Bureau International des Poids et Mesures

Consultative Committee for Thermometry (CCT)

Report of the 26th meeting
(24–25 May 2012)
to the International Committee for Weights and Measures

Comité international des poids et mesures

Note:

Following a decision of the International Committee for Weights and Measures at its 92nd meeting (October 2003), reports of meetings of the Consultative Committees are now published only on the BIPM website in the form presented here.

Full bilingual versions in French and English are no longer published.

M. Kühne
Director BIPM

LIST OF MEMBERS OF THE CONSULTATIVE COMMITTEE FOR THERMOMETRY

as of 24 May 2012

President

H. Ugur, member of the International Committee for Weights and Measures.

Executive Secretary

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

Members

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

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-INM/CNAM], Paris.

D.I. Mendeleyev Institute for Metrology [VNIIM], Rostekhregulirovaniye of Russia, St Petersburg.

Institute for Physical, Technical and Radiotechnical Measurements [VNIIFTRI], Rostekh-regulirovaniye of Russia, Moscow.

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-INMS], 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.

Observers

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

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

The twenty-sixth meeting of the Consultative Committee for Thermometry (CCT) took place at the International Bureau of Weights and Measures (BIPM), Pavillon de Breteuil, Sèvres, on 24 and 25 May 2012.

The following were present:

M. Arai (NMIJ/AIST), T. Baba (NMIJ/AIST), M. Ballico (NMIA), S. Bell (NPL), D. Del Campo (CEM), Y. Duan (NIM), S. Duris (SMU), B. Fellmuth (PTB), V. Fernicola (INRIM), J. Fischer (PTB), V. Fuksov (VNIIM), L. Hanssen (NIST), M. Heinonen (MIKES), Y. Hermier (LNE), K. Hill (NRC-INMS), J. Hollandt (PTB), J. Ishii (NMIJ/AIST), M. Kalemci (UME), M. Kühne (Director of the BIPM), G. Kytin (VNIIFTRI), H. Liedberg (NMISA), G. Machin (NPL), E. Méndez-Lango (CENAM), A. Merlone (INRIM), M. Moldover (NIST), P. Nemeček (SMU), J. Pearce (NPL), A. Peruzzi (VSL), A. Pokhodun (VNIIM), A. Schipunov (VNIIFTRI), N. Sokolov (VNIIM), P. Steur (INRIM), G.F. Strouse (NIST), A.D. Todd (NRC-INMS), H. Ugur (President of the CCT), L. Wang (A*STAR), R. White (MSL), K. Yamazawa (NMIJ/AIST), I. Yang (KRISS), H. Yoon (NIST), Z. Yuan (NIM), J. Zhang (NIM).

Observers: R. Teixeira (INMETRO).

Invited by the President: R. Feistel (Leibniz Institute for Baltic Sea Research), F. Pavese (INRIM), D. Zvizdic (HMI).

Sent apologies: M. Batuello (INRIM), E. Filipe (IPQ), F. Pavese (INRIM), A. Diril (UME),

Also present: A. Picard (Executive Secretary of the CCT), O. Altan (Executive Secretary of the JCRB), C. Thomas (Coordinator of the BIPM KCDB).

The President of the CCT, Prof. H. Ugur opened the meeting and welcomed the participants. Prof. H. Ugur greeted Dr Y. Duan, who will chair the next CCT meeting as the new President of the CCT. Prof. H. Ugur invited the Director of the BIPM Prof. M. Kühne to make his welcoming comments.

Prof. M. Kühne welcomed the delegates on behalf of the BIPM and wished them a productive two days. He commented that these are exciting times with the upcoming redefinition of the SI, including the kelvin. He indicated that he would make some comments when the report of the Strategy Working Group was discussed. Those comments relate to activities of the *ad hoc* working group of the CIPM regarding the long-term future and governance of the BIPM, which included ideas and strategy for different metrology areas as presented to the laboratory directors.

Dr R. White (MSL) was appointed *rapporteur*.

Prof. H. Ugur outlined the agenda and suggested items 6 and 7 be reversed. There were no objections. He welcomed Dr R. Feistel from the Leibniz Institute for Baltic Sea Research who would later present background information and progress on the collaboration between the CCT and the International Association for the Properties of Water and Steam (IAPWS). Prof. H. Ugur noted that there have been three requests for CCT membership: Egypt (NIS), Brazil (INMETRO), and Croatia (HMI), although there was no representative from Egypt present at the

meeting. Prof. H. Ugur indicated that the later discussions of the working group members will focus on Working Groups 7, 8 and the Strategy Working Group, since the other members should have been confirmed in advance of this meeting.

2 DOCUMENTS PRESENTED TO THE 26TH MEETING OF THE CCT

Prof. H. Ugur noted that more than 20 documents have been presented to the CCT, including the reports of the CCT working groups (Appendix T1). He reminded delegates that technical documents are normally discussed during the meetings within the working groups. The CCT plenary session will discuss issues including terms of reference, membership, chairmanships and other more general topics such as temperature scales. If a topic is of sufficient general interest there will be the opportunity for a workshop at the beginning of the week. Working group documents should be submitted on time through the appropriate working group chair to allow the chair to review the documents in advance of the meeting.

Prof. H. Ugur advised that all of the working documents would be made available via open access the following week. If anyone preferred a document to retain restricted access they should advise Mr A. Picard.

3 REPORTS OF THE WORKING GROUPS

3.1 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/12-11). He summarized the main tasks of the working group, i.e. the revision of the *Supplementary Information for the ITS-90* (the 'Redbook'), and preparation of the second version of the *mise en pratique for the kelvin* (MeP-K). He suggested that Working Group 1's responsibility for the overview of temperature scales is transferred to the Strategy Working Group, but this was not urgent. He then proceeded to summarize progress to date.

Dr B. Fellmuth gave an overview of the plans of the working group for revision of the *Supplementary Information*. The revision would be web-based and revised chapters or sections would be self-contained with links from the contents pages, and to the scanned sections of the Redbook where the text had not yet been replaced. In future, the *Supplementary Information* would not be available as a printed book, instead it will be in a web-based format for easy publication and revision. Drafts of the revised chapters or sections are first prepared by subgroups within Working Group 1, and discussed by the complete working group before submission to the CCT for approval and comments. Once the drafts are approved by the CCT, revisions will be posted on the BIPM website.

Dr B. Fellmuth reported on the current status of the revisions. The working group has a detailed task list with all members currently involved. There is support from outside the working group with Working Group 5 supporting the revision of the section on radiation thermometry (CCT/12-26), and Mr G.F. Strouse coordinating revision of the section on fixed points. Revisions for the foreword and contents (CCT/12-04), the introduction (CCT/12-12), and a chapter on interpolating gas thermometry (CCT/12-05) had been drafted and discussed by the working group, and are included in the documents presented to the CCT. Four other draft chapters on the water triple point, platinum resistance thermometry, radiation thermometry and metal fixed points are nearly complete, and outlines for other sections are in place. Dr B. Fellmuth commented that the updated chapter on the realization of the fixed points is important, especially with respect to impurities, and it will replace all current recommendations for the treatment of impurities. Data on impurities, such as the liquidus slopes, are being collated in a database. The working group plans to have completed the revised *Supplementary Information* by the next CCT meeting.

3.1.1 Task Group on the MeP-K: Second version of the MeP-K

Dr B. Fellmuth first summarized the current status of the MeP-K by noting that the CCT adopted the 'amended version' by e-mail voting. This 'amended version' emphasized the guidelines for the ITS-90 and PLTS-2000, and subsequently the estimates of $T–T_{90}$ developed by Working Group 4 had been added. At present there is no content describing the realization of the kelvin, although it is anticipated with the new definition. Dr B. Fellmuth noted that the new definition of the kelvin would simplify traceability for radiation thermometry and that the water triple point would no longer have a defined value but be attributed an uncertainty. The Special Task Group had concluded that, for contact thermometry, the international temperature scales will remain important and the new definition of the kelvin would have no effect on these scales. However, Dr B. Fellmuth indicated that one of the consequences of the new definition would be a need for a large number of key comparisons for the different thermodynamic methods.

Dr B. Fellmuth also commented on the current status of the second version of the MeP-K. There are three main changes including a restructuring, a clarifying statement about nomenclature, and a section covering approved primary methods. The nomenclature section defines primary thermometry, absolute primary thermometry, relative primary thermometry, defined temperature scales and approximations to thermodynamic temperature. The nomenclature section is required to clarify the terms used in the MeP-K, to ensure an unambiguous taxonomy of methods, and to avoid confusion with other terms in use, such as direct or indirect. The proposed definitions are given in Working Document CCT/12-19, which was endorsed by the Task Group at its meeting prior to the CCT meeting. Dr B. Fellmuth explained that for a method to be included in the MeP-K, it should satisfy a minimum set of criteria to ensure its utility and practicality. These criteria include an equation of state or a proven approximation and a CCT-approved uncertainty budget which should be within a factor of ten of the state of the art. Further, the method should have been realized independently twice and documented in the open literature, and it should be applicable over an important or useful temperature range. These requirements are detailed in Working Document CCT/12-17, which was also endorsed by the Task Group. A method included in the MeP-K will be described concisely, within one page, with links to detailed supporting information. Radiation thermometry is likely to be the first approved method. The second version of the MeP-K is planned for completion in time for approval by the CCT before June 2013.

Dr B. Fellmuth concluded and asked that the CCT reviews and approves the three working documents for the revised *Supplementary Information* and the two working documents for the MeP-K.

Prof. H. Ugur asked if the technical annex on the neon isotopic correction should go to the CIPM. Dr B. Fellmuth replied 'no'. Prof. M. Kühne advised that the MeP-K must go to the CIPM and be discussed with major stakeholders, and be approved by the CIPM. Dr B. Fellmuth commented that the technical annexes relate to the ITS and not the MeP-K. Prof. M. Kühne acknowledged that the CIPM would not be interested in such detail.

