

Bureau International des Poids et Mesures

# Consultative Committee for Thermometry (CCT)

Report of the 25th meeting  
(6–7 May 2010)  
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 and in the form presented here.

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

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

A.J. Wallard,  
Director BIPM

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

as of 6 May 2010

**President**

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

**Executive Secretary**

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

**Members**

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

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. Mendeleev Institute for Metrology [VNIIM], Rostekhnregulirovaniye of Russia, St Petersburg.

Institute for Physical, Technical and Radiotechnical Measurements [VNIIFTRI], Rostekhnregulirovaniye of Russia, Moscow.

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

Centre for Metrology and Accreditation [MIKES], Espoo

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

Instituto Português da Qualidade [IPQ], Caparica.

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

The twenty-fifth meeting of the Consultative Committee for Thermometry (CCT) took place at the International Bureau of Weights and Measures (BIPM), Pavillon de Breteuil, Sèvres, on 6 and 7 May 2010.

The following were present:

M. Arai (NMIJ/AIST), T. Baba (NMIJ/AIST), M. Ballico (NMIA), S. Bell (NPL), D. Del Campo (CEM), A. Diril (UME), R. Dubnicka (SMU), V. Fericola (INRIM), J. Fischer (PTB), L. Hanssen (NIST), Y. Hermier (LNE), K. Hill (NRC-INMS), J. Hollandt (PTB), J. Ishii (NMIJ/AIST), A. Kartal Doğan (UME), E. Korchagina (VNIIM), M. Kühne (Deputy Director of the BIPM), G. Kytin (VNIIFTRI), H. Liedberg (NMISA), L. Lira-Cortés (CENAM), G. Machin (NPL), M. Matveyev (VNIIM), E. Méndez-Lango (CENAM), A. Merlone (INRIM), P. Nemeček (SMU), A. Peruzzi (VSL), O. Podmurnaya (VNIIFTRI), A. Pokhodun (VNIIM), J. Ranostaj (SMU), P. Steur (INRIM), G.F. Strouse (NIST), H. Ugur (President of the CCT), A.J. Wallard (Director of the BIPM), L. Wang (A\*STAR), R. White (MSL), K. Yamazawa (NMIJ/AIST), I. Yang (KRISS), H. Yoon (NIST), Z. Yuan (NIM), B. Yuryev (VNIIFTRI).

Observers: M.E. Filipe (IPQ), M. Heinonen (MIKES), R. Teixeira (INMETRO).

Invited guests: P. Bloembergen, F. Pavese (INRIM), J. Hartmann (PTB).

Also present: R.S. Davis (Executive Secretary of the CCT), L. Mussio (Executive Secretary of the JCRB), A. Picard (BIPM), S. Picard (BIPM), C. Thomas (Coordinator of the BIPM KCDB).

Absent: J. Zhang (NIM) sent apologies. N.I. El Sayed (NIS), invited guest, sent apologies.

The President of the CCT opened the meeting and noted its significance with regard to the forthcoming personnel changes at the BIPM. This marks the last CCT meeting for Prof. Wallard who will be succeeded by Prof. Kühne at the end of 2010. Dr Davis will retire on 31 October 2010 and Mr Picard will take over the duties of Executive Secretary of the CCT. Prof. Ugur noted that he will leave the CCT at the end of 2012.

Mr Hill (NRC-INMS) was appointed *rappporteur*.

Prof. Ugur requested comments and concerns about the agenda. Dr Bell asked if the CCT-K8 key comparison will be discussed despite not being on the agenda. Prof. Ugur replied that CCT-K8 will

be discussed during reports of key comparisons. Dr Davis noted that the names of Working Groups may be incorrect in the agenda.

Prof. Ugur commented that some of the business of the CCT was carried out by correspondence in advance of the meeting to keep the week as free as possible for scientific discussions. The original intent was to hold a 1-day meeting, but this was changed to 1½ days. The attempt at conducting business by correspondence was not entirely successful, as evidenced by the failure to elect a new WG1 chair due to a lack of response from 7 member laboratories. Prof. Ugur stated that the failure to complete such tasks does not help the CCT to operate efficiently and requested that laboratories take such duties seriously.

## **2 DOCUMENTS PRESENTED TO THE 25TH MEETING OF THE CCT**

Prof. Ugur stated that 36 documents have been presented to the meeting of the CCT. Dr Davis commented that downloading a zip-file is the best method to guarantee that the updated versions of the documents are used. Prof. Ugur asked the authors to inform Dr Davis if they want their documents to retain restricted access before the end of the week following the meeting. Dr Davis stated that the CCT report will include links to the publicly-available documents and he will confirm with chairpersons and authors prior to moving any documents to the open access area.

Prof. Ugur reminded the members that the CCT agreed that documents presented to the meeting will be sent to the relevant WG chairs where they can be discussed and then sent to the CCT. This process is not being followed. Papers are submitted but not acted on and the CCT would like to make them more useful and effective because, at present, the papers do not get the attention they deserve. Dr Davis currently receives papers from delegates and publishes them on the website, the same practice followed by other CCs. The papers may indeed be orphans on the website, but publishing them represents the least that the CCT can do. Dr Fischer strongly supported the proposal by Prof. Ugur that papers should be submitted through the WG chairs. Dr Davis stated that such a practice would make the CCT unique among CCs. Mr Liedberg commented that some papers were submitted to him and simultaneously copied to the Executive Secretary. Dr Davis stated that he did not wish to be put in the awkward position of refusing to accept a document from a delegate. Dr Peruzzi commented that many documents were published very late. Dr Davis explained that there was a deadline for receipt of documents and this was clearly stated in the Convocation. The deadline was not widely respected so many documents arrived late. Prof. Kühne noted that many of the CCT's documents are so specialized and specific that it may be good practice to have them vetted by the WGs due to their limited interest to the broader community. Mr White commented that the CCT website is a useful repository for papers whether specialized or not. All of the documents relevant to WG3 were brought to his attention. He questioned whether the rule should be so strict and commented that the CCT website provides a repository for documents that may not be ready for

submission to a journal. Prof. Ugur stated that papers may be submitted for inclusion in the CCT website at any time. He noted that many papers are discussed during WG meetings, and cited his recent experience with WG5. A message will be circulated one year in advance of the next meeting to remind delegates of the submission process for documents that was previously agreed so that the CCT will have an opportunity to give them the attention and consideration that they deserve.

