in the thermometry community, which she has been part of for more than thirty years and assured the attendees that she will do her best to be at the service of the CCT.

Dr D. del Campo gave a tribute for the life and contributions of Dr Steffen Rudtsch who passed away in January 2024. A minute's silence was observed by the participants in his memory.

## 2. Approval of the agenda and introduction of delegates

Dr D. del Campo asked for any comments or changes to the agenda. She proposed moving point 5 in the agenda "news from the BIPM" to after the coffee break. No comments or changes were proposed by those in the attendance or online. The agenda was agreed.

The participants, both in-person and online, introduced themselves.

## 3. Approval of Rapporteur

Dr A. Merlone and Dr M. Sadli were proposed and approved as rapporteurs.

## 4. Status of Actions targeted at the 30th meeting of the CCT

There was only one action from the 30th meeting of the CCT in 2022:

CCT30/A1. WG-CMC should consider sending information to key comparison participants; specifically, the latest MRA guidance, how to handle outliers, and how to prepare the KCRV.

The action is completed.

## 5. News from the BIPM – Dr M. Milton, BIPM Director

Dr M. Milton gave key figures about the Member States and Associates as well as the CIPM MRA comparisons. The number of comparisons and the number of CMCs have reached stable levels in recent years.

Dr M. Milton expressed his satisfaction at the World Metrology Day 2024 Launch Event organized by UNESCO at its headquarters in Paris. The event was held in partnership with the

BIPM. This was the first time World Metrology Day was celebrated as a UNESCO International Day. This recognition has been achieved after many years of effort and lobbying. It is an important recognition of metrology and its importance to many countries even if they are not signatories to the Metre Convention.

The CIPM strategy consultation process and development of the new strategy are progressing. This strategy is centered around horizontal groups such as the Sectorial Task Group on Climate Change and Environment, chaired by Dr D. del Campo, the Forum on Metrology and Digitalization and a likely new horizontal activity on quantum technologies.

Another strategy activity running in parallel with the CIPM strategy development is the Young Metrologists Vision 2050+ initiative. This strategic exercise is led by the Regional Metrology Organizations (RMO) under the coordination of the BIPM. A meeting of the coordinators is planned in July 2024 to bring together the ideas as a complement to the CIPM strategy.

The year 2025 marks the 150th Anniversary of the signing of the Metre Convention. Several events will take place at BIPM during the week 19–23 May 2025. These events will: celebrate the achievements of 150 years of the Metre Convention; present a new vision and strategy for the BIPM for 2030 and beyond (developed by the CIPM); and promote metrology to the widest possible global audience. More information will be available on the BIPM website and social media.

Dr M. Milton concluded the presentation by pointing out the important work performed world-wide on capacity building and the workshop which took place at the BIPM to gather the secretariats from different RMOs to get to know each other and exchange information about their activities. Additionally, material from different RMOs is hosted on the BIPM e-learning platform for a wide audience.

Dr D. del Campo thanked Dr M. Milton for the presentation and stressed the importance of the recognition of World Metrology Day to raise awareness of the importance of metrology in all areas. Dr D. del Campo thanked Dr P. Pavlasek for his involvement in the Young Metrologists Vision 2050+ initiative.

## 6. Highlights of Working and Task Group progress

### 6.1 WG for Contact Thermometry (CCT-WG-CTh) - Dr C. Gaiser (PTB)

Dr C. Gaiser presented the evolution of the membership of the working group. Dr Feng has joined the group in replacement of Dr Zhang. Dr Gaiser thanked Dr Zhang for his contribution to the working group and welcomed Dr Feng.

Dr C. Gaiser presented the terms of reference of the working group, which were unchanged. He reported on some key points:

- Concerning the update of the $T$-$T_{90}$, the WG has published a recent paper summarizing the values obtained below 335 K. The previous publication of such values was in 2011. Dr C. Gaiser compared the values obtained in 2011 and in 2022 in this temperature range and emphasized the fact that there was a noticeable improvement in the uncertainty by a factor of circa. 10. The estimates of $T$-$T_{90}$ published on the BIPM website have been updated. A lot of work remains to be accomplished in the range

above 400 K in which the uncertainties are still too large. In this range, encouraged by the recommendation of the CIPM to work on the determination of $T$-$T_{90}$ above 400 K, the CCT needs new data with low uncertainties and new primary thermometers for direct realization of $T$.

- Dr C. Gaiser showed two examples of applications in which thermodynamic temperature is needed rather than $T_{90}$: pressure standards and atomic clocks. This justifies the necessity of maintaining a very good knowledge of $T$-$T_{90}$.
- In the field of concerted research activities, a new European project DireK-T was presented. This project, led by Dr R. Gavioso, will facilitate, among other tasks, a direct comparison of primary thermometers. Dr R. Gavioso presented this project in the technical workshop organized during this CCT meeting.
- A review paper about the practical realization of the kelvin by Johnson noise thermometry was published in 2024. The approach will be included in the *mise-en-pratique* of the definition of the kelvin.

Dr C. Gaiser introduced a new task for the WG-CTh, which consists of updating the paper by Bedford *et al* in *Metrologia* 1996[1] devoted to secondary fixed-point temperatures. Apart from some review articles by Fellmuth in 2022 and a NIST database of fixed-point temperatures, this important work has never been updated on a large scale. Dr C. Gaiser informed the CCT that an additional part will be devoted to high-temperature fixed points and a member of WG-NCTh was needed. He pointed out that Dr M. Sadli had volunteered to contribute to this topic. Dr Gaiser explained the need for an update of the Bedford paper as it is likely to become a valuable source of information for implementing relative primary thermometry (for example λ-point $^4$He for $T$ measurements below 2 K) or a replacement for Hg in a future temperature scale or revised ITS-90.

Dr C. Gaiser concluded his presentation by thanking all the members of the WG-CTh for their hard work. Dr D. del Campo thanked Dr C. Gaiser for his report and asked if there were any questions.

Dr D. del Campo asked about the evolution of the structure of the WG-CTh. Dr C. Gaiser replied that there will be a new task-group on new technologies and practical primary thermometers, which will be proposed; more details will be given in the presentation of Dr G. Machin in point 6.4 of the agenda. Along with the task group on emerging technologies, two other task groups will be closed, the one on thermocouples and the one on reference points.

### 6.2 Task Group "Emerging Technologies" – Dr Z. Ahmed (NIST)

Dr Z. Ahmed presented the terms of reference of the task group, which were: to identify, study and advise the CCT on matters related to the areas of emerging technologies.

The main roles of the task-group were:

[1] Bedford R.E., Bonnier G., Maas H., Pavese F., Recommended values of temperature on the International Temperature Scale of 1990 for a selected set of secondary reference points, *Metrologia*, 1996, **33**(2), 133-154 https://doi.org/10.1088/0026-1394/33/2/3

- to review the field and report to the CCT on emerging technologies for contact thermometry;
- to review and report on published data from various emerging technologies including a comparative study of the advantages, limitations, materials and temperature ranges;
- to review and report on the potential of these emerging technologies for primary thermometry.

Dr Z. Ahmed stated that all these tasks were accomplished and that details can be found in the published final report and in a review paper (Note of reporter: S. Dedyulin *et al Meas. Sci. Technol.* **33** (2022) 092001).

Dr Z. Ahmed thanked all the TG members who have contributed to the work over the duration of the task group. He informed the CCT that the TG has finished its work and published its final report.