Prof. M. Kühne asked for clarification about the definitions for the primary methods and whether they would be consistent with the International Vocabulary of Metrology (VIM). Dr B. Fellmuth explained that no temperature standards (e.g., fixed points) were required for the absolute primary methods and relative primary methods allowed for the use of already-determined temperatures and step-by-step propagation of the scale. Prof. M. Kühne asked if there had been any communication between the Working Group 2 of the Joint Committee for Guides in Metrology (JCGM). Dr C. Thomas pointed out that primary methods were not defined in VIM 3, and there was a similar definitional problem with mass. She indicated that the issue would be discussed at the next meeting of the JCGM working group. Dr J. Fischer advised that the use of the term 'primary' followed a definition introduced by Dr T.J. Quinn. Prof. M. Kühne then concluded that since there was no definition of 'primary' in VIM 3 there was no contradiction and suggested that Dr C. Thomas should raise the issue with the JCGM working group.

Prof. H. Ugur asked if there were any objections to the five documents. There were none.

3.2 CCT Working Group 2: Secondary contact thermometry

Mr H. Liedberg presented the report of the activities of Working Group 2 (CCT/12-24). He reviewed the terms of reference for the working group and summarized the current tasks, being the revision of the BIPM publication on *Techniques for Approximating the International Temperature Scale of 1990* (the 'Bluebook'), and updating of the list of secondary fixed points. The revision of the Bluebook was progressing with sections on thermistors, thermocouples, and the section on specialized fixed points almost complete. At the working group meeting earlier in the week of the CCT meeting, all the sections had been discussed. It was suggested that for the sections that had not yet commenced, the working group could provide an interim list of key references, with links to the older sections of the Bluebook, and with a disclaimer to the effect that the references were provided as an aid only. The working group also discussed a request from Dr M. Ballico (via Dr R. White) for a document on uncertainties in rare-metal thermocouples. It was agreed that Working Group 3 should prepare the document with help from the thermocouple experts in Working Group 2. No further progress had been made on updating the list of secondary fixed points, although there had been discussion with the BIPM IT staff about the possibility of a wiki approach for maintaining the list.

Mr H. Liedberg noted that Dr R. Feistel attended the Working Group 2 meeting, and that it was useful to have direct contact and feedback from users. It was proposed that a joint paper be prepared for TEMPMEKO 2013.

Prof. G. Machin asked if there was a place in the list of secondary fixed points for the fixed points used in radiation thermometry. Dr R. White commented that the revised section on specialized fixed points included metal-carbon fixed points and expected the same concerning the list of secondary points. Prof. G. Machin elaborated that the use of these points is not strictly in accordance with ITS-90, but that they constitute very good approximations. Mr H. Liedberg commented that including the radiation thermometry fixed points would contradict the terms of reference, revised at the previous meeting, so that Working Group 5 would become responsible for all radiation thermometry. Dr H. Yoon commented that it was logical that the fixed points are included in *Techniques for Approximating the ITS-90*. Prof. H. Ugur observed that a similar conflict would arise when uncertainties are considered. Dr A. Merlone noted that the previous terms of reference allowed such work and perhaps they could be restored. Prof. G. Machin commented that it was important to focus on a stand-alone text that would aid users. Mr H. Liedberg confirmed that the working group's approach had been to make the Bluebook sections modular and stand-alone. Dr M. Heinonen suggested that Working Group 5 provides the material for Working Group 2. Dr B. Fellmuth noted that the Bluebook had been written when there were no radiation thermometry approximations to ITS-90 - he would like to see this information included in the new revision. Prof. H. Ugur recommended this action, and asked if there were objections. There were none.

Prof. H. Ugur asked about the chairmanship of the working group since Mr H. Liedberg had advised that he would be standing down. Mr H. Liedberg indicated that Dr A. Merlone had volunteered, and that there was unanimous support from the working group, thanking Dr V. Fernicola for the nomination.

3.3 CCT Working Group 3: Uncertainties in contact thermometry

Dr R. White presented the report of the activities of Working Group 3 (CCT/12-08). Dr R. White reviewed the terms of reference and the tasks before the working group, which include addressing uncertainty in the extrapolation of long-stem standard platinum resistance thermometers (SPRTs) to the liquid nitrogen temperatures, evaluation of Type 1 non-uniqueness (sub-range inconsistency) in SPRTs, and the continuing revival of Bayesian statistics and its possible impact on uncertainty analysis. Following the meeting of Working Group 2 earlier in the week of the CCT meeting, there was an additional task to prepare an uncertainty guide for rare-metal thermocouples. Dr R. White reported that the working group met at the ITS9 conference held in Los Angeles, USA, on 19-23 March 2012, that the paper prepared for the previous TEMPMEKO symposium on topics for further research had been published, and listed changes to the group membership.

Dr R. White noted that the issue of the extrapolation to liquid nitrogen temperatures had largely been addressed with the EURAMET publication of a technical guide. Nevertheless there was an opportunity to support the guide with a mathematical treatment of the uncertainties and publication of both the theory and experimental results in an archival journal.

Dr R. White discussed the possibility of developing a better understanding of the Type 1 non-uniqueness in SPRTs. Although no significant progress had been made, a number of the larger national metrology institutes (NMIs) had expressed interest in collating SPRT data to further the study.

Dr R. White observed that Bayesian statistics continues to grow in influence, and that understanding the impact a Bayesian approach may have become very important with the recent announcement that the BIPM was to revise the GUM (*Guide to the Expression of Uncertainty in Measurement*). Dr R. White recalled that at the previous CCT meeting he had volunteered to prepare a document summarizing the issues around the possible adoption of Bayesian principles for uncertainty analysis. That document had been prepared with considerable help from statistician Dr R. Willink and was submitted as working document CCT/12-07. Dr R. White explained that since the previous meeting, he had changed his view from concerned but neither for or against, to very concerned and opposed to the use of Bayesian statistics. Dr R. White commented that he could discuss this in detail now if requested, or later in the meeting under scientific topics. He noted that his opposition was strictly a personal view and not that of the working group. The issue had been discussed by the members of the working group, while considering the issue complicated, considered themselves to be insufficiently well enough informed to express a firm view for or against, although a number of the members were very concerned.

Dr R. White discussed the proposed uncertainty document for rare-metal thermocouples, which is to be prepared with the assistance of experts from Working Group 2. The need for the document had been raised by Dr M. Ballico, who noted that there were two different annealing states in common use for platinum thermocouples, and that the consequential uncertainty due to hysteresis was significant. The scope of the revised Bluebook section, which is more general and includes base-metal thermocouples, was thought to be too broad to discuss rare-metal thermocouple calibration in sufficient detail.

3.4 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/12-14). Dr J. Fischer summarized the terms of reference for the working group and indicated that no changes were envisaged. He informed the meeting that the paper on $T–T_{90}$ prepared by the working group had been published. It gave the first complete account since the introduction of ITS-90, and provided recommended interpolation equations above and below 0 °C to allow estimates of thermodynamic temperatures from ITS-90 measurements. The data and equations had been addressed to Working Group 1 for inclusion in the MeP-K after approval by a full e-mail vote by the CCT in December 2010. Dr J. Fischer gave a short presentation showing the current situation. He identified two areas of concern: the discrepant data in the range from 25 K to 100 K resulting in a larger than desirable uncertainty in that range, and the lack of measurements in the range between 500 K and 700 K. In both cases, more measurements are required.

The current status of $T–T_{90}$ measurements was summarized. Some of the measurements made since 2010 were not yet included in the analysis, such as: preliminary ^{3}He vapour-pressure thermometry at the LNE; constant-volume gas thermometry at the NMIJ; radiation thermometry results from the PTB (however with uncertainties so far too high); and copper-point measurements at the INRIM. New results were also expected from the dielectric-constant gas thermometry at the PTB, acoustic gas thermometry at the NIST, refractive index thermometry at the NIST, and a joint NIST/NMIJ project on Johnson noise thermometry. Mr G.F. Strouse advised that the NIST noise thermometry was planned to go to 800 K.

Dr M. Ballico informed that the NMIA had published absolute radiation thermometry measurements that should be included, and that he would forward the paper to Dr J. Fischer.

3.4.1 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/12-13). After summarizing the terms of reference, he gave a detailed presentation summarizing the current state and prospects of all of the experiments that might contribute to the Boltzmann constant determination. Dr J. Fischer noted that the current CODATA value for the Boltzmann constant was dominated by the LNE value and uncertainty. He concluded that the best uncertainties that can be expected from the various experiments were:

- Acoustic gas thermometry: less than 1 part in 10^6;
- Dielectric-constant gas thermometry: less than 2 parts in 10^6;
- Johnson noise thermometry: about 5 parts in 10^6;
- Doppler-broadening gas thermometry: no less than 10 parts in 10^6;
- Refractive index thermometry: perhaps less than 10 parts in 10^6.

Dr J. Fischer reminded the CCT of the CCT Recommendation T2 from the 25th meeting (2010) that the redefinition of the kelvin should proceed only after an uncertainty of about 1 part in 10^6 had been achieved using two different methods, and that this had yet to be achieved.

Dr J. Fischer proceeded to discuss the impacts of the redefinition of the kelvin. The two main impacts are that the lower uncertainties achievable with absolute radiation thermometry above 2000 K would be recognized, and the triple point of water would no longer be defined but instead have an uncertainty of about 0.25 mK. The uncertainty followed from the uncertainty in the CODATA value of Boltzmann's constant of 0.91 parts in 10^6. He reiterated that the task group could not foresee any experiment where the uncertainty in the thermodynamic temperature of the water triple point would be a problem, and he was not aware of any new technology that would provide a better measurement of the triple point temperature. Dr J. Fischer noted that Max Planck had apparently suggested the use of 'natural' units for a temperature definition, by fixing both h and k, in 1900.

Prof. H. Ugur confirmed with Dr J. Fischer that the proposed fixed-constant style of definition for the kelvin was not being challenged. Prof. H. Ugur concluded that the remaining steps are to determine the value for k, to outline the role for the individual laboratories, and to finalize the wording for the definition. Prof. M. Kühne commented that if the CCT was not happy with the proposed style of definition then the CCT should recommend a modification to the CIPM, although he considered that the CIPM was unlikely to change its stance. Dr C. Thomas added that the wording of the definition was not exactly the same as the CIPM's proposed definition, and suggested that the CCT discuss the correct definition. Prof. M. Kühne commented that there was a lot of work to do before the meeting of the CGPM scheduled for November 2014, and that much progress had to be made in the numerical determination of Planck's constant. Further, the CIPM had to prepare its draft resolutions by October 2013, and the CCT and other Consultative Committees need to have their recommendations in place before this date. More work is required, especially for the kilogram.