### 3 REPORTS OF THE WORKING GROUPS

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

Dr Ripple (NIST) resigned his position as chair of WG1 some months prior to the meeting. Prof. Ugur raised the question of how to proceed and asked Mr Strouse for suggestions. Mr Strouse suggested that the CCT thank Dr Ripple for all of his efforts. Mr Strouse had a copy of the WG1 report (CCT/10-29) and mentioned CCT/10-26 and CCT/10-27. He offered to carry on with the report if there were no objections. Prof. Ugur thanked Mr Strouse but recommended that the report should not be read in its entirety. Instead, he called for the three significant issues concerning the MeP-K to be discussed:

- a. *Taxonomy of methods.* The 2006 version of the MeP-K closely linked the concept of primary thermometry to direct measurements of thermodynamic temperature. Discussions by the Task Group revealed a lack of consensus on what a ‘direct’ measurement was. On redefinition of the kelvin, thermodynamic measurements that use the triple point of water will no longer be ‘direct’ in the same sense as at present. The CCT needs to clarify the terms ‘direct’, ‘indirect’, and ‘primary’.

In response to Prof. Ugur requesting ideas for how to proceed, Mr White suggested that the problem be referred back to WG1. Prof. Machin described the WG5 meaning of ‘direct’ and ‘indirect’ – ‘direct’ refers to a primary realization of the kelvin and ‘indirect’ uses fixed points and interpolation. Prof. Ugur requested that all WGs consider the issue and inform the new WG1 chair of their concerns within two months. Output from WG1 can be expected within six months. Prof. Wallard commented that it is not always necessary to reinvent the wheel. The CCQM has defined ‘primary methods’. Dr Davis mentioned that the CCQM definition appears in the *VIM* (under ‘primary measurement standard’) and noted that it came to the CCQM via Dr Quinn, the basic ideas having been inspired by his experience in thermometry.

- b. *Level of detail.* Some sections of the proposed MeP-K will be short enough to be contained within the MeP-K text; other sections (e.g., radiometric methods) may require a separate document or appendix.
- c. *Inclusion of methods.* What criteria should be used to decide which technologies to include, for both primary and secondary methods?

Prof. Ugur stated that discussion of points **b** and **c** should be skipped. Mr Strouse enquired if a solution needs to be found before the TEMPMEKO symposium in order to incorporate it in the scheduled presentation. Prof. Ugur commented that the short timeframe made this impractical. Mr Strouse stated that Dr Ripple will prepare the TEMPMEKO presentation. Prof. Ugur commented that the TEMPMEKO editors should be able to accommodate any necessary corrections before publication.

Mr Strouse continued with the WG1 report and presented the future plans of WG1:

1. completion of the *Supplementary Information* is the highest priority;
2. impurity effects are in a separate appendix;
3. WG1 will continue to participate in the task group on the next temperature scale and maintenance of the *mise en pratique*.

There were no comments from the delegates. Prof. Ugur stated that there will be an opportunity to revisit future plans and the terms of reference (ToR) for all Working Groups. The strategy, when it is finalized, will provide input for the future plans of the WGs and possibly for the ToR of the WGs. The strategy Working Group should ensure that the strategy is aligned with the plans of the other Working Groups. The next CCT meeting will revisit the ToR of the WGs and their future activities.

Prof. Machin enquired about the preparation of a draft chapter on radiation thermometry for the *Supplementary Information*. The membership of WG5 expressed no interest in the task, so there is some confusion over the current status. Mr White explained that the draft was circulated a number of years ago, so the reporting of it should be considered as historical rather than current information. Much of the work was completed before to the last meeting of the CCT, when the task became the responsibility of WG5.

### 3.2 Working Group 2: Secondary contact thermometry

Mr Liedberg reminded the CCT that the name and the remit of WG2 were changed at the last meeting so that the concerns of WG2 are now limited to secondary contact thermometry. The main tasks of WG2 are updating the *Techniques for Approximating the ITS-90* (the 'Blue Book') and the list of secondary reference points. The Blue Book has a new title "*CCT Guidelines on Secondary Contact Thermometry*". Contributors will be acknowledged. Chapters will be circulated to the Executive Secretary and Prof. Ugur. Following approval by the CCT, the chapters will be posted on the open access section of the CCT website. There are no updates to the 1996 *Metrologia* publication on secondary reference points. An electronic database will be produced so that reference to new measurements can be added. WG5 will deal with the metal-carbon eutectics, so WG2 will not examine those publications. WG2 supported the CCT recommendation to NMIs to define traceability for climate studies and meteorological observations. A recommendation on this subject was presented later in the meeting. Mr Liedberg expressed his thanks to past members, Dr Fellmuth, Mr Hill, and Mr Marcarino, as well as to the newly departing members, Dr Morice and Mr Yamada, for their contributions to the WG2 work that is due to be published.



Prof. Ugur requested that the meeting discuss CCT Recommendation T3, submitted by Dr Merlone to the CCT through WG2. As an introduction, Prof. Wallard discussed the recent WMO-BIPM joint workshop on “Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty”, which was held in Geneva, Switzerland, from 30 March to 1 April 2010. The signing of the CIPM MRA by the WMO was a clear expression that the meteorology community wishes to take greater advantage of the metrology expertise in the NMIs. Although there have been many working-level contacts in various disciplines, signing the CIPM MRA represents a major commitment on the part of the WMO at the highest levels. All presentations from the workshop are available on the BIPM website. The aim is to prepare a joint BIPM/WMO report by the end of June 2010 which will be widely circulated to governments, intergovernmental organizations, NMI directors, the UNCCC, and other organizations tackling the measurement issues relevant to climate change, one of the major global challenges. The BIPM would like to create a clear liaison between the relevant CCs and the WMO. A joint group will be set up with the WMO to monitor actions. Prof. Wallard commented that this was one of the most exciting meetings that he has attended in a very long time. Prof. Ugur thanked Prof. Wallard and enquired how long it took for the WMO to sign the CIPM MRA. Prof. Wallard replied that it was about three years. Prof. Ugur stated that this represented a tremendous achievement for the whole world. Cooperation among large organizations is not very common.