Dr Z. Ahmed detailed the capabilities of the emerging technologies (for example, Doppler broadening thermometry, on-chip thermometry based on refractive index, fibre-optic thermometry, etc.) as well as some new and promising trends like nitrogen-vacancy diamond and quantum dots, Rydberg atoms as well as the development of fit-for-purpose photonic interrogators.

Dr Z. Ahmed explained that there are still many questions to answer at the level of the CCT community on how to interact with other communities in such a multidisciplinary area and how to bring these technologies to metrological applications, meeting the needs of the user community. He concluded by saying that the success of these technologies will depend on their simplicity and cost.

Dr D. del Campo thanked Dr Z. Ahmed for the work done in the task group and for the report, which has concluded the work of the task group. Dr D. del Campo commented that the report was interesting for our community and will pave the way for future developments. Dr D. del Campo asked if there were any questions to Dr Z. Ahmed and if there was any objection to closing the task group. No objections were raised.

Dr F. Sparasci asked what the follow-up of this work would be and if there would be a way of supporting the community working in this field.

Dr D. del Campo stated that there is no recommendation planned to encourage the follow-up of these activities. However, there is a plan to open another task group, which could take over these activities.

Dr Z. Ahmed confirmed that these activities will be included in the new task group of the WG-CTh. Dr C. Gaiser confirmed this point and said that the new task group will have a broader scope and will include other techniques such as Johnson noise thermometry.

### 6.3 Working Group for Non-Contact Thermometry (CCT-WG-NCTh), including (CCT-TG-NCTh-IRT) and (CCT-TG-NCTh-BTM) – Dr G. Machin (NPL)

Dr G. Machin reviewed the membership of the working group, which has not changed since the last meeting. One guest, Dr M. Gotoh, was invited to the meeting to present the International Electrotechnical Commission (IEC) standardization work involving members of the WG.

One meeting of the WG took place during the ITS-10 symposium in April 2023 and a meeting is planned during the Tempmeko/ISHM symposium in October 2025.

Among the actions completed before this meeting:

- the CCT-K10 key comparison was completed, and the results were published in *Metrologia* a few days before the CCT plenary. Dr G. Machin thanked H. McEvoy (NPL) for her excellent work in coordinating and completing this comparison.
- the completion and publication on the BIPM website of the guide for fever screening by thermal imaging and other non-contact thermometry approaches triggered by the COVID-19 pandemic.
- the completion and publication of medical-focused guides for ear, forehead and thermal imaging for body temperature measurement and fever screening. Consequently, the task group on body temperature measurement has completed its tasks and has been dissolved.
- measurements for the clinical thermometer key comparison (CCT-K11), led by NIM, are under way and should be completed so that a Draft A report is issued in March 2025. Dr G. Machin thanked Dr X. Lu (NIM) for leading this comparison.

The future actions planned are:

- the task group for the preparation of a guide on industrial radiation thermometry, led by Dr M. Sadli, is on pause to devote more time of the WG to working on two IEC standards in preparation (two-colour thermometry led by Dr Knazovicka and thermal imaging led by Dr M.J. Martin). It is considered that these are more urgent and would have a larger impact.
- a possible new comparison of thermodynamic temperatures in the high-temperature range is under discussion at the WG and will be reviewed during the next WG meeting.
- the CMC review protocol needs to be updated, and Dr K. Anhalt is in charge of this activity with other members of the WG by the next meeting (October 2025).
- a key comparison in the medium temperature range (typically 150 °C to 1000 °C) was discussed, but it was agreed that this comparison should be done at the regional level as it is not the ITS-90 primary realization in this temperature range.
- the annex for the *MeP*-K at high temperature has been updated with new high-temperature fixed point thermodynamic temperature values obtained in the Real-K project. An issue regarding uncertainties was brought up at the WG meeting. Dr P. Saunders proposed to investigate it.
- The uncertainties have been finalized after discussion in the working group. The values have been presented at the ITS-10 symposium by Dr M. Sadli who led this work, and the summary paper has been accepted for publication in the symposium proceedings. The *MeP* annex for relative primary thermometry will be circulated to the CCT for approval once the uncertainty issue is resolved.

Dr G. Machin concluded his presentation by identifying the actions planned for 2024 and 2025.

Dr del Campo thanked Dr G. Machin for the presentation and asked the participants if there were any questions. She asked if the task group on industrial radiation thermometry will continue its

work as this is an important task for the users. Dr G. Machin replied that the priority is given to the two IEC standards of which the WG-NCTh believes the impact will be wider. The TG on the industrial radiation thermometry guide will be convened at the next Tempmeko/ISHM symposium and will decide on future actions.

### 6.4 New Task Group within Working Group Contact Thermometry – Dr G. Machin (NPL)

Dr G. Machin introduced this new proposed task group within WG-CTh and the terms of reference (document CCT/2024-09). The draft terms of reference were said to be provisional and open to discussion.

Dr G. Machin explained that the TG would clarify the concept of traceability outside the usual ITS-90 scheme in the context of practical primary thermometry and *in situ* traceability techniques.

Dr D. del Campo thanked Dr G. Machin and Dr C. Gaiser for this new task group. She asked for questions and comments and informed the audience that the terms of reference of this task group will be discussed in the TG and submitted later for approval by the CCT.

A discussion followed about the title and the scope of the task group and the concept of traceability to thermodynamic temperature or temperature measurement. It was agreed that the title will be included in discussions within the TG along with the terms of reference.

Dr P. Pavlasek asked if this task group will include the work done formerly in the TG for Emerging Technologies. Dr G. Machin replied that it will include these activities.

Dr H. Yoon suggested that the terms of reference should not mention acronyms for European projects (DireK-T, Real-K.), which may be unknown outside Europe.

Dr D. del Campo asked the delegates to send to Dr C. Gaiser their expression of interest to join the task group within the following weeks.

### 6.5 Working Group on Humidity (CCT-WG-Hu) – Dr S. Bell (NPL)

Dr S. Bell gave an overview of the highlights of the working group on humidity since the last CCT meeting. No changes were reported in the terms of reference. The membership has evolved significantly during the last two years.

Key comparisons have been the main activity of the WG: CCT-K8 and EURAMET.T-K8 dealing with the dew-point temperature range 30 °C to 95 °C for which there is a joint effort in the analysis of data. A report was given by Dr R. Benyon during this CCT meeting on the progress of the CCT-K8 comparison. In addition, there will be a repeat of the CCT-K6 comparison devoted to the dew and frost point range −50 °C to +20 °C, the first iteration of which was completed in 2015. CCT-K6.2021 is in preparation with a pilot and an assistant pilot identified as BEV/E+E and VSL respectively.

Dr S. Bell reported on the progress of the other WG tasks among which:

- The revision of CMC review protocols in agreement with CCT-WG-CMC with a twofold objective: reducing the workload of CMC review and the effort of comparisons.
- Maintaining liaison activities with WMO (World Meteorology Organization) and IAPWS (International Association for the Properties of Water and Steam)

- Active involvement in digitalization activities in particular for the digitalization of essential humidity functions like the saturation vapour pressure of water and the water vapour enhancement factor.
- New research activities and facilities of the members of the WG, for example the research on the water vapour enhancement factor down to trace water vapour range or at the above-atmospheric pressures for different gases ($N_2$, $H_2$, Ar.)
- Reconvening the ISHM (International Symposium on Humidity and Moisture) symposium in conjunction with TEMPMEKO in October 2025.