Dr M. Heinonen stated that he was not happy with the fixed-constant style of definitions because they do not explain what quantity is measured and defined. Dr J. Fischer responded that explanatory notes would accompany the definitions. Dr R. White commented that with the kelvin definition, especially, there was great difficulty making a succinct informative definition. Such a definition will need to explain that temperature results of the measurement of the average translational kinetic energy of unbound particles, to avoid zero-point energy effects, in thermal equilibrium, and a factor of 2/3 was required. The fixed-constant definition is very much simpler. Dr Y. Hermier added that the CCT wanted the best definition for the scientific community, but that the CCT also exists for the users and must find a way to communicate the meaning of the new definition for more general users. He suggested that this could be incorporated into the MeP-K. Dr J. Fischer agreed that the MeP-K should include the definition and an explanation.

Prof. M. Kühne commented that the MeP-K will have to pass through the Consultative Committee for Units (CCU) before submitting the document to the CIPM and the next CCU meeting will be held in June 2013. Dr C. Thomas added that the global architecture of all of the documents associated with the SI revision is of interest, and all should be known preferably by June 2013. Dr J. Fischer responded that the document would be completed by then, although perhaps not yet approved by the CCT. Prof. H. Ugur suggested that approval could be obtained by correspondence, and that there should be no problem finishing the document by April 2013. Prof. M. Kühne confirmed with Dr C. Thomas that the CCU would require the document four weeks in advance of its meeting as it must be linked to the SI documents. Dr B. Fellmuth noted that this deadline could only be met by including radiation thermometry as a primary method, but no other methods. Dr P. Steur inquired whether the next document would follow the same procedure. Prof. H. Ugur replied ‘yes’, although there was not a problem with generating information, more a problem of compilation. He asked if everything would be ready for April 2013. There were no objections.

3.5 CCT Working Group 5: Radiation thermometry

Prof. G. Machin presented the report of the activities of Working Group 5 (CCT/12-20). Prof. G. Machin welcomed new members of the group from the NRC and the VSL, and thanked the working group members for their efforts and lively discussions. He reviewed the terms of reference and advised that there would be no changes. Prof. G. Machin commented that there had been two meetings of the blackbody users group, for which minutes were available, and that its next meeting will be at TEMPMEKO 2013 to be held in Madeira, on 14-18 October 2013.

Prof. G. Machin explained that the main activities of the working group related to high-temperature fixed points (HTFPs), including assigning thermodynamic temperatures. Other work included preparing a section for the *Supplementary Information*, and information on the fixed points, which was completed and had been forwarded to Working Group 1. The subgroup working on the *Supplementary Information* was progressing well. Prof. G. Machin noted that the agreed nomenclature for the MeP-K (CCT-12/19) was helpful, especially for interpolation schemes, which would now clearly be realized by primary methods. The group would now revise all three of the MeP-K related documents (CCT-10/12, CCT-10/13, and CCT-10/14) for nomenclature, and complete the uncertainty budget. The abstracts for the MeP-K should be ready by October 2012.

Prof. G. Machin summarized work on high-temperature fixed points. Work is progressing on studies of cobalt-, platinum- and rhenium-carbon points, which appear to be well suited as reference points. There are some problems with the robustness of the cobalt-carbon cells, and stability tests are on-going. At the working group meeting at ITS9, held in Los Angeles, USA, on 19-23 March 2012, cells were selected for the thermodynamic temperature determinations, including four copper cells, four cobalt-carbide cells, three rhenium-carbide cells and five platinum-carbide cells, but more cobalt-carbide cells are wanted. PTB reported that measurements at these points discussed at ITS9 showed good agreement with other measurements. The working group is now well placed to undertake the thermodynamic assignments over the next two to three years. It will prepare a rigorous uncertainty budget for the realizations.

Prof. G. Machin discussed the possibility of future key comparisons. The use of the HTFP cells seemed to be the best choice, although blindness might be an issue, as could robustness, and the cells are not typical artefacts. The regional metrology organization (RMO) comparisons could fill the gaps by using radiation thermometers. It seemed likely that APMP would organize the first comparison covering temperature regions above and below the silver point. EURAMET are also conducting an ITS-90 comparison up to 2500 °C.

Prof. G. Machin raised a question on thermal imagers. APMP had completed a survey that indicated that in most laboratories, thermal imagers were being treated like spot thermometers, which ignores some of their problems. He mentioned that an International Electrotechnical Commission (IEC) committee was looking into thermal imaging, including definition of terms and calibration, so for the moment Working Group 5 would step back. The next IEC committee meeting would be on 12 October 2012 where primary radiometric uncertainties would be discussed. Dr R. White asked if they are aware of the focus effect, where the readings of some imagers depend on the focus setting due to a faulty lens design – Dr P. Saunders had presented a paper at ITS9 on the effect. Prof. G. Machin replied that Working Group 5 was aware of the problem and that it intends to send a copy of the paper to the IEC committee.

Prof. H. Ugur asked about plans for comparisons. Prof. G. Machin noted that more information was required before they could establish a method. Prof. H. Ugur then asked about the competition between interpolation methods and ITS-90, and the possible differences. Prof. G. Machin responded that the uncertainties in the measurements were too large to discern any differences. Prof. H. Ugur inquired on the need to educate users about the different temperature definitions; T versus T_{90}. Prof. G. Machin thought it was not a problem.

Dr H. Yoon recalled an incident where a blackbody manufacturer claimed traceability to the NIST via thermocouple measurements. It was indeed traceable but had used very poor methodology. Dr H. Yoon considered that there was a need for a document from Working Group 2 explaining best practice. Prof. H. Ugur commented that there are impurity problems in fixed points, now isotope effects, and as the uncertainties get lower more confusion is introduced. A workshop on this question could be held at TEMPMEKO.

3.6 CCT Working Group 6: Humidity measurements

Dr S. Bell presented the report of the activities of Working Group 6 (CCT/12-23). She reviewed the membership noting that 17 institutes were represented and that there had been two changes in personnel since the 25th meeting of the CCT (2010).

Dr S. Bell summarized the comparison activity. For comparison CCT-K6, the measurements were complete. The draft A report had been completed and was under discussion by the participants. Other comparisons are planned in conjunction with CCT-K6, including CCT-K8 for high dewpoints, and related RMO and bilateral comparisons are on-going. The need for a comparison of trace moisture levels in gases remains an open question and the discussion is continuing. EURAMET is carrying out an exploratory comparison with a lower limit of 10 nmol/mol to establish a suitable methodology.

Working Group 6 continues to work on unambiguous definitions of quantities, terms, etc. A significant problem is that current standards and definitions from different scientific disciplines are not harmonized. For this reason, Dr R. Feistel (representing IAPWS) had attended recent Working Group 6 meetings. The group continues to work on an uncertainty guide, which is expected to be completed in near future.

Dr S. Bell noted that Working Group 6 had overlapping interests with the Consultative Committee for Amount of Substance (CCQM) with respect to the analysis of moisture in inorganic materials. The CCQM also has a working group on grain moisture and Working Group 6 will continue to track its activities. The main issue is traceability; Dr S. Bell posed the question - do we need comparisons? She noted that some RMOs are active in the measurement of moisture in materials. Dr S. Bell indicated that Working Group 6 will liaise with other bodies where there is a shared interest e.g. World Meteorological Organization (WMO), especially where these bodies could make a technical contribution.

The International Symposia on Humidity and Moisture (ISHM), a joint event with TEMPMEKO held in 2010 for which Working Group 6 was responsible, was discussed. The proceedings of this meeting are thought to be almost complete. A decision about the next ISHM had not yet been made but it will not be a joint meeting with TEMPMEKO. Prof. H. Ugur asked why the meetings should be stand-alone. Dr S. Bell replied that the ISHM is more specialized and therefore warrants a meeting every four to six years. It was recognized that humidity and moisture are a focus of TEMPMEKO but it fails to attract papers on moisture in materials, and for this reason Working Group 6 recognises that a separate ISHM is uniquely valuable. Dr S. Bell explained that there were a lot of advantages and disadvantages to a joint meeting, that it is still an open question, but consideration must be given to the fact that some humidity and materials papers were not attracted to the joint meeting.

Prof. H. Ugur asked about the progress on the vocabulary. Dr S. Bell replied that it was proving difficult because of the different approaches to measuring and defining humidity in different disciplines. Dr R. Feistel, who has experienced similar problems in the IAPWS, has been very helpful on this issue.

Mr G.F. Strouse asked about the timeline for the key comparison in trace moisture. Dr S. Bell responded that it was too soon to give a firm timeline as there were several issues that must be clarified first, such as quantity, method and choice of technology. Dr M. Ballico asked if pilot comparisons had been considered. Dr S. Bell replied that although pilot comparisons had not been explicitly considered, the EURAMET comparison was very much in this spirit.

3.7 CCT Working Group 7: Key comparisons

Dr M. Ballico presented the report of the activities of Working Group 7 (CCT/12-25). Terms of reference were reviewed and the duties and operation of the working group summarized. Currently the working group is tasked with:

- examining all relevant documents for each key comparison starting with the protocol and ending with the Draft B Report;
- advising the pilot laboratory in preparing the text of the entry to Appendix B of the CIPM MRA as required, and to prepare a recommendation on these subjects for approval by the CCT;
- advising the pilot laboratory about the preparation of a comparison status document.

Dr M. Ballico explained that Working Group 7 suggests two modifications to the tasks to better reflect present practice. Firstly, an editorial change to the second item, to read

- advising the pilot laboratory in preparing the text of the entry to Appendix B of the CIPM MRA as required, and to approve the draft-B report on behalf of the CCT for inclusion into the BIPM key comparison database (KCDB).

and secondly, the addition of a further item to reflect the recent Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB) clarification on supplementary comparisons:

- review and comment on supplementary comparison Draft B reports.

There were no comments or objections to the proposed changes.

Dr M. Ballico summarized the activities since the 25th meeting of the CCT (2010). Working Group 7 continues to use the BIPM forum, which enables a detailed recording of protocols, reports, comments, and responses. An Excel spread-sheet on the forum contains a detailed record of actions and the current status for each comparison. During the year, nine Draft B reports and five protocols have been reviewed, and four Draft B reports- approved. The KCDB pages have been reviewed to ensure that the current status of comparisons is reflected.