Prof. Wallard explained that the WMO will designate, for the present, three laboratories which will hold the standards or capabilities that will be disseminated within the meteorological community, and which will submit CMCs:

1. Physikalisch-Meteorologisches Observatorium Davos / World Radiation Centre (PMOD/WRC, Dorfstrasse 33, 7260 Davos Dorf, Switzerland): for solar irradiance;
2. Swiss Federal Laboratories for Materials Testing and Research (EMPA, Überlandstrasse 129, 8600 Dübendorf, Switzerland): for surface ozone;
3. National Oceanic and Atmospheric Administration Earth System Research Laboratory (NOAA/ESRL, 325 Broadway, Boulder, Colorado 80305, USA): for carbon dioxide, methane, nitrous oxide, sulphur hexafluoride and carbon monoxide concentrations.

There will therefore be recognized CMCs within the WMO network. Prof. Ugur stated that WG2 will be the owner of the recommendation and asked if it is appropriate for the CCT to make a recommendation to the CIPM on this matter. Prof. Wallard considered it appropriate for the CCT to do so. Prof. Ugur requested a discussion by the CCT. Prof. Kühne commented that the current wording of the draft recommendation touches on topics that are beyond the remit of the CIPM and explained his concerns. Prof. Wallard agreed that rewording is necessary. Prof. Ugur and Dr Thomas made additional comments and Prof. Ugur called for volunteers to prepare a new draft of Recommendation T3 for presentation later in the meeting. Mr White and Dr Yoon offered to help Dr Merlone revise the Recommendation. Dr Davis suggested that guidance from Prof. Wallard and/or Prof. Kühne would be useful.

Prof. Ugur stated that the WG2 report is still open for discussion. Prof. Machin enquired what WG2 intends to do about using metal-carbon eutectics to calibrate thermocouples, particularly as some laboratories are already using them. Mr Liedberg stated that there will be a chapter produced

regarding specialized fixed points above 630 °C, and metal-carbon eutectics can be addressed there, although this task is not a high priority.

### 3.3 Working Group 3: Uncertainties

Mr White commented on document CCT/10-33. The guide on *Uncertainty in the realization of the SPRT subranges of ITS-90* was completed approximately one year ago. Mr White thanked all those who contributed, including manufacturers and members of the CCT outside of WG3. Mr White acknowledged the work of Dr Bonnier, former WG3 chair, who initiated the process. Mr White stated that WG3 has contributed a paper to TEMPMEKO 2010 with information about topics for further research. The information is contained in the appendix to the report. There are currently 3 issues being considered by WG3:

1. Uncertainties associated with extrapolation of the ITS-90 below the argon point to measure temperatures near the nitrogen boiling point, following a request from Dr Rusby, NPL. The problem remains under discussion. WG3 would like to see an archival paper published on the subject. Mr White requested members of the CCT to supply WG3 with any data relevant on this issue.
2. Some of the uncertainty associated with subrange inconsistency may be attributable to specific SPRTs. WG3 will begin by assembling material before it proceeds.
3. Frequentist versus Bayesian Statistics. In recent years there have been a large number of papers in *Metrologia* advocating the use of Bayesian statistics and the Joint Committee on Guides in Metrology (JCGM) recently produced two publications that are, according to Mr White, essentially Bayesian. These should be of concern because statisticians consider frequentist and Bayesian statistics fundamentally incompatible and the *GUM* is essentially frequentist with a slight bias towards Bayesian statistics in the treatment of Type B uncertainties. Mr White advised the CCT that there are philosophical issues associated with changes to a Bayesian approach and cautioned that the implications need to be fully understood.

Prof. Kühne asked Mr White to elaborate on the terminology. Mr White explained that frequentist statistics are probabilities determined by repeated events. Bayesian probabilities derive from the belief of the person observing the event. Mr White provided as an example the possibility of Mr Brown winning the election in the UK. Frequentists see this as a singular event that will either be won or lost whereas Bayesians might attribute a probability of 50 % to the likelihood of winning. The philosophies are different, the meaning of probabilities is different, confidence levels are different, and the modes of calculation are very different, and the CCT should be concerned about this change. Prof. Kühne asked if Mr White was referring to *Supplement 1*. Mr White confirmed that this was the case. Prof. Ugur stated that Mr White's advice was not clear, he was warning us to be aware of consequences, but are we to remain passive in this debate or should we have some say in it? Mr White responded that we should not be passive and WG3 should prepare some examples so that the CCT can better judge the consequences. Prof. Ugur referred to Tuesday's workshop and raised the possibility of supplementing the membership of WG3 with specialists in statistics with the aim of preparing an advisory report to guide the development of the *GUM*. This is preferable to

registering complaints at the end of the process. Prof. Ugur enquired whether WG3 is prepared to take on such a duty. Mr White responded that WG3 will investigate, but added that it is practically impossible for a Bayesian and a frequentist to speak sensibly to one another and noted that it would be unusual to find a statistician who understands both points of view. It was also thought unlikely that they would listen to someone who is not a statistician. He stated that it is important that the BIPM understands that it has a group producing documents that are supplements to the *GUM* but which are inconsistent with the *GUM*. Dr Davis commented that it would be helpful for the CCT to see common examples worked out with both approaches. Mr White stated that initially the Bayesian approach is appealing as a mathematical construct, but it is highly subjective, involving difficult calculations that need to be carried out using Monte Carlo techniques, is not as intuitive as the frequentist approach, and the *GUM* appears to be every bit as good as (and perhaps better than) the Bayesian approach advocated in the *Supplement* to the *GUM*. Examples are still being examined and will be available to examine before the next CCT meeting. Dr Ballico commented that it is difficult to appreciate the differences in the two approaches without specific examples. He suggested concentrating on one or two dominant uncertainty components to see if there is a benefit to using prior information to inform the analysis. Prof. Kühne agreed that examples would be useful and noted that he was somewhat confused by the discussion as he understood that the *GUM* followed a Bayesian approach. Dr Davis and Prof. Wallard commented that this is only the case for the Type B components. Prof. Wallard stated that the Monte Carlo *Supplement* contains a considerable amount of information on prior distributions. Dr Ballico mentioned the effective degrees of freedom in the *GUM* and how this is somewhat analogous to a prior distribution, though many people do not specify the effective degrees of freedom in their estimates. Dr Yoon recommended a number of statisticians at NIST who are expert in the two approaches, and, in particular, suggested that Mr Guthrie; who made a presentation at the workshop on Tuesday, is very approachable. Prof. Ugur considered that the CCT should take the process on board as the scientific authority for temperature.