Finally, Dr S. Bell announced that she is stepping down from chairing the WG and that the incoming chair is proposed to be Dr H. Abe, who was already acting as vice chair of the WG-Hu.

Dr D. del Campo thanked Dr S. Bell for this report and for her support to the humidity community and the continuous effort she made over all the years during which she chaired the WG.

Dr D. del Campo asked the CCT for approval of the new WG Chair as Dr H. Abe. No objections were raised.

***CCT31/D1: Dr H. Abe from NMIJ approved as new chair of the CCT-WG-Hu.***

Dr D. del Campo asked if there were any questions. She asked Dr S. Bell if there was a timeline for the digitalization of humidity functions and if there is support from the BIPM for this activity.

Dr S. Bell replied that the idea was led in the WG by Dr S. Tabandeh who is the liaison member with CCT-TG-Dig. The main difficulty is that there are several versions of the humidity functions. The WG needs to decide which functions will be digitalized. The BIPM would host these functions.

Dr M. Milton explained that the BIPM has the role of providing the SI Reference Point, which is only part of the digitalization requirements. The BIPM will be supporting CCs but cannot do all the work, especially as different CCs have different requirements.

Dr M. Milton expressed his surprise that there is no agreement on the humidity functions to use.

Dr S. Bell replied that in the metrology community a convention was recently established on some of the functions in use for air. However, there are new data for other gases, but the idea is that with the digitalization process there will be no ambiguity in these functions.

Dr S. Tabandeh explained that he recently made a collection of the equations, especially for the enhancement factor, he noticed an improvement in these equations above the state-of-the art and that there is a need to decide if there is a consensus on using the new equation or to continue with the old ones.

Dr M. Milton asked if there will be a need for CCT to make a choice among these equations. Dr D. del Campo replied that it would be necessary to formally agree to any change. Dr S. Bell said that this will not move so fast, and it is a strategic view for the moment and the changes will take time.

Dr V. Fernicola added that the equations proposed a need to be analyzed in terms of uncertainties and the WG will need to endorse the ones with the best uncertainties and then propose them to the CCT. Dr S. Bell confirmed that this is among the duties of the WG.

Dr P. Rourke said that he will address the issue of APIs (Application Programming Interface) in his presentation and that the ITS-90 API is a major effort of his TG.

Dr A. Peruzzi asked if these functions will be given in the uncertainty document on humidity under development, which is supposed to include uncertainties on, for instance, vapour pressure and enhancement factor formulations.

Dr S. Bell replied that this document has not progressed much and that it is still in discussion. The document is still in the workplan of the WG, and new incoming members will hopefully contribute to and help finalize the document.

Dr D. del Campo thanked Dr S. Bell again for the report and the excellent work.

### 6.6 Task Group for Thermophysical Quantities (CCT-TG-THQ) – Dr J.R. Filtz (LNE)

Dr J.R. Filtz presented the changes in membership of the working group and gave the status of the different supplementary comparisons in the field:

- CCT-S1 on emissivity was completed and the results have been published
- CCT-S2 on thermal conductivity was completed and the results have been published
- CCT-S3 on thermal diffusivity was completed but Draft B has still to be updated; it should be published by the end of 2024.

Concerning the CMC review protocols, only the one on Thermal Diffusivity has been published. The review protocol of CMCs in Emissivity was completed and is pending publication. Finally, the review protocol on Thermal Conductivity is still in progress.

Two comparisons were proposed in the recent past. One on Gas Calorimetry, which was supposed to be led by VNIIM and which the WG decided to abandon. The second one on the thermal expansion coefficient either by the absolute method or the comparative method, led by VNIIM. This comparison was delayed for the absolute method and put on stand-by for the comparative method.

A proposal for a new comparison of the measurements of enthalpy of fusion of pure materials in the range from room temperature to 800 °C. LNE-CNAM has volunteered to pilot this comparison if there are other National Metrology Institutes (NMIs) interested in participating.

Finally, Dr J.R. Filtz presented the technical and scientific news from the different members of the WG among which:

- Supplementary comparisons APMP T-S9 on thermal diffusivity led by NMIJ and APMP T-S10 on thermal conductivity led by KRISS. The measurements are finished for the first one and almost finished for the second. Both Draft A reports are in preparation.
- COOMET project n° 744/RU-a/18 concerning a comparison of combustion energy of coal samples with different sulphur content, led by VNIIM, has been completed.

- COOMET project n° 780/RU-a/19 concerning a comparison of national reference gas calorimeters using samples of gas mixtures, led by VNIIM, has been completed in 2023.
- EURAMET project 1524 concerning a comparison of thermal diffusivity measurements of high-conductivity materials by the laser flash method, led by LNE-CNAM has started and specimens prepared by LNE-CNAM have been sent to the participants. The comparison is now registered in the KCDB as EURAMET.T-S8.

Dr J.R. Filtz finished his presentation by thanking the participants in this task group.

Dr D. del Campo indicated that the review protocol on spectral emissivity has indeed been published on the BIPM website. She asked about the status of the CMC review protocol on thermal conductivity. Dr J.R. Filtz replied that this protocol still needs some work as it was launched just before the COVID-19 pandemic, and it has not yet been discussed in a formal TG meeting to agree on the draft.

Dr D. del Campo thanked Dr J.R. Filtz for the presentation.

### 6.7 Working Group for Environment (CCT-WG-ENV) and Task Group on Air Temperature (CCT-TG-AIR) – Dr A. Merlone (INRIM)

Dr A. Merlone reported on the activities of the WG-ENV and TG-Air and started with the subject of interaction with the WMO.

Almost all CCT Members have representatives in the WG-ENV together with three representatives of the WMO (World Meteorological Organization) involved in the IPCC (Intergovernmental Panel on Climate Change) and in the GCOS. Several members of CCT-WG-ENV are now nominated experts in the WMO, the GCOS (Global Climate Observing System), the Global Cryosphere Watch and participate in marine projects, also with the relevant chairing positions in the WMO expert team on uncertainties (A. Merlone, Chair) and GCOS task team on Surface Reference Network (sub-group reference stations - A. Merlone, Chair) as well as in the cryosphere domain (A. Merlone co-chair permafrost best practice team); A. Merlone is also a delegate at the WMO Congress.

The CCT-WG-ENV contribution to the WMO is mainly based on air and sea temperature and of the permafrost in the cryosphere. It also deals with the definition and requirements of climatological reference stations and provides training. The work is constantly growing through projects, activities, guidance preparation, memberships and events.

Dr A. Merlone reported that the MMC 2023 conference scored a record number of participants, with around 150 attendees from all continents and equally distributed among the climate, meteorology and metrology communities, with a number of associated trainings and satellite meetings of the WMO and the GCOS.

The scientific production was also relevant in the last two years with several papers published in journals such as *Int. J. of Climatology* and *Nature Physics*.

Dr A. Merlone reported on the different activities of the WG members:

- INRIM has proposed some of its laboratories and field sites to be nominated “WMO Measurement Lead Center on Traceability and Field Metrology”. The evaluation process is ongoing.