Dr M. Ballico noted that there were many recurring problems with Draft B reports, and that Working Group 7 has prepared a checklist for comparison pilots (attached to CCT/12-25).

Dr M. Ballico raised a concern that had been prompted by a request from Working Group 9 to assign a comparison number to a pilot comparison. On one hand, pilot studies are essential and informative activities and the resulting reports are useful, but according to the JCRB rules, pilot comparisons cannot be used to support Calibration and Measurement Capability (CMC) applications. On the other hand, if a formal comparison number is issued to a pilot comparison, and it is reviewed in the same way as other comparisons, there is a risk of misuse by commercial interests who could cite the comparison number in support of their marketing material. This risk was exacerbated by the frequent participation of private companies in pilot comparisons. It was noted that the CCQM had issued formal numbers for their pilot studies. After some deliberation, Working Group 7 had concluded that the safest approach was for the working group to not be involved in pilot comparisons, but that policy guidance from the CCT should be sought.

Dr M. Ballico noted that membership of Working Group 7 had declined as many of the members no longer worked in thermometry or were no longer available. This has substantially reduced the pool of people available to review reports. Dr A. Peruzzi confirmed that this was a problem and

that several comparisons had started before the protocols had been approved, because of serious delays in Working Group 7.

Dr T. Baba asked again whether Working Group 7 would consider issuing numbers for pilot comparisons. Prof. H. Ugur asked Dr M. Ballico to clarify the motivation for not issuing comparison numbers. Dr M. Ballico explained that unlike the CCQM pilot studies, the comparisons within thermometry were informal; they do not conform to the requirements of the CIPM MRA. Reviews of such comparisons by the working group could be misinterpreted as a CCT approval of the results for use in CMCs. Prof. H. Ugur asked whether the working group could reconsider and use a disclaimer. Dr R. White explained that the issue was one of deliberate misuse by commercial interests, and so long as there was any badge of approval from the CCT, a disclaimer would not help. Dr M. Ballico explained that many of the participants are universities and commercial companies and it seemed to be a matter of CCT policy to balance the aid of Working Group 9, and others, against the risk of misuse. Dr T. Baba asked if, when preparing the final reports of the three Working Group 9 pilot studies, the group could use their own numbering system. Prof. H. Ugur concluded the discussion and stated that there will be two more opportunities to discuss this issue before the end of the meeting.

3.8 CCT Working Group 8: CMCs

Mr G.F. Strouse presented the report of the activities of Working Group 8. Mr G.F. Strouse reviewed the terms of reference and advised that no changes were required. No changes in membership were noted, although the APMP representative will change in January 2013. Mr G.F. Strouse thanked Dr J. Ishii and NMIJ for their support.

Mr G.F. Strouse summarized current activities. The working group is still adding new CMCs and is trying to maintain a six-week turnaround. For each new CMC the group prepares review criteria, and the criteria for high-temperature fixed points are currently being developed with the assistance of Working Group 5. Criteria for air sensors and dry-block calibrators will be developed next. All of the processes and activities of Working Group 8 are open to review and interested parties should request the password from their RMO representative. Working Group 8 presented a paper on best practice at the ITS9 symposium held in Los Angeles, USA, on 19-23 March 2012.

Mr G.F. Strouse summarized the current situation with key comparisons, and reminded the CCT that key comparisons should test key skills. It was noted that Working Group 5 is planning a comparison, as is Working Group 6 for trace moisture, and Working Group 9 on some thermophysical properties. Mr G.F. Strouse reiterated that Working Group 8 recognized the activities of Working Group 9. Dr T. Baba informed Mr G.F. Strouse that the APMP was considering supplementary comparisons on thermal conductivity and thermal diffusivity.

3.9 CCT Working Group 9: Thermophysical properties

Dr T. Baba presented the report of the activities of Working Group 9. Dr T. Baba reviewed the terms of reference and summarized the tasks and membership of the working group. He recorded that the group had met on average more than once a year since 2005. The current service categories covered by Working Group 9: thermal conductivity, thermal diffusivity, specific heat

capacity, heat of fusion, calorific value, spectral emissivity, total emissivity and thermal expansion coefficient were summarized.

Dr T. Baba commented that Working Group 9 has three pilot studies in progress: on the thermal conductivity of insulating materials, the thermal diffusivity of dense materials, and the normal spectral emissivity of solids. Measurements for all three studies have been completed and the first reports are in preparation. The working group's next steps will be to develop a CMC review protocol before organizing appropriate Key and Supplementary Comparisons. This will lead to CMC registrations in these areas. The development of certified reference materials will follow.

Dr T. Baba gave a presentation demonstrating the wide range of applications and problems associated with measurement of thermophysical properties and examples were drawn from the power generation, building, and electronics industries. Some of the methods employed in the measurement of thermophysical properties were described. Dr T. Baba concluded by summarizing some of the areas that Working Group 9 will need to investigate further, especially measurements in support of the climate and energy sectors, and dynamic measurements.

Dr J. Hollandt commented that all of those involved in the pilot studies are NMIs or Designated Institutes, and questioned why Working Group 7 should not review the results for CMCs. In his opinion there was no reason for concerns about commercial misuse. Prof. M. Kühne agreed stating that since all participants were members of the working group, no problems were envisaged, although there would be an additional delay. Prof. M. Kühne asked for clarification of the distinction between calibration and testing services, and suggested that thermophysical properties might be more closely related to testing. Dr S. Bell advised that the pilot studies measured thermophysical quantities, whereas testing usually involved a pass/fail assessment.

Dr J. Hollandt noted that the results of comparisons are available and questioned 'what to do next'? Are CMC entries needed? Dr M. Heinonen suggested that care should be taken to identify key areas because not everything can be covered, i.e to define the key parameters and services required from a particular area. Dr M. Ballico commented that the purpose of a comparison was to test proficiency and to demonstrate that measurements of a quantity are traceable to the SI. He elaborated that one of the outcomes is a measure of dispersion, which would include the dispersion due to different methods. Of course there would be no understanding of possible systematic errors if the same methods are used.

Prof. H. Ugur summarized that the pilot studies in question involve established metrology institutes, investigating the measurement of quantities that are needed. He recommended that the problem of commercial abuse is addressed when it happens and not before, and suggested that Working Group 9 should consider this issue. Prof. M. Kühne commented that there are participation criteria for all CCT activities and there is no reason for concern, and that this applies also to regional activities. Dr R. White gave a hypothetical example of a company that would participate in a pilot comparison so that it could imply, in its marketing material, some sort of approval of its measurements by the CIPM. This may be possible in pilot comparisons because there is no requirement for a company to be a NMI or DI. Mr G.F. Strouse confirmed that he has received requests from companies to participate in comparisons purely for marketing purposes, and stressed that the CCT should discourage this practice. Prof. M. Kühne commented that this issue should be raised with the CIPM because a CIPM overview is required. Dr S. Bell recommended that one should be careful how this is reported; a number of DIs are commercial companies. Prof. M. Kühne clarified that he was referring specifically to those companies that are not DIs, and noted that for CC comparisons, only NMIs and DIs may participate. RMO key

comparisons, using the same protocol, are open to all members of the RMO, the CIPM, and the CIPM MRA. Supplementary comparisons are decided by the RMO with approval granted by the CC. Dr S. Bell commented that for CCT-K6, the CCT had agreed EURAMET participants which included the MIKES and the INTA, neither of whom were members of the CCT at that time. Prof. H. Ugur replied that this decision was made before the CIPM decision and therefore would not now take place. Prof. M. Kühne advised that the document CIPM MRA-D-05 (Points 4.1, 5.1 and 7.1) is followed. Prof. H. Ugur recommended that this topic is raised again in the discussions on CCT-K8.

Dr A. Pokhodun suggested that care should be taken to make the distinction between quantity and property. A material has a thermophysical property, but the measurement is of a thermophysical quantity. The title of the Working Group therefore should be Thermophysical Quantities, not Thermophysical Properties.

Prof. H. Ugur returned to the issue of pilot studies. Mr K. Hill recommended that Working Group 7 reviews the studies, their suitability to supporting CMC claims, and to check that they meet the requirements of a supplementary comparison. Prof. M. Kühne supported this idea. Mr K. Hill noted that pilot studies were insufficient to support CMCs. Dr J. Hollandt replied that usually the importance of the work is unclear when the pilot study is started, nor is it definitely known how much effort will be required, or if CMCs are wanted. Lessons can be learned from Working Group 7 to improve the comparisons. Dr M. Ballico suggested that pilot studies often start as research projects and therefore without inspection it is unclear whether the study can be classified as a proper blind comparison, or competency testing, or as a confidence building exercise. For CMCs it must be blind, independent and transparent. Dr L. Hansen replied that in the case of the emissivity study, three materials had been chosen and sample variations ensured that the emissivity was not known in advance. Mr Hill noted that for the water triple point, the value was known so the need for blindness is not clear, and scientific judgment must be used. Mr G.F. Strouse recommended that Working Group 9 should prepare the paperwork for a supplementary comparison and submit it for review. Dr J. Hollandt reported the group is already working on it. Prof. G. Machin commented that while emissivity is important for radiation thermometry, it is not essential for traceability, so why not publish in the peer reviewed literature where it will have the appropriate credence. Dr J. Hollandt replied that publication in the peer reviewed literature is taking place. Dr L. Hansen asked what would happen if all three studies were published but, if afterwards they are to be considered to be supplementary comparisons, may a review still be made? Dr M. Ballico confirmed with Dr L. Hansen that all data had been used. Prof. H. Ugur concluded that the studies should not be wasted and Working Group 7 should treat the studies as supplementary comparisons, and that in future, the CIPM will decide how to manage the situation. Mr G.F. Strouse reminded Working Group 9 of the requirements for supplementary comparisons submissions to Working Group 7. Prof. G. Machin suggested that if this problem continues, pilot studies should no longer be made. Mr G.F. Strouse agreed. Prof. H. Ugur responded that NMIs are still learning how to participate in comparisons. Mr G.F. Strouse advised that review workload of Working Group 7 is heavy and that to allocate additional pilot studies for tentative review is unacceptable. Dr H. Yoon commented that spectral emissivity is important for solar thermal measurements, and these types of measurements will increase in conjunction with climate studies.