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

Dr Fischer gave a presentation focussing on documents [CCT/10-15](#) and [CCT/10-16](#). He reminded the CCT that WG4 is tasked with reviewing and making recommendations with respect to thermodynamic temperature determinations and the definition of the kelvin. Recent actions included a review of  $T - T_{90}$  including the range below 4 K. Based on the data in hand, recommendations have been agreed on values and uncertainties of  $T - T_{90}$ , as well as on the discontinuity of the interpolation functions at the triple point of water (TPW). New measurements are under way as follows:

1. NIST – Acoustic gas thermometry will be extended to the range between 550 K and 700 K. Noise thermometry is planned at 77 K and between 700 K and 930 K. Refractive index gas thermometry at microwave frequencies will be continued at the Hg and Ga fixed points.
2. LNE-INM – Acoustic gas thermometry will be extended to the temperature range from 77 K to 4 K. Following this, absolute radiation thermometry will be performed at the Cu point.

3. PTB – Dielectric constant gas thermometry will be used to measure around the TPW and below. Absolute radiation thermometry will be used at the Au and Cu fixed points, and later at higher temperatures.
4. NPL – Acoustic gas thermometry will be used between the Hg and Sn points and later up to the Zn point. Relative radiation thermometry will determine the Ag-Cu interval. Following this, absolute radiation thermometry will be performed to measure the Au and Cu fixed points.
5. NIM – measurements are under way with acoustic gas thermometry around the TPW.
6. KRIS – A comparison of ITS-90 and thermodynamic temperatures between -40 °C and 110 °C will be carried out.
7. INRIM – Acoustic gas thermometry will be repeated between the Hg and In points at INRIM and Doppler broadening thermometry will be performed in cooperation with the University of Naples between the TPW and the Ga point.

Since 2008, the following new measurements have been performed:

1. Acoustic gas thermometry at LNE-INM between the TPW and 77 K (contribution to TEMPMEKO-ISHM 2010).
2. Dielectric constant gas thermometry at PTB between 23 K and 36 K (contribution to TEMPMEKO-ISHM 2010, [CCT/10-17](#)). Absolute radiation thermometry has been finalized between the Zn and Al points and has already been included in the WG4 analysis. Preliminary results have been obtained at the Au and Cu points (contribution to TEMPMEKO-ISHM 2010).
3. Johnson noise thermometry at NIM at the Ga point [[Metrologia 45 \(2008\) 436–441](#)].
4. Johnson noise thermometry at NIST at the Sn and Zn points (contribution to TEMPMEKO-ISHM 2010).
5. Relative radiation thermometry at INRIM at the Cu point [[Metrologia 47 \(2010\) 231-238](#)]

Dr Fischer commented that new work is required on  $T - T_{90}$  in the following temperature ranges: between the TPW and the Ne triple point; between 550 K and the Zn point; and at the Cu point (to a lesser extent thanks to the recent INRIM result). These three ranges need further consideration before any recommendation can be made towards a new temperature scale. In conclusion, WG4 strongly encouraged the NMIs to undertake additional measurements of thermodynamic temperature in these ranges, preferably before the next CCT meeting. The report on  $T - T_{90}$  was approved by the CCT in 2009 by e-mail. A text is being prepared for inclusion in the *Mise en pratique for the definition of the kelvin* (MeP-K). An update of the figures for inclusion in the MeP-K will only be made once the problem below 77 K is resolved. Prof. Ugur summarized that new work has been carried out and a new reference function is being recommended. He enquired whether any action is required by the CCT. Dr Fischer stated that a minor amendment of this sort required no further approval by the CCT. Prof. Kühne questioned the consequences for the MeP-K arising from updating the interpolation function. Dr Fischer explained that, as yet, nothing has been delivered for inclusion in the MeP-K, so there is no reason for concern. Dr Thomas noted that the MeP-K is available on the BIPM website. Dr Fischer explained that the present text of the MeP-K will be extended; one inclusion will be  $T - T_{90}$ . Prof. Kühne enquired about the timeframe for publication of

the MeP-K. Dr Fischer stated that the complete documentation is not required until the kelvin is redefined. There was a further discussion on the MeP-K, the *Supplementary Information*, and ITS-90. Dr Fischer drew the attention of the CCT to documents CCT/10-26 and CCT/10-27 that explain the strategy and structure for the MeP-K. Mr Strouse noted that CCT/10-27 contains a very helpful block diagram.

Prof. Ugur suggested that the WG4 work be accepted as ‘preliminary’. Dr Fischer stated that there will be no change for the next two to four years, so the work should go forward to the MeP-K. Prof. Ugur expressed his concern regarding the lack of confidence that may arise if updates are made too frequently. Dr Fischer explained that the change that took place over the last two years is not a good predictor of future events and stated that he expects the present WG4 recommendations to have reasonable longevity. Prof. Ugur withdrew his proposal to label the interpolation ‘preliminary’ and accepted the WG4 recommendation.