- INTiBS has increased its national collaborations with the Polish meteorological service and research institutes in oceanography.
- NMIA works on air temperature including the radiation and self-heating effects.
- CEM works and coordinates a research project in the Arctic, with membership in WMO expert teams and is coordinating a new EURAMET project on Cryosphere.
- KRISS is also involved in a WMO expert team with special interest in radiosondes.
- NMIJ is traditionally oriented towards water and ocean thermometry.
- CMI has a significant participation in EURAMET projects dealing with different environmental activities.
- SMU has a large involvement in the characterization of sensors.
- VNIIM has a significant activity to establish the stability of the many weather stations in the Russian Federation and has also worked on the improvement of travelling standards.
- LMK has a direct membership in WMO expert teams and pilots a worldwide WMO intercomparison.

Dr A. Merlone reported on a relevant decision of the WMO INFCOM on the adoption of the Measurement Quality Classification Scheme, with clear distinction of groups of uncertainty, distinguishing instrumental factors, maintenance and environmental effects.

**Dr A. Merlone reported on the activities of the Task Group for Air Temperature.** There are several underrated problems in measuring air temperature, such as uncertainty of measurement, the evaluation of environmental factors, the calibration of thermometers in air and even the definition of the measurand.

Three sub-groups have been established to deal with these issues: SG1 on the definition of air temperature (Dr S. Bell, Chair), SG2 on evaluation of uncertainty (Dr D. Zvizdic, Chair), SG3 ILC (Dr Y-G. KIM, Chair). Work is ongoing with the planning of an inter-laboratory comparison that will follow the one already carried out within EURAMET. A workshop is being planned for the next MMC 2025 conference.

The activities of the CCT-WG-ENV and the CCT-TG-AIR are perfectly aligned and respond to the relevant requirements of the CCT Strategy document.

Dr M. Milton commented on the importance of developing short and impactful messages to the wider community on the need for metrology in meteorology and climate. Dr A. Merlone responded that the IPCC recognizes the importance of metrology and its need in developing impact and adaptation measures. Dr M. Milton commented that engagement with the IPCC is a priority and the inclusion of the need for “traceable measurements” in their reports.

Dr D. del Campo reminded the attendees that the 1st Stakeholder meeting of the CIPM Sectorial Task Group on Climate Change and Environment will take place in September 2024; the call for abstracts is still open. Dr A. Merlone commented that several submissions were planned from members of the CCT-WG-ENV.

### 6.8 Task Group on Digitalization (CCT-TG-Dig) – Dr P. Rourke (NRC)

Dr P. Rourke presented the highlights of CCT-TG-Dig over the last two years with a focus on three items to discuss:

- Machine-friendly version of the *MeP*-K (doc. CCT/2024-04)
- Archiving, indexing and outreach recommendation for CCT documents (document CCT/2024-05)
- Update to CCT-TG-Dig terms of reference.

The TG was created during the last CCT meeting in 2022. Its primary goal is to examine what information in the documents related to the *Mise en pratique* for the definition of the kelvin (*MeP*-K) could usefully be made available in digital machine-readable form and to recommend an indexing and archiving approach for the documents (see later in this section).

The members of CCT-TG-Dig are also members of CCT-WG-CTh, CCT-WG-NCTh, CCT-WG-Hu, CCT-WG-KC, CCT-WG-CMC and CCT-WG-SP – soon CCT-TG-ThQ. They represent NMIs from SIM, EURAMET and APMP.

Ten key CCT documents related to the *MeP*-K have been reviewed among which the ITS-90 text and the PLTS-2000 text for which the BIPM staff have begun to make Application Programming Interfaces (APIs).

Seven of the documents were deemed to contain information that could usefully be made machine readable. TG members extracted, validated and delivered the data to the BIPM.

The TG had anticipated extracting data from several further documents in a second round of API creation. These could include digital functions for the difference between thermodynamic temperature $T$ and ITS-90 temperature $T_{90}$, humidity-related calculations, etc. Dr P. Rourke pointed out that the support of the BIPM in the creation of the APIs is essential for the progress of these activities. In particular the preparation of the API on $T$-$T_{90}$ consensus values is an important expected output.

Among the successfully coordinated activities of the TG with the BIPM, Dr P. Rourke cited the future availability of digital object identifiers (DOIs) for the main CCT documents.

Finally, Dr P. Rourke presented the following three subjects for agreement by the CCT:

- *New machine-friendly version of the Mise-en-Pratique of the kelvin (MeP-K):* The TG has worked on restructuring the current text of the *MeP*-K-19 (version 2019) to issue a digital version *MeP*-K-19D, which is more machine-friendly and still human-friendly with bookmarks and adapted to screen readers. Moreover, the references have been updated with the most recent publications.

Dr D. del Campo asked if there were any objections to the approval of the *MeP*-K-19D. No objections were raised.

***CCT31/D2: MeP-K-19D approved by the CCT***.

- *Archiving, indexing and outreach of CCT documents recommendation to the CCT:* Dr P. Rourke explained that the aim is to make the CCT documents widely and

consistently used by the community, by ensuring that the versions of the CCT documents are archived and indexed correctly, when a new version is available, and that the users are informed about the version change. Dr P. Rourke gave as an example chapter 5 of the Guide to the realization of the ITS-90 which has several previous versions (2016, 2018, 2021 and a possible update in 2024) with subtle changes including changes to equations used for uncertainty calculations.

It is proposed that archiving, indexing and information steps are undertaken anytime a CCT document is updated.

Dr D. del Campo opened the discussion by pointing out that this would mean important changes to the BIPM website and document management. Dr P. Rourke added that the changes would only concern the future updates of documents and that these changes can only be made within the BIPM website policy and architecture.

Dr M. Milton replied that he hopes that there will be a document archiving system in the future. It would be interesting to offer this service to all the CCs. Dr D. del Campo proposed to raise this point at the next CIPM meeting. Alternative solutions need to be found to communicate about the changes as it is not a task that BIPM can readily achieve.

***CCT31/A1: Dr D. del Campo to bring data management topic at CIPM, in relation to digitalization and towards a general approach about data management and archiving, including all metadata in the documents, their revisions, DOIs, repositories and archive schemes.***

- *Transformation of the task group into a working group:* Dr P. Rourke explained that the role of the group has evolved from an advisory body to accomplishing tasks in relation to digitalization in collaboration with the BIPM. These tasks are likely to last for a long time and justify that the TG becomes a WG.

Dr D. del Campo asked the participants if there were any objections to this change. No objections were raised.

***CCT31/A2: Dr del Campo to ask the CIPM for agreement of the transformation of the TG digitalization into a WG and propose the new terms of reference.***

### 6.9 WG for CMCs (CCT-WG-CMC) – Dr J. Bojkovski (MIRS/University of Ljubljana)

Dr J. Bojkovski presented the terms of reference of the working group and informed the CCT that the last meeting of the CCT-WG-CMC took place in Anaheim, USA, during the last International Temperature Symposium in 2023.

The membership of the WG changed with the arrival of two new TC-Chairs in COOMET and EURAMET.

Dr J. Bojkovski reported the highlights of the working group activities. The review of the results in CCT-K9 were discussed and each RMO TC-Chair was asked to describe the action plan

following the results of this key comparison. An analysis of the effects on the published CMCs was studied.

One other task concerned the working group since the last meeting: updating the CMC review protocols in the light of the findings of the most recent comparisons and the recent publications.