3.10 CCT Working Group on Strategy

Prof. M. Kühne first gave a brief report on the recent meeting of the CGPM and the NMI directors meeting at the BIPM. At the 24th meeting of the CGPM (2011), delegates agreed on Resolution 10 which invited the CIPM to establish an *ad hoc* Working Group under the Chairmanship of the President of the CIPM, with representation from the CIPM and the Member States. The *ad hoc* Working Group was charged with conducting a review of the role, mission, objectives, long-term financial stability, strategic direction, and governance of the BIPM. The working group met in March 2012; their recommendations have been reflected on and will be discussed at a meeting of the NMI directors'.

One of the issues raised was how the BIPM programme of work could be improved. Currently, the NMI directors have too little influence. In the past, the content of the programme was determined by the consultative committees (CCs), prioritized by the CIPM and subsequently adapted to the dotation. The NMI directors had no input other than via directors' meetings. It is suggested that the CCs should create 10-year roadmaps and suggestions, such as what comparisons might be needed to support CMCs of the NMIs, and what type of work should be carried out by the BIPM or with the cooperation of the NMIs. This would give directors the opportunity to comment via templates and the BIPM website. The CIPM would look at CC suggestions and comments and make proposals for comments, which would lead to the final draft for the CGPM. The government representatives would then be aware of how the programme of work was developed and the financial implications. This would lead to a positive decision and the appropriate dotation to support it. For example, at the 24th meeting of the CGPM (2011), the programme of work was approved but not the dotation to support it, and the BIPM director has had to rework the programme.

Mr G.F. Strouse asked if this means that NMI directors will make the decisions on key comparisons, rather than technical experts. Prof. M. Kühne replied that the directors simply wanted a closer look at the disciplines and the key comparisons, because comparisons are a major activity, especially for comparison pilots. They want to know what resources are needed and should be prioritized. Prof. H. Ugur noted that there was nothing definite in the review for the time being and the first picture would be available in October 2012. Prof. M. Kühne reiterated that the meeting was held in a very positive atmosphere and it seems that a second meeting was not required as all of the recommendations were supported; the process seemed to be moving ahead well. All CCs would be asked to make recommendations on work that should be made together. In response to a question from Mr G.F. Strouse, Prof. M. Kühne advised that ultimately the president of the CCT would be responsible for completing the template, but it would be mainly the work of the Strategy Working Group and Working Group 8. There was no deadline at present but recommendations would be discussed in June 2012. In the meantime the CCs just need to be aware of what is expected.

Mr G.F. Strouse summarized the activities of the CCT Working Group on Strategy. First, he read the final comments from the chairman of the group's Task Group 1. Dr F. Pavese reported that the task group had completed its first task, i.e. to prepare the CCT terms of reference, but had not completed the second task, to prepare a methodology for the Working Group on Strategy. This was in part due to the lack of feedback and in part because the task seemed unnecessary. Task Group 1 has now terminated its activities. Mr G.F. Strouse thanked Dr F. Pavese for his efforts and support.

Mr G.F. Strouse then reviewed the working group membership noting experts who had been invited to participate in the meetings. There had been two recent meetings, one at the ITS9 symposium, and the other immediately before the current CCT meeting. The achievements of these meetings were summarized:

The proposed term of reference for the working group is to

- Develop and update the mission statement and strategy roadmap for the CCT.

The proposed CCT mission statement (no change from 2010) is to ensure that

- The SI units of the quantities relevant to thermal metrology are realized and disseminated in a uniform and appropriate manner worldwide in order to establish and maintain global compatibility of such measurements through promotion of traceability to the SI.
- The CIPM is advised on all scientific matters that influence thermal metrology, including any BIPM scientific programme activities in the relevant field, and that the relevant actions required by CIPM are implemented.

Thermal metrology is understood to include temperature, thermal energy (heat), humidity and thermophysical properties.

The proposed CCT objectives (simplified from 2010) where the mission is achieved through:

- Implementing all duties required by the CIPM relevant to thermal metrology, as stated in the "Responsibilities of CCs";
- Providing recommendations to the CIPM for the definition and realization of the SI unit of temperature, the kelvin, of temperature scales and of derived quantities;
- Recommending research on thermal measurement to NMIs to ensure the appropriate development of the SI in relation to the kelvin, including its definition and realization, and that of the units of derived quantities;
- Supporting the NMIs provision of traceability to thermal metrology quantities;
- Encouraging NMIs to address emerging thermal metrology needs;
- Providing thermal metrology guidance to users.

Mr G.F. Strouse then discussed the CCT roadmap. The working group had identified seven key roadmap areas, including the redefinition of the kelvin, the MeP-K framework, ITS-90 improvements, new temperature scales, Key Comparisons, thermal metrology, and moisture. In each of these areas the group will identify tasks, purposes and impacts. Mr G.F. Strouse advised that the list of seven areas is not exhaustive, and asked if there should be additions to the list. Discussions had taken place on the redefinition of the kelvin, the MeP-K framework, Key Comparisons, and thermal metrology, and the conclusions reached were summarized. Analysis of the other areas will follow the same pattern and continue by email. Prof. H. Ugur asked when the roadmap was expected to be finished. Mr G.F. Strouse responded that it is a growing and evolving document so will continue indefinitely, however a draft is expected in the next month or so. It will be made available to CCT members on request. Prof. M. Kühne, who had attended the group's meeting, congratulated the group on its work. Prof. H. Ugur reiterated that the document needed to be finished before October 2012 in time for feedback from the *ad hoc* committee. Mr G.F. Strouse questioned whether the strategy would have to be reviewed

annually. Dr M. Kühne confirmed that it will, and requested final recommendations by March 2013 so that implementation could begin straight away.

Dr Y. Duan raised a concern about the definition of thermal metrology. Mr G.F. Strouse replied that his understanding is that thermal metrology is used in two different ways in different places. Also thermophysical properties would be changed to thermophysical quantities.

Prof. H. Ugur clarified the activities of the group's Task Group 2, which was responsible for preparing a SWOT analysis following the completion of Task Group 1 activities. Since the Strategy Working Group is already undertaking impact studies a second analysis would be unnecessary. Prof. H. Ugur suggested keeping Task Group 2, with Dr S. Bell as Chair, in case it was needed for other activities.

4 REPORTS OF THE KEY COMPARISONS

4.1 CCT-K5: Realizations of the ITS-90 between the silver point and 1700 °C using vacuum strip lamps as transfer standards

Dr A. Peruzzi advised that the Draft report B of the EURAMET.T-K5 had been completed and he was waiting for Working Group 7 to complete their reviews. Dr M. Ballico confirmed that reviewers had been allocated. Prof. H. Ugur commented that he was always available to sort out delays if required. The comparison should be completed in 2012.

4.2 CCT-K6: Comparison of Humidity Standards

Dr S. Bell explained that the comparison covered dewpoints in the range –50 °C to +20 °C. The completed Draft A report has been circulated to participants. Initial comments had been received and the results were in closed discussion. Working Group 6 had agreed on a formula for the KCRV with approval of the participants, as the formula had not been completely defined in the protocol. The participants had also met earlier in the week of this meeting and the picture emerging from the comparison was very good. Some material has been prepared for the Draft B report. However, final calculation of the KCRV, calculation of the uncertainty of the artefacts, as well as addressing minor questions, consideration of questions raised by participants and linkage to other key comparisons have still to be made.

Dr S. Bell commented that time delays were a major issue for comparisons. CCT-K6 had been planned with limited measurements and with only ten participants to keep the time manageable. The comparison commenced in 2001 with an initial study, and measurements were completed in seven years between 2003 and 2009. During this period ten instrument breakdowns had occurred, most requiring repair, and in some cases the instruments to be shipped back to the manufacturer. In addition, participants had to agree on the actions, and necessary additional checks were carried out by the NPL or the INTA. Questions had arisen from participants about aspects of the measurement or measurement anomalies that could not be reproduced, which introduced further delays. Some additional measurements were made at the INTA and it took two years to complete the Draft A report. Investigation into the root cause of the problems

determined that is was due to the use of old instruments. However, they were the best available at the time and had a good track record of use. There did not appear to be any discontinuities in the comparison data as a result of the repairs. The Draft A report does discuss some ambiguity in the data, but this is being addressed. The experience highlights that long term stability is an issue. The likely time delay needed to be considered in the planning of APMP-K6, and a repeat of CCT-K6 is being considered.

Dr S. Bell indicated that the evaluation of the linkages for the Draft A report is expected to be completed in the near future, then work on Draft B will begin. Draft B is expected to be completed by TEMPMEKO 2013. Mr K. Hill asked if Dr S. Bell envisaged any modification to enable a linkage with RMO comparisons. Dr S. Bell replied that the CCT comparison should normally finish first. Dr M. Ballico added that APMP.T-K5 was in a similar situation; the APMP results were published, then later when the CCT-K5 had been completed, a small section was written on the linkage. Dr C. Thomas noted that the timing for CCT-K6 was peculiar and that other comparisons were already in the database, and asked how the linking will be managed. Dr S. Bell acknowledged the concerns and noted that there were also a number of bilateral comparisons to consider, but that linkage was not a huge task. Dr M. Heinonen suggested that it might be better to do this in a single exercise, and Dr S. Bell agreed. Dr C. Thomas added that linkage is normally included in the Draft B reports, and recommended using a single document. Dr S. Bell suggested the possibility to also use annexes to existing reports. Dr M. Ballico commented that a single document had several advantages, and it was easier to address issues and analysis on one document. It would also influence the statistical treatments and a single document would ensure consistency.

Prof. H. Ugur returned to the issue of the time delay and asked about the cost, and the added costs to the comparison of not using new equipment; this would be a good case-study for the CIPM. Dr S. Bell stressed that the use of old equipment was not an issue of saving money as they had used the best equipment available at the time.

4.3 CCT-K8: Comparison of realizations of local scales of dew-point temperature of humid gas

Dr S. Bell presented the report on behalf of Dr R. Benyon and Dr D. Del Campo. The comparison covers dew-points in the range +30 °C to +95 °C. The INTA is the pilot laboratory, with the NIST co-piloting and carrying out some extra measurements. New instruments are being used, with a separate calibration of the platinum resistance thermometers before assembly. Preliminary measurements are in progress and the protocol is under development. The list of participants and the schedule of measurement times have been completed, although the INTI had withdrawn which left only one SIM.T-K8 participant as the link. They may prepare a video to aid in the communication of the protocol, and share the costs of the comparison. Dr S. Bell elaborated on the points chosen emphasizing the 5 °C intervals at elevated temperatures to accommodate the upper temperature limits of all participants. She also noted that there would be multiple measurements by the pilot and co-pilot laboratories, and outlined the linkages proposed noting that these had been the basis for selection of the participants. The measurements are scheduled to be completed between December 2012 and January 2015.