#### 3.4.1 SI Task Group: redefinition of the kelvin

Dr Fischer began his presentation by discussing the progress achieved in the European research project to determine the Boltzmann constant. The 3rd Workshop on Progress in Determining the Boltzmann constant was held at the LNE in 2008 and the 4th Workshop at INRIM in 2009. At the PTB, the dielectric constant gas thermometry (DGCT) project has received the required pressure balances and they are currently under investigation by the pressure group in Braunschweig. The pressure balances will be transferred to Berlin in June 2010. The DCGT is not expected to produce a value for the Boltzmann constant with the desired uncertainty during 2010 mainly due to delivery delays. Acoustic gas thermometry (AGT) has made remarkable progress at the NPL and the LNE with preliminary values in agreement with the CODATA value within the standard uncertainty of about 3 ppm. At INRIM, the difference is higher but still within their stated uncertainty. All partners used copper spheres and the same theory so another method is needed to test the results. NIM uses a different AGT method involving cylindrical rather than spherical resonators and they sent a report to the TG-SI. NIM would like the deadline to be delayed by at least one more year so that it can complete its measurements. Doppler broadening thermometry (DBT) is performed at the University of Paris and at the Universities of Naples and Milan. The main problem is with line fitting. They have at least 5 free parameters that must be fitted to the data. At present, the uncertainty level is  $10^{-4} - 10^{-5}$  due to unresolved problems with the fitting. Johnson noise thermometry (JNT) performed at NIST resulted in a 2009 *Metrologia* publication. The statistical uncertainty has been reduced to 11 ppm, but the systematic uncertainty is 50 ppm. A new system is under construction at NIST, Boulder, and some results will be presented at CPEM in Korea. NIST will have a better idea of the achievable uncertainties in the near future when the system starts operating. The uncertainty target remains 6 ppm, but there are doubts that this value will be achieved in 2010.

Dr Fischer summarized the discussion. NPL will finish its AGT work in 2010. A new 3-litre sphere has been developed at LNE with which they expect to obtain an uncertainty of 1 ppm, but measurements will not be possible before 2011. At INRIM, the value of the Boltzmann constant disagrees with the CODATA value by 7-8 ppm. During 2010, experiments are expected to achieve

uncertainties of 3-4 ppm and they envisage that it will take an additional two years to finish the work. AGT at CEM is just starting and it is not possible to forecast the final uncertainty. At NIM, cylindrical AGT is under development and an estimated two years are required to achieve the final uncertainty at the ppm level. DCGT at the PTB will only achieve uncertainties of 5-10 ppm in 2010 and it is anticipated that two more years will be required. The line-fitting problem will limit DBT to 10 ppm in 2010. At DFM, Denmark, discrepancies at the 2 % level will need to be resolved. A new experiment has started at the University of Western Australia but they are in the early stages and have an uncertainty of about 400 ppm. JNT at NIST reported a 50 ppm systematic uncertainty and the forecast for achieving 6 ppm during 2010 is very challenging. A JNT experiment has started at INRIM, but this has a target uncertainty of about 20 ppm to be achieved within 2-3 years. There is a clear indication that the intended goal will not be reached during 2010. AGT at the NPL and the LNE may reach the 1 ppm level in 2010, but there are no other methods able to confirm the AGT results. This is due to the higher current uncertainties of more than 5-10 ppm compared to the other methods. The VNIIM has brought forward a resolution requesting that a number of criteria be met before changing the definition of the kelvin.

Dr Fischer proposed a discussion of draft Recommendation T2 (2010). The recommendation is based on the CCT 2007 Recommendation, which anticipated that by 2010 it would be possible to reach an uncertainty half that of the recommended CODATA value. The draft recommendation is similar to that of 2007 but with a different timescale.

Discussion of the recommendation followed and rewording was suggested to produce a format suitable for the CIPM. Dr Yoon noted that the new results provide confirmation of the current value, but Dr Fischer replied that the new results use the same technique and are therefore highly correlated. Dr Yoon commented that other techniques seem unlikely to achieve the uncertainties of AGT within the timeframe available. He enquired what will be gained by waiting. Dr Fischer offered a more optimistic point of view, but suggested that draft Recommendation 2, as written, does not present an impediment to the redefinition of the kelvin. He indicated that if sufficient progress is not achieved within two years, then the CCT will need to reconsider. Prof. Ugur commented that it was obvious to him that not all of the units (kg, A, K, mol) will be ready for a redefinition by the time of the CGPM in 2011. He suggested putting forward the case for the kelvin by itself, although there is no pressure to do it right away. If possible, the redefinition will go ahead in 2015. Prof. Ugur referred to questions raised in CCT/10-34 about the contribution from VNIIM and expressed concerns over the consequences of discrepancies in the values of the fundamental constants. In light of these issues Prof. Ugur considered the delays to be reasonable. Prof. Kühne reminded the CCT of the three conditions set out by the CIPM for the redefinition of a unit:

1. sufficient confidence in the numerical value of the key constant related to that unit;
2. an agreed *mise en pratique* for the realization and dissemination of the new unit;
3. the *mise en pratique* communicated to stakeholders with no objections.

Prof. Kühne believed that the last two items had not been accomplished and will not be accomplished before October 2010. Prof. Wallard asked what has been done to communicate the changes to stakeholders. Dr Fischer mentioned the upcoming “New kelvin dissemination workshop” that will take place at the NPL on 27-28 October 2010. Dr Hermier commented that AGT offers a

realistic possibility to reach an uncertainty for the Boltzmann constant below 1 ppm (equivalent to 0.25 mK at the TPW), and waiting two more years seemed reasonable. Discussion of the wording of the recommendation continued.

Prof. Ugur called for a discussion of document CCT/10-34. Dr Davis stated that one of the consequences of a redefinition, often unappreciated by stakeholders, is that you can no longer measure a fundamental constant once its value has been fixed. Experiments that had been measuring the Boltzmann constant will instead measure the temperature of the TPW. Discussion continued with regard to correlations between various units and the constants. Assurance was given that the CCU is aware of the issues, and that CODATA handles such matters in a consistent way. Dr Fischer believed that the most serious issue raised was the possibility of multiple definitions of temperature scales. Prof. Kühne was concerned that the clear distinction between ITS-90, as is currently disseminated by the NMIs, and thermodynamic temperature may be lost in the future. Dr Fischer agreed that this is a concern, but stated that the differences will be small and negligible for most applications. Prof. Kühne stated that ITS-90 is the basis for CMCs. This means that there are clear procedures for realizing and disseminating ITS-90 and it is possible to make key comparisons that test capabilities. In the future, the unit kelvin may possibly vary more than it varies now. Dr Fischer replied that any change will simply reflect reality and there are, even now, CMCs related to the dissemination of thermodynamic temperature. Dr Yoon confirmed that this is indeed the case. Mr White agreed that the problem exists now although most people are unaware of the distinction. The incidence of the problem will not change. Prof. Ugur expressed concern with the two options: the small relative uncertainty offered by ITS-90 and the larger uncertainty for thermodynamic temperature. The new definition is better from a physics point of view but there are possible consequences and there is a need to alert the stakeholders. Dr Ballico commented that customers currently have  $T_{90}$  in their calibration certificates, but also have  $T$  through the document that gives  $T - T_{90}$  and its estimated uncertainty. The situation will not change following the redefinition. He suggested that consideration should be given to which specific users would be confused or affected by the change, although he was unable to think of any users that would be disadvantaged. Prof. Kühne queried what will happen with, for example, safety limits for powerplant operators that specify  $T_{90}$ . They operate at as high a temperature as possible while staying below the maximum allowable temperature by the uncertainty. In future, what instruments should they use.