For instance, the ITS-90 sub-range review protocol evolved to reflect the results of the CCT-K9 comparison. Dr J. Bojkovski asked for the approval of this review protocol.

Dr D. del Campo asked if there were any objections to the approval of this review protocol about ITS-90 sub-ranges. Dr H. Yoon asked what the effect of these changes in the protocol would be. A discussion followed after which it was concluded that the conditions of agreement of the CMCs will not be stricter; the main change is that the threshold values will be more realistic. No objections were raised.

***CCT31/D3: Modifications on the ITS-90 subrange CMC review protocol approved by the CCT.***

Dr J. Bojkovski launched a discussion about the extent to which the NMIs should participate in comparisons depending on their calibration capabilities. Should all CMCs need a comparison? In other words, the scope in terms of CMCs and validation of CMCs by comparisons? There is obviously a need to reduce the workload in the comparisons and in the CMC review process. Key comparisons usually last for too long due to their complexity and the large number of participants. Dr J. Bojkovski asked, under these conditions, how can a comparison underpin CMCs 10 years or more after the completion of the measurements? The CCT-WG-CMC will work on a proposal to reduce the burden. Suggestions were presented to establish a hierarchy between CMCs to ensure that a high-level service CMC would automatically justify lower-level service CMCs.

Dr J. Bojkovski reported on the other activities of the CCT-WG-CMCs:

- Additional information needed from participants in key comparisons to justify CMCs: are the staff, the methods, the equipment and the location of the laboratory still the same as during the comparison? This is particularly important when the comparison was performed long before the CMC submission.
- There is a need to repeat some comparisons to support CMCs, for instance CCT-K4 or a new CCT-K9 based on fixed point cells rather than SPRTs as comparison artefacts.
- Speeding up the data analysis process of key comparisons. A good example of efficient data processing was CCT-K7.2021.

Dr J. Bojkovski concluded the presentation by noting that the median time for the publication of a CMC is about 200 days and that most of the remarks to CMCs are technical rather than editorial or for missing evidence, showing a good maturity of the review protocols.

Dr D. del Campo opened the floor for questions.

Dr M. Milton pointed out that the update and refinement of service categories would also be a good idea as they were established about 20 years ago. Other CCs are in the process of achieving this update to reflect the changes and the experience gained.

Dr D. del Campo thanked Dr J. Bojkovski for the presentation and the work performed and suggested that the CCT-WG-CMC prepare a proposal for changes for the next CCT meeting.

***CCT31/A3: WG-CMC, to come to next CCT with revised service categories, and reduction of number of CMCs and duration of comparisons.***

### Technical Workshop on Traceability and Dissemination

A technical workshop organized by Dr A. Peruzzi took place in the afternoon of the first day of the CCT plenary meeting. It included the following presentations:

- Naohiko Sasajima, NMIJ/AIST, "Dissemination and international comparison of thermodynamic temperature in non-contact thermometry"
- Roberto Gavioso, INRIM, "Perspectives for the dissemination of thermodynamic temperature in contact thermometry"
- Jonathan Pearce, NPL, "Approaches to *in situ* SI traceability of temperature measurements through self-validation and practical primary thermometry"
- Patrick Rourke, NRC, "Traceability in a mixed dissemination environment"
- Jeff Gust, Fluke Corp., "The Benefits of a Potential Revision of ITS-90 for Industry".

The workshop fostered a discussion on the need for a revision of the ITS-90. After an exchange of views among the attendees and the speakers it was concluded that the WG-CTh and the WG-NCTh need to undertake a study on the conditions required to initiate a revision of the ITS-90.

***CCT31/A4: WG CTh and WG NCTh to present to the next CCT meeting an analysis on the conditions for a future update of the ITS-90.***

**CCT meeting formally closed – day 1.**

## 6.10 Working group for Key Comparisons (CCT-WG-KC) – A. Peruzzi (NRC)

Dr D. del Campo welcomed the attendees to the second day of the CCT plenary meeting and gave the floor to Dr A. Peruzzi who presented the highlights of CCT-WG KC. Dr A. Peruzzi recalled the invaluable contribution and role of Dr Steffen Rudtsch who passed away in January 2024. Dr R. White has asked to step down from the working group, due to his retirement; Dr Sun from NIM (China) was nominated and approved. The members of the group were remined that they acted as independent reviewers not representing their respective NMIs.

Since the last CCT meeting, the WG has completed the evaluation of 26 different comparisons by reviewing different iterations of their technical protocols or draft reports. Out of the 26 comparisons, eleven were completed, two were abandoned, and 13 are still active and progressing to completion. There are 26 "silent comparisons" about which nothing is known since the last CCT. Dr Peruzzi asked the pilots of these comparisons to report their status and develop a plan to achieve completion as soon as possible.

In the last 20 years seven KC's have been completed (without including CCT-K8 which will be completed soon). The second cycle of some of them has already been completed (CCT-K7-2021,

CCT-K9 andCCT-K10), and CCT-K6-2021, the cycle of CCT-K6, has been initiated. There is a need to initiate two new KCs. CCT-K9 has been relatively recently completed but it is considered obsolete as the Standard Platinum Resistance Thermometers are not adequate transfer standards; it would be recommended to launch a new KC with fixed points as travelling standards. In addition, it is necessary to start a comparison to cover the ITS-90 range from the Al to Ag.

Dr G. Machin clarified that CCT-K5 and CCT-K10 were completely different in terms of technology and uncertainties. CCT-K5 was performed with lamps as transfer standards while CCT-K10 used radiometers and black bodies. There will also be a potentially new key comparison on thermodynamic temperature above the Ag point that will be discussed at the next meeting of the working group.

The repetition of CCT-K9 and the possibility of shipping Argon devices and mercury cells were discussed. Dr C. Gaiser raised this issue and Dr A. Peruzzi mentioned that it requires further discussion due to its complexity. Dr Yang commented on the lack of harmonization in the nomenclature of CCT KCs (for example, the second cycle of CCT-K7 was assigned the acronym CCT-K7.2021, while the second cycle of CCT-K9 was assigned the acronym CCT-K9), to which Dr A. Peruzzi responded that the acronym is assigned by the KCDB Office. Dr M. Milton noted that most Consultative Committees find this alignment helpful and highlighted that the CCT has a limited number of key comparisons compared to other CCs. The practice of assigning new numbers for repeated items helps in keeping clear mental notes.

The discussion included comments on other key comparisons and mathematical and statistical approaches. Dr M. Milton emphasized that the question of mathematical and statistical support for key comparisons has been a recurring topic over the past 20 years. Currently, JCGM WG1 is engaging with the Consultative Committees to some extent, as different CCs adopt different approaches, whether philosophical or mathematical. Dr A. Merlone asked if an action could be assigned to the WG to draft guidance on mathematical approaches, to which Dr A. Peruzzi confirmed that this action would be taken.

***CCT31/A5: WG-KC, to develop guidelines, by the time of the next CCT, to assist the pilots of key comparisons in the analysis of the results***.

## 7. Highlights on CCT Comparisons

### Status of the key comparison CCT-K8 “Comparison of the realizations of dew-point temperature between 30 °C and 95 °C” (anticipated)

Dr R. Benyon, the pilot of the CCT-K8 comparison, presented the progress of this comparison, which concerns nine NMIs from three Regional Metrology Organizations (RMOs). The comparison was designed with two loops with pilot, co-pilot and linking laboratory.