Prof. H. Ugur asked when the participants had been approved by the CCT. Dr S. Bell replied that it was not clear, and approval may not have been granted by the CCT. Prof. H. Ugur reiterated

the criteria for RMOs and that there should be at least two laboratories from each RMO, but wondered if the CCT should accept all participants? Mr K. Hill volunteered that the NRC may be able to participate to give two participants from the SIM. Dr M. Ballico recalled that the CCT had discussed comparison participation, and that the CCT had agreed to provide linkage in RMO comparisons. What was proposed for the SIM? Dr S. Bell said that the INTI and the NIST were in the original plan, but the INTI had withdrawn. Initially this had not presented a problem because no SIM comparison was planned, but now it appears that one is planned. Mr G.F. Strouse added that the NIST planned to continue comparisons into SIM, and that Working Group 7 should be prepared. Dr M. Ballico asked if there was to be a SIM.T-K8, is there another linkage. Dr R. Benyon has indicated that he will participate if required, but that is not the only solution. Mr G.F. Strouse indicated he could ask Dr P. Huang to resend the invitation. Prof. G. Machin also noted that Austria had a Designated Institute, and there was no objection at previous meetings to the inclusion of DIs.

Prof. H. Ugur welcomed Dr D. Zvizdic to the meeting and continued to discuss the CCT-K8 comparison. It was noted that a review of the minutes of the previous CCT meeting indicated that the INTI was not a CCT member. However, unless otherwise advised by the CIPM, membership falls under the jurisdiction of the CCT; in this case the CCT had not yet approved the participants (although it was noted that the list of proposed participants had been presented to the previous CCT meeting and no objections had been raised then). Prof. H. Ugur reminded the participants about the SIM, and asked the question: 'do we want another participant?'. Dr S. Bell presented the participant list and confirmed that at the time no-one else in the SIM was capable of participating, and this was why the INTA had volunteered to make the additional link. Mr G.F. Strouse reminded the CCT that the NRC can now participate. Prof. H. Ugur noted that the participation by the INTI had been approved at the previous CCT meeting, and suggested that the CCT should make a decision. Prof. M. Kühne agreed that the CCT should make the decision; either to accept one link or approve CCT-K8 and allow the organisers to choose an additional participant. Dr M. Heinonen recommended having two links, with the INTA providing the second link. Prof. H. Ugur suggested that the CCT should approve existing participants and allow them to add one more, with the decision to be made by Working Group 6 in consultation with the SIM. There were no objections to this suggestion. Mr G.F. Strouse advised that the NIST should be the primary contact for the SIM.

4.4 CCT-K9: ITS-90 SPRT Calibration from Ar triple point to Zn freezing point (proposed)

Prof. G. Machin suggested discussing CCT-K9. Mr G.F. Strouse informed the CCT that preliminary measurements were progressing, two laboratories had brought thermometers to the NIST within the deadline, and four NMIs had still to supply thermometers. It was noted that NIST has probably completed 40% to 50% of the SPRTs received.

5 REVIEW OF WORKING GROUP TASK DEFINITIONS, ROLES, RESPONSIBILITIES AND OPERATIONAL PROCEDURES

Prof. H. Ugur recalled comments made earlier in the meeting which suggested that the terms of reference of Working Group 5 and the Strategy Working Group may need to be updated. Dr A. Merlone noted that Working Group 2 would like to revise its terms of reference, tasks and title, to better reflect its current tasks and anticipate closer links with users. He suggested:

CCT Working Group 2: Secondary thermometry (previously techniques for approximating ITS-90)

Proposed terms of reference:

- to gather and review techniques and provide authoritative guidance for dissemination of temperature measurements through contact methods;
- to monitor new perspectives, needs, projects and activities related to traceability, quality assurance and calibration procedures for temperature measurements by means of contact thermometers.

Working Group 2 is tasked to

- continue with the updates to the CCT Guidelines on Secondary Contact Thermometry, including advice on secondary fixed-point construction and operation;
- update the list of secondary reference points;
- report to the CCT on the emerging needs for traceability in secondary contact thermometry;
- advise the CCT regarding cooperation with the other CCs, institutions, organizations, committees, scientific communities, users' associations and other stakeholders, in order to encourage an appropriate approach to traceability and good practice in secondary thermometry;
- encourage training on traceability, including calibration procedures in thermal measurements, by means of secondary thermometers.

Prof. G. Machin commented that this was a very good expansion of the terms of reference, but that the work on approximations of ITS-90 should be a specified task to ensure that the work continues. Mr K. Hill expressed concern about the use of the term "secondary" since it is not well-defined: approximating ITS-90 is clear, but he was uncertain that "secondary" covers what the CCT intends it to cover. Dr B. Fellmuth endorsed these concerns about the use of the term "secondary", and noted that Working Group 1 had removed the term from all of its documents. Dr Y. Hermier supported Dr A. Merlone's suggestion indicating that it aligns better with EURAMET, and that the CCT should look for similar alignments with other groups. Dr A. Merlone agreed that this was the intent, and noted that the ITS-90 is not limited to secondary thermometers, it includes secondary thermodynamic thermometers. Dr H. Yoon requested clarification stating MeP-K refers to absolute and relative primary methods and the terminology must be harmonized to avoid confusion. For example, radiation thermometry below the silver point will be secondary for ITS-90 and relative primary for thermodynamic thermometry. Dr A. Peruzzi commented that the main task of the working group should be to revise the Bluebook, and if the number of tasks is increased, then progress will be even lower.

Dr A. Merlone replied that terminology is not a current primary topic and that there are emerging tasks just as, or even more, relevant to WG2, according to a revision of the terms of reference of the working group itself. Prof. H. Ugur asked if there were any strong arguments against Dr A. Merlone's proposals for Working Group 2. There were none and the proposals were accepted. Prof. H. Ugur noted the raised concerns about the increasing number of tasks but suggested that the new chaiman is given a chance to achieve them, and that the situation is reviewed at the next CCT meeting. Dr B. Fellmuth proposed to change the title of the Bluebook revision to include PLTS-2000. Dr K. Yamazawa asked for clarification of the term "encourage" in one of the tasks, and if there are any actions. Dr A. Merlone replied that NMIs are already involved in training and quality assessments, including meteorology organizations. It was suggested that perhaps the CCT could collate these activities. Dr K. Yamazawa asked if Working Group 2 would collate such information. Dr A. Merlone confirmed that Working Group 2 would collate and share such information.

Prof. H. Ugur then enquired about other working group terms of reference. Dr B. Fellmuth suggested that the first term of Working Group 1, the overview of temperature scales, be transferred to the Working Group on Strategy. Prof. H. Ugur asked if there were any objections to the transfer. There were none.

Prof. G. Machin noted that Working Group 5 had made minor changes to their terms of reference as recorded in the report from Working Group 5 and no objections had been raised.

Dr M. Ballico commented that there were proposed changes to the tasks for Working Group 7 to better reflect practice and any additional tasks related to JCRB requirements. Prof. H. Ugur asked if this included pilot studies. Dr M. Ballico replied that they could be included. Prof. H. Ugur asked if there were any objections to their inclusion. There were none.

6 CCT AND WORKING GROUP MEMBERSHIPS

Prof. H. Ugur commented that there are suggestions for changes in the chairs of Working Group 2 and 7. Working Group 2 nominated Dr A. Merlone as Chairman, and there were no objections. Mr K. Hill was nominated as Chairman for the Working Group 7, and there were no objections.

Prof. H. Ugur noted that membership of Working Group 8 is determined by the RMO representatives, and confirmed that the CCT is comfortable with this situation.

Prof. H. Ugur returned to Working Group 7 noting that its composition has become weak with many of the past comparison pilots having left the CCT, and commented that the membership was not a matter of having laboratory representatives but experts due to the nature of the work. Dr M. Ballico confirmed the situation adding that 10 to 15 comparison reviews are received each year, with some reports exceeding 100 pages in length making them time consuming to review. Each report is reviewed by three members of Working Group 7 with expertise in the area. He suggested expanding the working group so that there are at least three people in each main competency area. Dr M. Ballico agreed that the persons should be past pilots, or persons who have written reports and are familiar with the requirements of the CIPM MRA. Prof. G. Machin

commented that finding three such people for thermophysical quantities would be impossible. Dr M. Ballico suggested that reviews could be outsourced to the appropriate technical working groups. Prof. G. Machin added that it would require only one person on Working Group 7 instead of three to provide such links. Mr K. Hill suggested that an alternative could be to allow Working Group 7 to second additional members as required. Dr E. Méndez-Lango noted that the experts often are already participating in the comparisons, so there may not be experts readily available for the review. Consideration was given whether the reviews could be managed in the same way as a journal-paper review, with Working Group 7 coordinating. Prof. H. Ugur concluded the discussion by supporting Mr K. Hill's suggestion of secondment and for identifying expertise within the CCT member laboratories and to seek approval from the director of the institute. There were no objections.

Prof. H. Ugur then raised the issue of the title of Working Group 9, suggesting that it be changed from Thermophysical Properties to Thermophysical Quantities. Dr T. Baba advised that the issue had not been discussed within Working Group 9 and commented that he was not concerned about the name. Prof. M. Kühne stated that he supported the name change because the SI nomenclature for quantities and units were the responsibility of the CIPM whereas properties were not. Prof. H. Ugur concluded that it seemed like a good idea, and concluded that if there are no objections from Working Group 9 a modification could be carried out at the next CCT meeting.

The discussion then considered membership of the working groups. Dr A. Merlone confirmed the membership of Working Group 2 and asked that there be co-opted members from Working Group 5 and from Working Group 6. Dr B. Fellmuth requested that Dr S. Duris from the SMU, who is retiring, be replaced with Mr K. Hill from the NRC. Prof. H. Ugur advised that working group membership was essentially voluntary, with the exception of the special Working Groups 7 and 8. However, Working Group members are expected to take an active role and should be discouraged if they are not willing to participate actively. Dr Y. Hermier advised that the LNE intends to withdraw from Working Group 3.