Mr Hill commented that the measurement community has had to deal with measurable changes in temperature approximately every 20 years since 1927. As an example, the boiling point of water changed by 25 mK in the change from IPTS-68 to ITS-90. Among the effects noted by users was that the corresponding 5 mK change at 20 °C was sufficient to influence precision dimensional metrology. A precision comparison of silica capacitors was also influenced by this 5 mK change at 20 °C due to dimensional changes. In essence, some members of the user community are conditioned to occasional changes to the temperature scale definitions. The changes have resulted in no real problems, and although education has been required and there may have been inconveniences, the community has been able to cope with the changes. He added that many of the past changes have been much larger than the changes being contemplated in the next iterations. Dr Heinonen stated that the current definition of the kelvin is based on the TPW, not on ITS-90. He added that for powerplant issues, traceability will be required to standards that realize the unit, and

that will not change. There is a need for primary realizations of the unit or the practical realizations of a scale, so that there appears to be no real effect. A user with a primary realization will still need to show equivalence with others. It was mentioned that for traceability when going below 1 K, there are no measurements related to the TPW but they are thermodynamic values. Dr Hermier mentioned that fixed points in the ITS have no assigned uncertainty, and as a result there is a larger uncertainty for thermodynamic measurements than for the ITS.

Dr Ballico did not understand the difficulty. The current documents relate  $T$  to  $T_{90}$  and the only change is that the uncertainty of the TPW will become 0.25 mK. Prof. Kühne mentioned again the possible consequences of using different instruments for measuring  $T$  and  $T_{90}$  with possibly very different uncertainties. And queried how this will be explained to people. Dr Fischer quoted from a WG4 document produced in 2007: "It is expected that the new definition for the kelvin will have little immediate impact on the status of ITS-90. However, the ITS-90 will no longer be the only practical option for temperature measurement. Thus, the most immediate and beneficial consequence of the change is for temperatures below 20K and above 1300K where primary thermometers may offer users a lower thermodynamic uncertainty than is currently available with ITS-90. For the foreseeable future, most temperature measurements in the core temperature range from about  $-200\text{ }^{\circ}\text{C}$  to  $960\text{ }^{\circ}\text{C}$  will continue to be made using standard platinum resistance thermometers calibrated according to ITS-90. Because ITS-90 will remain intact, with defined values of  $T_{90}$  for all of the fixed points, the uncertainties in  $T_{90}$  will not change: they will continue to be dominated by uncertainties in the fixed-point realizations". Dr Hollandt stated that the major concern of Prof. Kühne is not that metrologists understand, but that the users may be confused because in future they may receive two different temperatures depending on the method, and that this needs to be communicated to the stakeholders. Dr Ballico referred to an earlier comment by Dr Yoon that this is already being done for radiation thermometry above  $1000\text{ }^{\circ}\text{C}$ . The radiometry community really needs  $T$ , not  $T_{90}$ . Any difference is subsumed within the uncertainty statement. Prof. Kühne requested clarification that calibration reports will indicate either  $T$  or  $T_{90}$  as appropriate, and that this distinction will be clearly stated within the MeP-K.

Prof. Ugur drew the attention of the meeting to CCT/10-05 and invited Dr Pavese to elaborate. Dr Pavese summarized his concern: Boltzmann statistics represent the high-temperature limit of other statistics. At low temperatures, Bose and Fermi statistics dominate under certain conditions. The quantity thermodynamic temperature should hold from zero to infinity. If the kelvin is based on the Boltzmann constant, what happens if this is applied where Boltzmann statistics do not apply. Dr Fischer noted the failure of the virial expansion in the experiment that suggests bosonic clustering near 3 K. However, this does not justify the definition of a special temperature and does not impinge on the definition of the kelvin. Different statistics are used according to the particles, but the same Boltzmann constant applies. Dr Davis believes that the important point is that the combination  $kT$  always appears in the equations of physics. In his opinion, Maxwell-Boltzmann statistics are merely one manifestation of this. Prof. Ugur commented that he has found no evidence for Mr Pavese's concern based on his own research.

Prof. Ugur enquired whether a meeting should be organized with representatives of the stakeholders. Prof. Wallard stated that this action normally resides with the NMIs. Organizations such as IMEKO



and NCSLI were mentioned as possible forums to discuss the issue with the stakeholders. Prof. Kühne enquired if the change in uncertainties arising from the redefinition will have any effect on the uncertainties of the calibration reports issued by the NMIs. If so, then the stakeholders must be notified of what the changes are. There are many accredited laboratories that receive their traceability from NMIs, so these are stakeholders that could be contacted. If the stakeholders can be assured that the calibration certificates they have will remain valid following the redefinition and that future certificates will look the same, then there will probably be few concerns. Any changes should be explained. Mr Hill commented that some experience was gained with the conversion to ITS-90, which did not happen uniformly for all clients when ITS-90 came into effect. Some clients continued to request calibrations on IPTS-68 and the NRC and other NMIs responded to such requests until sufficient time had elapsed for them to convert to the new scale. Some flexibility will be offered to give stakeholders time to convert. For the most part, the changes to be introduced are likely to be small. However, differences between  $T$  and  $T_{90}$  are certainly measurable and if there is a sudden change from one to the other, the shift would be visible to some clients and would have a potential impact. But, as Mr Hill and others have already stated, the NMIs will continue to disseminate ITS-90 for many years to come if that is what the client community demands and there will be no change for these users.