The comparison started once the pre-selection of the thermometers was performed yielding negligible long-term drift. The measurements were completed in November 2017, 9 years after the launch of the comparison.

Some issues were encountered with instruments and temporary exportation administrative procedures, which slowed the completion of the comparison.

Dr R. Benyon presented some of the results in an anonymized mode, since the report is still in the draft A stage. The results at all dew-point temperatures show a remarkable agreement among the participants.

Dr R. Benyon said that there was a long and unjustified delay in completing the comparison and especially the data analysis, but there were a lot of lessons learned during this comparison. A common and more advanced method of analysis has been put in application with the cooperation of PTB and BEV/E+E.

The fourth, and hopefully last, version of the draft A comparison report, including all replies to the reviewers, will be circulated at the end of May 2024, with the aim of completing draft B to be sent to the CCT-WG-KC by the end of June 2024.

Dr D. del Campo thanked Dr R. Benyon for the presentation and expressed her appreciation that the comparison was coming to an end soon.

**CCT.K7.2021 on TPW Cells**

Dr A. Peruzzi informed the CCT that there were initially 19 participants in this comparison, but this number was later reduced as CENAM, INRIM, and NIST were asked to withdraw because of problems with their transfer standard. Additionally, VNIIM was excluded at the request of the majority of participants. The topology used in the comparison was a collapsed star.

The timeline for this comparison was notably fast, with the technical protocol approved in January 2021 and the final report published in May 2023, which is considered good compared to the average duration of CCT KCs. The results were analysed using the adaptive weighted average method, revealing that the new Key Comparison Reference Value is 66 μK above the result obtained in the previous comparison.

Important outputs of the comparison include a reduced spread of the transfer cells and national references, as well as triple point of water realizations closer to the ideal. Recommended good practices included using vitreous silica cells, employing multiple cells in the national reference, conducting periodic checks of national references with newly purchased cells, and applying isotopic corrections

**CCT-K6.2021**

Dr S. Bell noted that this comparison is a repeat of CCT-K6 in the dew and frost point range, from −50 °C to 20 °C. It follows the previous comparison completed in 2015 with ten participants. BEV/E+E will act as the pilot, with VSL assisting.

Thirteen NMIs from all RMOs except GULFMET, expressed interest. VNIIFTRI (Russian Federation) could be linked to this comparison by a bilateral comparison, with UME as the linking COOMET partner. The GULFMET representative confirmed that GULFMET is not interested. The transfer standards are two new dew point condensation hygrometers, tested at the pilot's facilities before circulation. The structure of the comparison is still under discussion, and the protocol is being prepared. It will be similar to the one developed for CCT-K8, with lessons from that comparison's data analysis to be applied.

Dr A. Merlone raised the question about the exclusion of Russian institutes in the Key Comparisons. Dr M. Milton clarified that there is no regulation to exclude any Member State. Dr S. Bell indicated that she followed the general instructions issued by the CIPM for this particular situation. Dr Peruzzi explained that the majority of participants in K7 requested that the Russian Federation be excluded and the pilot took the decision. Dr Merlone replied that partners are not allowed to exclude a participant (the pilot can exclude a participant only on technical grounds, which is not the case of the two mentioned KCs). Dr Peruzzi noted that, in fact, the CIPM general instructions give the KC pilot the authority to take such a decision. Dr D. del Campo suggested not continuing the discussion, emphasizing that given the political situation, the only solution is to follow national rules, considering that NMIs are governmental institutions.

**New comparison on ITS-90 Fixed Points**

During the presentation by Dr I. Yang on the new CCT-K9, it was noted that the previous comparison had concluded, but some results were unsatisfactory for the participants. The main issue identified was the drift of the travelling standard platinum resistance thermometer. As a consequence, the new comparison will be based on the use of fixed-point cells as travelling standards noting that it would be complicated to transport the Hg triple point and impossible by plane. The comparison protocol depends on whether the cell is supplied by the pilot or by the

participants. Regardless, it is crucial to find good cells with minimal temperature deviation for accuracy. However, the use of fixed-point cells pose the question of blindness of the comparison. One possible solution proposed is to use chemically doped cells; other possibilities discussed included using a larger number of SPRTs or a combination of cells and SPRTs.

Dr D. del Campo mentioned that there is much to discuss, which could not be covered in the current meeting and should be properly discussed within the WG-CTh and WG-KC.

***CCT31/A6: WG-CTh and WG-KC, to prepare a new CCT-K9 draft protocol by the time of the next CCT.***

## 8. Highlights of RMO activities

### 8.1 AFRIMETS

Dr E.K. Ejigu reported on the activities of AFRIMETS since the previous CCT meeting. AFRIMETS TC-T met on 5 July 2022 in virtual mode and on 16 July 2023 in-person in Cairo (Egypt).

Among the subjects discussed during these TC-T meetings were the two supplementary comparisons currently running:

- AFRIMETS T-S3 (IPRT calibration between −50 °C and 450 °C), which started in 2012 and was postponed and restarted in 2022
- AFRIMETS T-S7 (noble-metal thermocouple calibration between 0 °C and 1200 °C).

Both comparisons are still in the measurement phase.

The other activities are the participation in comparisons organized by the CCT or other RMOs in which NMISA is an associate member: CCT-K9.3, CCT-K4.2, CCT-K7.2021, CCT K11, APMP T-K4.2, APMP T S11/S12, T-S16, T-S13, T-S17.

The other important activity in AFRIMETS is the CMC submission. After the publication of 34 CMCs over the last 6 years from Zimbabwe, Zambia, Botswana, Morocco and Egypt, a number of AFRIMETS NMIs are in the process of validating their CMCs, which are mostly under intra-RMO or inter-RMO review.

AFRIMETS is actively involved in inter-RMO review as well as capacity building activities (also with each other's support among NMIs in training) and consultancy.

Dr D. del Campo thanked Dr E.K. Ejigu for the presentation and noted the significant progress of the activities in Africa and the contribution of NMISA to this progress.

### 8.2 APMP

Dr H. Abe reported on the organization of the APMP TC-T and its five working groups.

He presented the status of the APMP TC-T key comparisons:

- APMP.T-K4.1 on Ag realization, which is now approved for equivalence

- APMP.T-K4.2 dealing with Al point realization which is in the draft A status
- APMP.T-K6.2013 on dew point measurement for which the measurements are in progress
- APMP T-K9 for the calibration of SPRTs from Ar to Zn points currently waiting for data submission from some participants.

The last two can be categorized as silent comparisons as there was no progress reported to the CCT-WG-KC in the last five years.

Dr H. Abe listed ten supplementary comparisons and one hybrid comparison running currently, eight of which are considered as “silent comparisons”, but work is ongoing to push for progress and conclusion. The progress of all comparisons is monitored during the APMP TC-T meetings.

Concerning CMCs, Dr Abe explained that five NMIs submitted new CMCs in August-September 2023. About 74 CMC lines were submitted. Thirty CMCs were submitted to inter-RMO review. Six CMCs from NMIM (Malaysia) were published on the KCDB in 2023. Dr H. Abe reported on the inter-RMO CMC reviews performed by APMP reviewers in 2023.

Dr H. Abe concluded his presentation by presenting the next APMP TC-Chair who will be Dr Xiaojuan Feng from NIM starting from the next TC-T meeting in December 2024.