Prof. H. Ugur the considered CCT membership applications, stating that an application for membership of the CCT has been received from the INMETRO, Brazil, which is presently an observer, and an application for membership or observership had been received from the HMI, Croatia. Prof. H. Ugur invited Dr R. Teixeira to present the application on behalf of the INMETRO. Dr R. Teixeira presented a summary of the economic status of Brazil, the size of INMETRO, the number and qualifications of its staff, current research activities, papers published, the quality system and its activities within international organizations, including hosting the IMEKO and ISHM conferences in 2006. Dr R. Texeira concluded by summarizing current thermometry CMCs held by INMETRO, adding that INMETRO is involved in Working Groups 3 and 5.

Prof. H. Ugur then invited Prof. D. Zvizdic to present the application from the HMI, Croatia. Prof. D. Zvizdic explained that the measurement organization in Croatia include several laboratories and equipment which are located throughout the country. The HMI operates two main laboratories located within scientific institutions, and that different quantities were maintained by different groups. Prof. D. Zvizdic presented the number of staff and their qualifications, the laboratory area devoted to thermal metrology, the number of comparisons the HMI is involved in and the CMCs it held. The HMI has published over 260 papers with some in thermometry. All of the laboratories in the organisation are accredited, some since 1994, i.e. before the CIPM MRA. Prof. D. Zvizdic discussed the HMI's temperature-related research

activities including multi-entrance fixed points, hysteresis in IPRTs, low and high-range humidity generators, and modelling of gradients in fixed points.

Following these presentations, Prof. H. Ugur asked the two representatives to leave the meeting room, and invited comments on the requests for membership. An extended discussion followed. Prof. H. Ugur declared that he will propose to the CIPM that the INMETRO become a full member, and that the institute HMI/FSB-LPM obtains observer status. There was unanimous support for this proposal.

7 OTHER SCIENTIFIC TOPICS

Prof. H. Ugur confirmed that there were three topics for discussion: opportunities for cooperation with the International Association for the Properties of Water and Steam (IAPWS), closer links with Consultative Committee for Photometry and Radiometry (CCPR), and Bayesian versus frequentist uncertainty analysis.

Prof. H. Ugur introduced Dr R. Feistel who presented background information on the interactions between Working Group 6 and the IAPWS. He explained that he was a physicist and oceanographer with 10 years' experience working with IAPWS, and that he had been involved with the development of the new oceanographic standard. He observed that relative humidity is closely linked to relative fugacity, and that it is possible to define humidity in terms of fugacity. He noted that there are different definitions for humidity in use by, for example, WMO, IUPAC, and ASHRAE, and a joint effort between CIPM, IAPWS, and WMO is presently in progress to harmonize the definitions. In April 2012, he liaised with the CCQM in discussions on salinity, and he was now taking the opportunity to discuss atmospheric humidity and moisture with the CCT. For this reason, he gave an overview of the structure of the IAPWS, its working groups, and the new committee on collaboration. Dr R. Feistel also described the new seawater standard (www.teos-10.org), including the rationale for its modular structure and use with derived properties for mixtures and composites. He outlined the proposed cooperation steps between the CCT and IAPWS. This will include: a joint position paper for Metrologia which was in preparation; attendance of the IAPWS at the CCQM and the CCT; attendance of the CCT and the CCQM representatives at the IAPWS meetings in 2012 and 2013; a BIPM keynote speech; and 3 workshops at the ICPWS conference in Greenwich, UK, in September 2013. He indicated that the cooperation partner will most likely be the IAPWS Joint Committee on Seawater (JCS), and that it should also involve the BIPM-WMO as a cooperation partner.

Prof. H. Ugur asked if there were any reasons why the collaboration should not take place. Prof. M. Kühne responded that, on the contrary, there were very good arguments why it should take place, remarking on the important issues surrounding the climate and the interactions of the oceans with the atmosphere which require humidity and temperature measurements. NMIs should be encouraged to participate in these activities where there are challenges for thermometry. Prof. H. Ugur asked how this would be realized. It was proposed that this task lies within the responsibility of Working Group 6, and probably others including Working Groups 2, 3 and 9. Prof. H. Ugur suggested entrusting the tasks to Dr S. Bell and Working

Group 6. There were no objections. Dr S. Bell replied that the areas of cooperation that had been identified fitted well within the tasks and responsibilities of the working group, but some of the mechanisms were unclear: was it appropriate for the working group to include membership from outside the CCT? Mr A. Picard indicated that there are precedents, including in the current Working Group 2. Prof. H. Ugur stated that as long as Prof. M. Kühne supports the cooperation then there should be no problems. Prof. M. Kühne confirmed that he did support the collaboration, because improved understanding of climate change is important, and that metrologists have a mandate to be active in this field.

Dr K. Yamazawa commented that this interaction was useful, but wondered about the criteria; can anyone bring a wish list to the CCT? Should the CCT consider the boarder view and establish criteria? Prof. H. Ugur agreed that there is a problem, but advised that this case be considered first. The request should be addressed to the president of the CCT, from which an invitation may follow for either the plenary meeting or the working group meetings, to give the opportunity to make a presentation. Interactions outside the scope of the CCT must be filtered by the president of the CCT and the BIPM. Dr A. Merlone recalled other interactions including those with the WMO, horizontal interactions between working groups, and gave examples from EURAMET where NMIs have contacts and exchanges. He considered that the CCT should monitor these projects. Prof. H. Ugur responded that there were also interactions between CCs.

Prof. H. Ugur returned to the question of IAPWS collaboration asking if there were any objections to allowing Dr S. Bell to supervise the collaboration and suggested that emails are copied to Working Groups 2, 3 and 9. If other working groups find it necessary to invite other participants, they should notify the president of the CCT. Mr G.F. Strouse noted that at least three NMIs had approached to the International Surface Temperature Initiative Steering Committee, and the committee wanted to report to the CCT. He reminded the CCT members that the ITS9 conference included sections on climate studies, and that the Strategy Working Group should also consider climate studies. Dr R. Feistel concluded the discussion by thanking the CCT for the positive discussion.

Moving to the next topic, Prof. G. Machin informed the CCT that links with the CCPR had been maintained, and that the CCT-CCPR delegate had made presentations to both committees.

Prof. G. Machin then gave a presentation to inform the CCT about the EURAMET project, developed within the frame of European Metrology Research Programme (EMRP) called "Implementing the new kelvin" (InK). The three aims of the project are to

- Develop and demonstrate primary thermometry methods that will challenge and supplant the defined scales at very high (>1000 °C) and ultra-low (<1 K) temperatures;
- Determine new values of $T - T_{90}$ with the world's lowest uncertainties (≤ 1mK) between 1 K to 933 K;
- Determine new values for $T - T_{2000}$ which will address the discrepancy in existing background data of the PLTS-2000.

The project has an extensive list of partners and collaborators including CEM, CNAM, CSIC, LNE, MIKES, NIST, NMIA, NIM, NMIJ, NPL, NRC, PTB, VNIIOFI, RHUL, TUBITAK, and UVa. The work is divided into 4 work packages:

1. Assignment of thermodynamic temperature to HTFPs above 1000 °C.
2. Realization and dissemination of thermodynamic temperatures at high temperature.

3. Determination of $T - T_{90}$ with ultra-low uncertainties
4. Primary thermometry for low temperatures.

The scientific output is expected to include at least 20 peer reviewed papers, and more than 20 conference presentations, posters and reports. A discussion workshop to be held at the Royal Society (UK) in 2015 is envisaged. The project is currently in contract negotiation with an expected start date of October 2012. The inaugural meeting will take place at the INRIM, Turin, Italy from 10 to 11 October 2012. Dr J. Fischer observed that this project is a follow-up project of the various Boltzmann-constant projects.

Dr A. Peruzzi noted that there is a second EMRP project coordinated by Dr D. Del Campo that was concerned more about dissemination. The APMP is planning to start a programme similar to the EMRP of the EURAMET and possible synergies between the EURAMET EMRP and the programme to be started by the APMP should be considered. Dr D. Del Campo advised that the EMRP project complements the InK project with a focus on improved and new dissemination methods for the kelvin. It involves 13 institutes in 12 countries, starts on 1 June 2012 and will run for three years. It is anticipated that the project will generate many papers, TEMPMEKO presentations, etc. Prof. G. Machin concluded the discussion by commenting that if anyone identifies activities of interest in either project they were welcome to approach and join as a collaborator.

Dr R. White recalled that at the previous meeting he had promised to prepare a paper advising the CCT on the consequences of the trend away from frequentist statistics and towards Bayesian statistics, a trend which is becoming increasingly apparent in both the metrological literature and in the BIPM guides on metrology. The paper has been prepared with considerable help from statistician Dr R. Willink, a working colleague, and is included in the working documents (CCT/12-07). Dr R. White commented that at the outset he had no strong opinion for or against the move to the use of Bayesian statistics for uncertainty analysis, but was concerned about the possible consequences. However, during the preparation of the paper he developed a strong opposition to the use of Bayesian statistics. Dr R. White advised that it was a complex topic so he did not expect to raise any discussion at the meeting, but noted that the BIPM Director had recently announced that there will be a revision of the GUM (*Guide to the Expression of Uncertainty in Measurement*) and had invited NMIs to comment. He explained that it was very important that the CCT members become well-informed, communicate with staff involved in uncertainty analysis and with statisticians, and respond to the survey.