Prof. Kühne commented that governments might constitute stakeholders. In Germany, there is a law stating that the SI is the basis for the legal units. In such cases, will there be a need to change the legislation or will it remain the same? Prof. Ugur stated that he does not see any reason to change the legislation. He queried whether there was any concern that some laboratories operating in radiation thermometry are issuing certificates in  $T$  rather than  $T_{90}$  and the range of radiation thermometry could be as low as  $-60\text{ }^{\circ}\text{C}$ . If this becomes a more widely used service, there is a chance that there will be two kinds of certificates, one reporting results in  $T_{90}$  and one in  $T$ . This will force some laboratories to issue certificates using both temperatures, maybe using the formulae discussed earlier, with its associated uncertainty. Prof. Ugur asked if the delegates considered this scenario to be a threat or at least a potential complication, or will temperature metrology evolve so that customers will be able to resolve the differences. Mr White replied that the likelihood of problems with a particular client is extraordinarily small. Most of the thermometry processes are such that the uncertainties in their processes, or in the thermometry associated with their processes, vastly exceed the differences between  $T$  and  $T_{90}$ , let alone the uncertainties in  $T$  or  $T_{90}$ . There are very few customers who have the chance of being affected, and fewer who care whether they are dealing with  $T$  or  $T_{90}$ . The task group went back through its client lists to identify the groups of people who may be affected and there are very few. Dr Hollandt stated that he is also convinced that customers will not be affected. At the moment, the calibration certificates state  $T_{90}$ . In future, they will state either  $T$  or  $T_{90}$  depending on the method applied. Most customers will compare the old certificates with the new one. There will also be an education process to explain the reason why  $T_{90}$  has been replaced and to reassure users that there is no practical effect.

### 3.5 Working Group 5: Radiation thermometry

Prof. Machin began his report by mentioning changes to the membership. Dr Batuello was replaced by Mr Girard and new members were Ms Martin (CEM), Dr Teixeira (INMETRO – a long time observer), and Mr Cardenas-Garcia (CEM). In addition, there were co-opted members with expertise in high-temperature fixed points and primary radiometry. A task group was formed to draft a text for the MeP-K at high temperature. Prof. Machin expressed his thanks to Dr Yoon, Dr Hartmann, Dr Woolliams (NPL), Mr Yamada (NMIJ), Dr Bloembergen, and Dr Saunders (MSL). The Terms of reference from the previous meeting have been slightly reworded with help from Dr Davis. WG5 believed the task list was appropriate. There was a workshop during NEWRAD in 2009 (held at KRISS) on high-temperature fixed points and all of the presentations are available on the website (refer to CCT/10-25 for information). An informal meeting was held at TEMPBEIJING to advance the MeP, the high-temperature research plan, thermometer specifications, etc. The first meeting of the Blackbody User's Group (BBUG) was held at NEWRAD and there will be another at TEMPMEKO. This is an initiative with the CCPR and Mr Sperfeld (PTB). A meeting of the MeP-K HT task group was held at the PTB in 2009. A small number of outstanding issues remain to be resolved. There will be a meeting at TEMPMEKO 2010 and a later one at the IEC meeting in Seattle, USA, dealing with thermal imager standards (chaired by Prof. Machin). Dr Hollandt will chair an IEC meeting at TEMPMEKO on radiation thermometer standards. The BBUG meeting to be held following the TEMPMEKO symposium will address the refractive index issue related to how radiation is transferred from the hot blackbody to the radiometer. There will also be an afternoon meeting to discuss how to bring high-temperature fixed-point (HTFP) research to a conclusion. The next WG meeting will probably be at NEWRAD 2011.

The HTFP research plan addresses all the remaining issues concerning high-temperature fixed points. The plan is currently about 50 % complete. The plan will include stability and robustness studies, an approach to the construction of primary cells for the assignment of  $T$ , a study of operational requirements – particularly furnace effects, and a comparison of absolute radiometry which is ongoing (led by PTB) and for which initial results are very promising. Work Package 5 will plan and perform absolute measurements of a restricted set of HTFPs. These will be undertaken after WP4 (the PTB work) is completed.

The task group has been working intensively on developing the MeP-K text and this work formed the basis of a focussed session at TEMPMEKO 2010. A section is being prepared on primary thermometry by absolute radiometry and approximations to primary thermometry using high-temperature eutectic fixed points in conjunction with appropriate interpolation equations. Three documents have been produced. CCT/10-12 is a background document on primary radiometry techniques and includes a long list of references on primary radiometry and high-temperature fixed points. CCT/10-13 deals with direct methods (primary methods) by absolute spectral band radiometry. CCT/10-14 addresses indirect methods, allowing high-temperature fixed points to have measured thermodynamic temperatures with thermodynamic uncertainties that, in conjunction with defined interpolation equations, allow realization of the thermodynamic scale using high-temperature fixed points and the Cu point, if required. WG5 recommended that the CCT accept the documents so that they can be passed to WG1 for incorporation into the MeP-K.

Prof. Machin noted that CCT-WG5 is linked to two active standards committees through IEC SC65B WG5. Mr Hollandt's group on technical standards for radiation thermometers has made good progress. A "how to measure" standard is being formulated. Prof. Machin has started a similar activity for focal-plane array thermal imager specifications.

Prof. Machin raised three discussion points for consideration by the CCT plenary:

1. addition to the WG5 task list explicitly giving WG5 the task of identifying key comparisons relevant to radiation thermometry;
2. approval of the text produced by WG5 for the MeP-K at high temperatures;
3. support of CMCs below the Ag point through relevant RMO comparisons.

In response to remarks from Prof. Ugur, there was a discussion of the mechanism by which the MeP-K text is to be advanced. Prof. Machin stated that the documents have been circulated twice to the CCT and CCPR and there were no substantive objections. Mr White found the text much longer and detailed than expected. Prof. Machin replied that the background document (CCT/10-12) was intended to be long, whereas CCT/10-13 and CCT/10-14 are short documents. Mr White expected much of the detail to appear in a guidance document and queried the practice for MePs within other Consultative Committees. Dr Davis stated that MePs can be quite short. For the definition of the metre, the MeP is a list of frequencies and corresponding uncertainties. Every unit has its own needs in this regard. The thermometry text is the most detailed. There can, he believes, be quite a degree of latitude depending on what the CCT experts consider necessary. Prof. Kühne commented that CCT/10-26 refers to the MeP for the *definition* of the kelvin whereas the WG5 documentation uses the term *realization and dissemination of thermodynamic temperature*, which he preferred. Dr Davis replied that the report of the CIPM meeting in 2008, referred to both the MeP for the unit and the MeP for the realization of the unit in the same paragraph, but felt the intention was to refer to the realization of the unit at the highest accuracy. Prof. Kühne stated that you cannot realize the definition of the kelvin and do nothing with it, what you can do is to realize and disseminate thermodynamic temperature, so that this will come much closer to what you are actually doing. Prof. Ugur recommended that WG5 submit the long version of the documents to WG1. The CCT does not need to take further action at present.