Dr D. del Campo thanked Dr H. Abe for the presentation and wished all the success to Dr X. Feng in her new responsibilities.

### 8.3 GULFMET

Due to internet connection problems, the online presentation was not possible, but it was uploaded on the website.

### 8.4 COOMET

Dr S. Kondratev presented the structure and activities of COOMET in his role of Acting TC-T chair (he was nominated in June 2024).

COOMET includes 17 members and five associated members from other RMOs.

- The main objectives of the COOMET TC-T were reported to be: Practical implementation of CIPM MRA, research on new and improved national standards of thermophysical quantities
- Their research activities aim at introducing the new definition of the kelvin into measurement practices.

Dr S. Kondratev reported about the published CMCs (more than 340) for COOMET laboratories and gave the status of the comparisons. Two comparisons were completed in 2023: COOMET 744/RU-a/18 (COOMET.T-S4, a supplementary comparison of combustion energy of coal samples with different content of sulphur) and COOMET Project 780/RU-a/19 ( a pilot study of national reference gas calorimeters using samples of gas mixtures) both led by VNIIM.

Dr S. Kondratev listed the comparisons in progress and announced the start of two new comparisons in thermophysical quantities in 2023.

Dr S. Kondratev concluded his presentation by presenting the content of a training webinar about the realization of the new definition of the kelvin, which was organized on 27 April 2023. The main topics of this webinar were:

- Redefinition of the kelvin and its consequences in the practice of temperature measurements
- Realization at VNIIM of the new definition of the kelvin above 961.78 °C
- The practice of using high-temperature fixed points in the implementation of the new definition of the kelvin by relative primary thermometry
- Acoustic gas thermometry equipment in VNIIFTRI in the range from 4.2 K to 273.16 K.

Dr D. del Campo thanked Dr S. Kondratev for his presentation.

### 8.5 EURAMET

After a tribute to the former EURAMET TC-T chair, Dr Steffen Rudtsch who passed away in January 2024, Dr M. Sadli reported about the highlights in the activities of the EURAMET TC-T.

The main event during the recent two years was the organization of the second EURAMET TC-T summer school in Ljubljana (Slovenia) which gathered 57 students from 32 countries (many outside of Europe). The lectures were given by experts from several European NMIs/DIs and one expert from the NRC (Canada). The feedback from the students was very positive.

Dr M. Sadli gave a short summary of the recent TC-T meeting which was held in Wroclaw (Poland) and hosted by INTiBS. This meeting was attended by about 70 representatives from the European NMIs/DIs.

During that session, besides the meetings of the five working and task groups and the Humidity sub-committee, a technical workshop devoted to “the digital workflows in thermometry” was held. This was a good opportunity to discuss information about the progress in digitalization among the participants.

### 8.6 SIM

Dr C.A. Sanchez presented SIM activities remotely. The SIM thermometry activities are dealt with in SIM working group 3, which includes 113 people from 34 countries. The latest meetings took place online in 2022 and 2024 and in-person during the ITS-10 symposium in April 2023.

Dr C.A. Sanchez reported about the comparisons running currently: SIM.T-S11, SIM.T-S12, CCT-K9.2, CCT-K9.3, CCT-K9.4 and SIM.K6.8.

As for CMCs, three NMIs published new CMCs in 2023 and 2024: Panama, Brazil and Canada.

In terms of knowledge transfer, a technician from SECAMER (Venezuela) benefited from training in temperature and humidity at INM (Columbia) during two weeks in April 2024, with support from SIM. The next meeting of SIM’s working group thermometry will take place in Montevideo (Uruguay) in June 2024. It will be a hybrid meeting to allow for a large participation and will include a workshop.

## 9. News from the JCRB – Mr I. Ahmed (BIPM)

Mr I. Ahmed, JCRB Executive Secretary, presented the latest news from the JCRB. He reminded CCT members that the comparison pilots are required to report annually on the progress of their respective comparisons. Regarding the review of CMCs, all RMOs have the right to review them. There is an emphasis on increased cooperation, sharing of best practices, and exchanging comments. Thorough intra-RMO reviews are necessary before the JCRB review.

New guidance materials are being developed to assist in writing and reviewing CMCs, which are currently being tested. The JCRB recommends the use of CMC identifiers and encourages NMIs to register with the Research Organization Registry (ROR) to obtain a digital identifier. NMIs need to open ROR accounts.

The KCDB statistics show a total of 25 877 CMCs, with 2 965 CCT CMCs, including 23 new ones since September 2023. The CMC status from the CCT indicates that only GULFMET has no CMCs. The median review duration is 56 days for intra-RMO and 80 days for JCRB, with thermometry slightly higher than the median of the JCRB but below that of intra-RMO review.

Mr I. Ahmed reported a loss of rights, in the CMC review, for several regions: AFRIMETS (10), APMP (6), COOMET (46), EURAMET (27), GULFMET (26), and SIM (24). There are 678 greyed out CMCs, with only seven from the CCT. There are 37 CMCs under “revision requested” status. Additionally, the CCT has seven uncompleted KCs/SCs.

The JCRB Secretary encouraged RMOs to adhere to deadlines and accept the review of CMCs. The CCT is performing well but needs to ensure timely completion of CMC reviews, with 37 CMCs having been under review for more than six months. It was commented that some rejected CMCs are still listed, and Dr S. Maniguet (KCDB coordinator) noted that rejected CMCs should remain visible to the NMI.

Dr S. Maniguet also pointed out that CCT takes a lot of time in completing the comparisons in general. She reminded the CCT that it is advisable not to register a comparison if it is not planned to start it immediately. Dr J. Bojkovski highlighted the issue of NMIs not reacting after negative results, leading to hanging CMCs.

## 10. News from the KCDB

The KCDB has recently welcomed a new staff member, Mr Anderson Mania, who is expected to contribute significantly to the ongoing projects and initiatives. The KCDB continues to receive strong support from the CBKT programme, which has been instrumental in various advances.

The web platform remains a crucial tool for the registration and review of CMCs (Calibration and Measurement Capabilities) and comparisons. Currently, there are 1 700 registered user accounts, with a total of 41 000 users accessing the platform. There are 251 CIPM MRA participants and 1174 Key Comparisons, 25 894 CMCs, and 690 Supplementary Comparisons (SCs) recorded in the KCDB.

An e-learning session focused on the use of the KCDB is in the pipeline, with invitations to be sent out soon. To date, 2 966 CMCs in thermometry have been published, alongside 79 KCs and 53 SCs. The publication of DoE (Degrees of Equivalence) values as numerical data marks a significant step towards digitalization.

The web platform undergoes continuous updates to enhance functionality, including fine-tuning notifications and introducing new features. A new user account for an NMI CMC responsible has been created, and the comment tool has been updated to improve user interaction. Users can now search for CMCs using a menu-based or keyword-based system, aligning with the FAIR (Findable, Accessible, Interoperable, and Reusable) principles.

The release of a BETA version of the platform is in progress, and feedback is encouraged. New DoEs have been published, complete with graphical representations. The KCDB API is now available, enhancing interoperability through the use of ontology and persistent identifiers.

The ongoing work includes a review of the types of quantities and units used in the CMCs, with plans to extend the list where necessary. Efforts are also being made to establish a digital reference point for service categories in physics. Additionally, updates to the KCDB API are under way to ensure it meets the evolving needs of its users.