Dr R. White explained that although he would not present a detailed argument, he would like to briefly note some key points to emphasize the importance of the issue. He outlined the historical development of the GUM noting that it followed the 1980 recommendations of a BIPM Working Group led by Dr R. Kaarls, which were unambiguously based on frequentist statistics. After 13 years of work by an ISO task group, the GUM was published. Unfortunately, the GUM clouded its philosophical foundations by discussing degrees of belief and associating probability distributions with parameter values for the Type B assessments, which evidenced some Bayesian thinking. Nevertheless, the Type A assessments, the idea of using effective degrees of freedom for Type B assessments, and the combination of uncertainties using the Welch-Satterthwaite formula are all demonstrably frequentist. Dr R. White noted that among some of the papers endorsing Bayesian uncertainty analysis are claims that the GUM is fundamentally Bayesian, a claim that is demonstrably incorrect. Many papers also claim that the Bayesian approach offers a single self-consistent and all-encompassing approach to statistics. This too Dr R. White asserted

is incorrect, citing that there are two distinct approaches to Bayesian statistics, the subjective and objective approaches, and that these are considered incompatible by most statisticians. Unfortunately the BIPM supplements to the GUM draw on both by using a subjective approach for Type B assessments and an objective approach for Type A assessments. This means that the GUM supplements are not more philosophically consistent than the GUM, as often claimed. Dr R. White explained that the most worrying feature is that the meaning of probability changed from the frequentist view, where it was based on the observed frequencies of real events and error distributions, to an information theory approach where probability measures the strength of belief or the state of information. This means that confidence intervals, credible intervals in Bayesian terminology, would no longer be numerically accurate in the way that uncertainties are normally used. In fact, it is only in the case of very simple, linear systems and infinite numbers of measurements that the two approaches give the same answers. In other cases, the frequentist approach was better because it aimed to give numerically correct confidence intervals. Dr R. White concluded by noting that the Bayesian approach has the potential to completely undermine the achievements of the GUM, which although it may be flawed, has nevertheless been very successful.

Prof. H. Ugur invited comments. Prof. G. Machin commented that although he had not yet read Dr R. White's paper he had read other papers using the Bayesian approach and that he too was very concerned. He also felt very strongly that one of the main benefits of the GUM was that it ensured a uniform and harmonized approach to uncertainty analysis. It would be a mistake to compromise that situation by introducing another approach. Prof. G. Machin drew attention to a paper presented to the ITS9 by Dr D. Del Campo, where the uncertainty estimations using the GUM were compared to Bayesian statistics and Monte Carlo Simulations applied to SPRTs in fixed points. Dr R. White noted another concern which is the mathematical complexity of the Bayesian approach, which is considered too difficult to teach in undergraduate statistics courses. The thought of trying to teach Bayesian statistics to staff in second-tier labs, who already struggled with adding in quadrature, is a major concern. Prof. M. Kühne added that he appreciated any efforts to contribute to the survey, especially negative comments. It is important that the CCT gives strong feedback, and Dr R. White's document would be forwarded to the working group. Prof. H. Ugur offered two observations. Firstly, as a director he had noticed considerable differences between different sections in their evaluation of uncertainty. This was also a problem with the first CMCs and the first Key Comparisons. Secondly, with smaller NMIs, training in uncertainty is needed, but a lot of it appears confusing. It was suggested that Working Group 3 could prepare some guides, also for humidity and radiation thermometry. Prof. H. Ugur concluded by noting that the GUM was for guidance, and it should evolve. The CCT should indicate its desire to the working group, but it was the responsibility of the working group to decide. Prof. H. Ugur agreed with Dr R. White that it was important to receive feedback from individuals.

8 REPORTS TO THE CIPM AND RECOMENDATIONS

Prof. H. Ugur reminded the meeting of the discussions on pilot studies, and invited comment on how to formulate the question to be put to the CIPM. Dr M. Ballico commented that any approach needed to be consistent across different CCs, for example, in how members were selected, whether they are NMIs or DIs only, where the reports go, what the reports are used for, and should the reports be published in the *Metrologia* supplement? What rules of process and participation does the CIPM want for this class of comparison? Prof. M. Kühne commented that participation is important, but that it would be helpful to have guidance to ensure there were no loop holes. He suggested that what can be done within a pilot study should not be too restrictive, but left deliberately open and flexible and avoid the requirements for CMC entry. The difference between supplementary comparisons and pilot studies should be maintained. Prof. H. Ugur indicated he would take these questions to the CIPM, and would contact the chair of Working Group 7. Dr T. Baba thanked the meeting for the discussion.

Prof. M. Kühne asked if the three studies discussed previously had been treated differently. Dr M. Ballico responded that no problems had been encountered but one unresolved issue was the publication of some pilot studies in the *Metrologia* Supplement, and questioned how this had happened. Dr C. Thomas advised that most pilot studies are CCQM studies and had been approved by the relevant CCQM working group. Prof. H. Ugur asked to be informed of the process for approving those comparisons. Dr M. Ballico noted that there is no formal process, and Mr K. Hill reminded that for supplementary comparisons there is no approval process, only review and comment, and therefore some clarification is required. Prof. H. Ugur concluded that this issue will be discussed by the CIPM, and that the outcome will be reported in three weeks.

9 NEXT MEETING

Prof. H. Ugur recommended that the next CCT meeting be held in two years, and asked if there were any objections. Mr K. Hill commented that the CCT may want to consider the redefinition of the SI and meet in one year. Dr J. Fischer suggested that the criteria for acceptance are clear, and if they have not been met by mid-2013 the CCT will need to restart the discussion. Prof. H. Ugur suggested voting by correspondence. If there are objections, the discussion can be brought to the CCT. Mr A. Picard will notify members of the date of the next meeting.

Prof. H. Ugur noted that this was his last CCT meeting. He thanked the BIPM staff, including the support staff. He thanked the CCT members and expressed that he was impressed and very proud to have worked with the CCT. He also presented a wish list: better measurements of k, by at least two orders of magnitude; better wording for the definition of k; a better material than platinum easily modelled by physics; the removal of temperature scales; and greater interest in other areas of physics. He suggested that there are other techniques for measuring temperature that may be of use to metrology, and hoped that the economic situation would be such that the work can be carried out. Prof. M. Kühne recalled their first meeting together in 2000, and he has kept a close interest in thermometry, even after his responsibility changed at the PTB. He approved of the wish list but was sceptical of the wished-for improvement in the uncertainty in

the Boltzmann constant. Prof. M. Kühne concluded that it is a great job, it needs to be done, and that the CCT were all very grateful that Prof. H. Ugur had given his support over a long period of time. He joined all to thank Prof. H. Ugur, and noted that this would not be the end of the relationship as Prof. H. Ugur would remain active within the CIPM.

Prof. M. Kühne congratulated Prof. H. Ugur's successor, Dr Y. Duan. Dr Y. Duan responded that it was a great honour to rejoin the temperature community and to work with the CIPM. He saw it as a challenge to chair the CCT, and with the CCT's help achievements may be realized supported by the new strategy. Dr Y. Duan also looked forward to Prof. H. Ugur's support in the CIPM, and observed that there were now two members from thermometry in the CIPM. Prof. M. Kühne added that there were three.

Dr D.R. White, *Rapporteur*

May 2012.

APPENDIX T1: Working documents submitted to the CCT at its 26th 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/12-1	Draft agenda, Dec. 2011, 2pp.
CCT/12-2	MeP-K Draft 3, B. Fellmuth *et al* (Working Group 1), 2pp.
CCT/12-3	Estimates differences $T–T_{90}$ 2010, J. Fischer *et al* (Working Group 4), 3pp.
CCT/12-4	Supplementary Information for the ITS-90: Foreword and Contents, Edition 2012, B. Fellmuth *et al* (Working Group 1), 1pp.
CCT/12-5	Supplementary Information for the ITS-90: Chapter 5 Interpolating Constant-Volume Gas Thermometry, Edition 2012, B. Fellmuth *et al* (Working Group 1), 9pp.
CCT/12-6	On the Equivalence of Least-squares Approaches to the Evaluation of Measurement comparisons, A. Koo, J. Clare, D.R. White, 1pp
CCT/12-7	Disentangling Classical and Bayesian Approaches to Uncertainty Analysis, R. Willink and D.R. White, 19pp.
CCT/12-8	Working Group 3 Report to the CCT - May 2012, D.R. White, 2pp.
CCT/12-9	CCT WG-Strategy Meeting Minutes, G.F. Strouse, 4pp.
CCT/12-10	CCT WG-Strategy Terms of Reference, G.F. Strouse, 2pp.
CCT/12-11	Working Group 1 Report to the CCT - April 2012, B. Fellmuth, 3pp.
CCT/12-12	Supplementary Information for the ITS-90: Chapter 1 Introduction, Edition 2012, B. Fellmuth *et al* (Working Group 1), 14pp.
CCT/12-13	Task Group on the SI Report to the CCT, J. Fischer, 8pp.
CCT/12-14	Working Group 4 Report to the CCT, J. Fischer, 3pp.
CCT/12-15	On the Difference of Meanings: Zero correction, Zero Value, versus no Correction, and of the Associated Uncertainties, F. Pavese, 9pp.
CCT/12-16	Optimising the extrapolation to zero current in SPRT self-heating corrections, J.V. Pearce, R.L. Rusby, P.M. Harris and L. Wright, 7pp.
CCT/12-17	Proposal for Criteria for the Inclusion of a Method in the MeP-K, B. Fellmuth and J. Fischer, 2pp.
CCT/12-18	Low Temperature Noise Thermometry by Shot Noise Measurement in a Metallic Tunnel Junction, J.H. Park, W.S. Song, L. Spietz and Y. Chong, 5pp.

CCT/12-19 Proposal for Nomenclature for the MeP-K, B. Fellmuth and J. Fischer, 2pp.

CCT/12-20 Working Group 5 Report to the CCT – May 2012, G. Machin, 6pp.

CCT/12-21 Isotopic Effects in the Neon Fixed Point, P.P.M. Steur, F. Pavese, B. Fellmuth, Y. Hermier, K.D. Hill, J.S. Kim, L. Lipinski, K. Nagao, T. Nakano, A. Peruzzi, F. Sparasci, A. Szmyrka-Grzebyk, O. Tamura, W.L. Tew, S. Valkiers and J. van Geel, 6pp.

CCT/12-22 International inter-laboratory comparison on thermal conductivity of insulating materials by guarded hot plate - Pilot Study, B. Hay, R. Zarr, C. Stacey, N. Sokolov, L. Lira-Cortes, U. Hammerschmidt, J. Zhang, J.-R. Filtz, N. Fleurence, 47pp.

CCT/12-23 Working Group 6 Report to the CCT, S. Bell, 3pp.

CCT/12-24 Working Group 2 Report to the CCT - May 2012, H. Liedberg, 2pp.

CCT/12-25 Working Group 7 Report to the CCT- May 2012, M. Ballico, 5pp.

CCT/12-26 Supplementary Information for the ITS-90: Chapter 6 Radiation Thermometry (draft), H. Yoon *et al* (Working Group 5), 20pp.