**Digitalization progress at the BIPM**

Dr F. Meynadier provided insights into the SI Reference Point, emphasizing the various levels of digitalization, which range from L0 (analogue documents) to L5 (machine-controllable content). The foundational pillars of this system include SI units and prefixes, defining constants, selected quantities and key decisions. Dr F. Meynadier illustrated how units can be constructed from expressions, providing practical examples.

Dr D. del Campo encouraged the CCT members to test and provide feedback on the BETA version of the platform. In discussions about ontology, Dr S. Tabandeh raised the question of distinguishing between $T$ and $T_{90}$. Dr F. Meynadier clarified that it is possible to specify the quantity, allowing for different quantities to share the same unit. Dr P. Rourke highlighted the extensive work required, which necessitates collaboration with data modellers.

Dr M. Milton noted that significant work remains on the quantities and the ontology of temperature, a concern shared by other Consultative Committees. Dr S. Bell mentioned that Dr J. Miles has already initiated efforts to define the necessary quantities in the field of humidity. Dr F. Meynadier pointed out that Permanent Identifiers (PIDs) are now available, further supporting the digitalization efforts.

## 11. Report on the activities of the CIPM Sectorial Task Group for Climate Change and Environment (CIPM-STG-CENV) – Dr D. del Campo (CEM)

Dr D. del Campo presented the main activities of the CIPM STG–CENV, the objective of which is to provide a global focal point for metrology activities related to climate change and environment. She informed the CCT about the 1st Stakeholder meeting of the group that focused on following up on the recommendations from the 2022 BIPM-WMO workshop. The abstract submission deadline for the meeting is 31 May 2024. The event aims to identify areas where activities are lacking and to understand the reasons behind this. The goal of the group is to coordinate activities and facilitate contact between institutions.

She informed the CCT that the BIPM has gained observer status at the COP meetings and has applied for official IPCC observership. This is seen as a significant step forward in recognizing metrology as an important player in climate change and environmental activities.

During the questions, Dr A. Merlone recalled that in 2010, the CCT recommended that NMIs should work directly with National Hydrological and Meteorological Services, as well as the Climatology and Oceanography Communities. This recommendation, T3-2010, was accepted by the CIPM and led to the formation of the WG Environment, focusing on thermal measurement needs in climatology. Dr A. Merlone reported that during the meeting of the WG-Strategy, he requested formally that the CCT-WG-ENV be included as member of the CIPM STG-CENV.

***CCT31/A7: Dr D. del Campo to ask CIPM to include a representative of CCT WG-ENV among the members of the CIPM- STG-CENV.***

## 12. Report on the activities of the Forum on Metrology and Digitalization (Forum-MD) – Dr P. Rourke

Dr P. Rourke reported on the activities of Forum-MD. The mission of the forum is to advise the CIPM on the SI Digital Framework and the broader implications of the global digital transformation for metrology and Quality Infrastructure. It aims to harmonize internal digitalization processes among NMIs, CCs, RMOs and the BIPM, as these entities might be working on digitalization in potentially overlapping areas. Additionally, the forum seeks to facilitate information exchange, create synergies and foster collaboration opportunities.

The Forum operates in a similar way to a Consultative Committee and includes Working Groups (WGs) and Task Groups (TGs). The first plenary meeting was held on 7–8 March 2024. The Forum-MD includes members from CENAM, METAS, INTI, MSL, NIM, NIST, NMIA, NPL, NRC, PTB, and VNIIM. Some workshops were organized, including one titled “Towards Digital Quality Infrastructure” that was held on 5–6 March 2024. There is a strong desire for Forum-MD to become operational as soon as possible.

Some discussions took place around Digital Calibration Certificates and self-calibration instruments and the necessary evolution of the VIM to allow the future steps in digitalization.

## 13. AOB

Dr C. Sanchez, head of temperature and humidity at INM (Colombia), presented their activities as they seek to become a new CCT member. He described the staff, laboratories and activities, noting that the team consists of four people. Their equipment includes SPRTs, bridges, and a 2-pressure humidity generator. They have 37 CMCs in contact thermometry and humidity published in the KCDB, with fixed point cells ranging from Hg to Al, covering a temperature range of −80 °C to 1200 °C. For humidity, they cover the range from 12 % to 85 % RH. Additionally, they have 14 CMCs currently under review. Their scientific production includes 16 papers.

Dr D. del Campo thanked the INM speaker and after some questions and comments from the attendees it was decided to discuss the INM application within the WG-Strategy.

***CCT31/A8: Dr D. del Campo to continue the discussion within WG-Strategy about the admission of INM-Colombia as a member.***

**Events**

The CCT members were informed about various events that will take place in the coming months:

- A Workshop on Air Temperature will be organized together with MMC 2025 – 24–26 June 2025 in Vienna (Austria).
- Workshop hosted by the Royal Society "The redefined kelvin: progress and prospects", 24–25 February 2025, Glasgow (United Kingdom).
- International Metrology Congress (CIM2025), 11–14 March 2025 Lyon (France).
- TEMPMEKO/ISHM 2025, 20–24 October 2025, Reims (France).

## 14. Approval of open access documentation.

Dr S. Solve said that all working documents associated with the 31st CCT meeting will be made public unless there is a particular reason to keep them confidential.
Dr D. del Campo and the CCT plenary confirmed that the documents could be made public.

## 15. Next CCT Meeting

Dr D. del Campo opened the discussion about the date of the next meeting. According to the list of actions agreed it seems sufficient to have the next CCT Meeting in May 2026. However, the Working Groups were encouraged to have meetings during the TEMPMEKO conference to monitor the progress on the different activities.

## 16. Closure of the 31st meeting of the CCT

Dr D. del Campo thanked all the participants for their contributions and the fruitful discussions and closed the 31st CCT meeting.

## 17. Actions and decisions

**Actions**

The following actions are to be undertaken:

CCT31/A1: Dr D. del Campo to bring data management topic at CIPM, in relation with digitalization and towards a general approach to data management and archiving, including all metadata in the documents, their revisions, DOIs, repositories and archive schemes.

CCT31/A2: Dr D. del Campo to ask the CIPM for agreement of the transformation of the TG digitalization into a WG and propose the new terms of reference.

CCT31/A3: WG-CMC, to come to next CCT with revised service categories, and reduction of the number of CMCs and duration of comparisons**.**

CCT31/A4: WG-CTh and WG-NCTh to present to the next CCT meeting an analysis on the conditions for a future update of the ITS-90.

CCT31/A5: WG-KC, to develop guidelines, by the time of the next CCT, to assist the pilots of key comparisons in the analysis of the results**.**

CCT31/A6: WG-CTh and WG-KC, to prepare a new CCT-K9 draft protocol by the time of the next CCT meeting.

CCT31/A7: Dr D. del Campo, to ask CIPM to include a representative of CCT WG-ENV among the members of the CIPM- STG-CENV.

CCT31/A8: Dr D. del Campo to continue the discussion within WG-Strategy about the admission of INM (Colombia) as a member.

**Decisions**

The following decisions were taken unanimously**:**

CCT31/D1: Dr H. Abe from NMIJ approved as new chair of the CCT-WG-Hu.

CCT31/D2: *MeP*-K-19D approved by the CCT.

CCT31/D3: Modifications on the ITS-90 subrange CMC review protocol approved by the CCT.

*Dr A. Merlone and Dr M. Sadli, Rapporteurs*

*October 2024*