Prof. Machin stated that WG5 is not proposing any new key comparisons. There are two main reasons. The high-temperature research plan is only halfway to completion, and the WG5 members would prefer to allow the direct and indirect methods to operate for a while before arranging key comparisons. Prof. Ugur commented that he would like to have a key comparison initiated in the near future. It is important to support CMCs, and he reminded the delegates of the difficulties encountered with CCT-K5. The issue will have to be revisited.

### 3.6 Working Group 6: Humidity measurements

Dr Bell referred to CCT/10-18. Discussions are ongoing within WG6 regarding the need for comparisons below the range of CCT-K6. There is currently a project within EURAMET for the

trace moisture range ( $-70\text{ }^{\circ}\text{C}$  frost point and below, or 1 ppm moisture content and below). This is a comparison in terms of amount fraction using a technology relevant to that measurand (cavity ring-down spectrometers). The work is being carried out by NIST, PTB, NMIJ, and NPL. This will form a pilot comparison that will indicate what is feasible and what benefits there would be to making wider comparisons in that range. Although it is not a CC activity, the decision of WG6 was to monitor this comparison and wait to decide what action to undertake in that range.

The harmonization of quantities, units, symbols, and realizations related to humidity was discussed. Terms and definitions and many other aspects of this subject are still not consistently agreed in the humidity field. This was discussed during the WG6 meeting. Questions were raised about how important it is to pursue the many details of areas that are being considered for harmonization. Dr Bell was unclear whether WG6 reached a clear conclusion on this topic, except that the WG is working on a document which touches on some areas of terminology. When the document is complete, the WG will have a better idea of how much additional work will be required regarding terms, definitions, etc. Dr Heinonen agreed to lead this task.

WG6 is producing a document on uncertainty calculations for humidity standards and realizations. This document has been in production since at least 2003. Mr Lovell-Smith of MSL is the driving force behind the document. Following TEMPMEKO and ISHM 2010, WG6 will focus on this document.

WG6 will coordinate with the CCQM in the areas of trace moisture in gases and moisture in materials. In most NMIs these topics are considered as part of the chemistry field, although most of the members of WG6 address the same topics by means of humidity standards. The task is to maintain coordination between both groups. There are no formal coordinated projects linking the work of WG6 to the CCQM but contact is maintained by people on those Working Groups. It is considered a watching brief at this stage. Dr Bell also mentioned EURAMET 1065, which is a project now under way to obtain a snapshot of the state-of-the-art for the metrology of moisture in materials, with a view to formulating a strategy for European NMIs in this area. The deliverables from this project are expected to be a workshop and a report.

WG6 has responsibility for convening the International Symposium on Humidity and Moisture (ISHM). In 2010 it is a joint event with the TEMPMEKO symposium. WG6 had a major role in the co-organization of that event. Dr Bell was on the steering panel for the event and Mr Lovell-Smith (MSL) was the humidity co-chair.

Prof. Wallard mentioned discussions within the CCQM network on moisture in grain, and asked Dr Bell if she had been copied on that correspondence. Dr Bell replied that she had not but reported that she maintains occasional contact with Dr Sargent (Chair of the CCQM WG on Inorganic Analysis). She was not aware of this issue. Prof. Wallard explained that CMCs have been proposed in that area. Dr Bell noted that it is a specialized field and will discuss the matter with Dr Sargent. Prof. Ugur enquired about progress with ISHM and the convenor. Dr Bell replied that there is no doubt about WG6 being the convenor. There was general satisfaction with the current joint event,

but no decision has been made regarding the future. If it continues, ISHM is not likely to be held in conjunction with the next TEMPMEKO symposium. TEMPMEKO symposia will continue to include humidity and moisture papers if they are submitted. Prof. Ugur asked if ISHM will be a separate event or held in connection with some other temperature event. Dr Bell replied that all options will be open for discussion after the current joint event is completed. Dr Heinonen commented that it has been generally agreed that the triennial timing of TEMPMEKO is too short for the humidity community. Dr Bell added that historically the time interval between ISHM meetings has been between 4 and 20 years. Prof. Ugur noted that 6 years would make it convenient for every other TEMPMEKO symposium. Dr Bell stated that this is one of the possibilities being considered.

### 3.7 Working Group 7: Key comparisons

Dr Ballico reported on document CCT/10-28. WG7 has considered 15 comparisons over the last two years and they are listed in the full report. One issue recurs in all the reports: linking to the corresponding key comparisons, which may be separated by 10 years. Details need to be given regarding how the pilot laboratories have maintained the equivalence of their present standards to the standards maintained 10 years ago, so that meaningful linkages can be made. It is a necessity for those coordinating the bilateral comparison or RMO comparison to make sure they choose a pilot that can provide the necessary information to demonstrate that the linkage can be maintained. Participants in key comparisons have a responsibility to keep the necessary documentation and hardware in their laboratories to provide the linkage for comparisons that may occur years after the key comparison.

At the moment, the CCT does not have a process for pilot comparisons, sometimes referred to as pilot studies (PSs). By contrast, the CCQM registers each PS, gives it a number, and the protocols and reports are recorded in a section of the website. The reports are registered and published in *Metrologia*. The PSs are not recorded in the KCDB. Instead, they are maintained by a Working Group within CCQM. CCT WG9 has four comparisons in progress that are referred to as pilot studies. They have not been registered with WG7 and there is no process for recording the protocol and no process for dealing with comparisons of this nature. WG7 has requested some status for the PSs so that any information learned could be used as the basis for a key comparison in the future. WG5 also has a comparison in progress and WG6 is running a comparison it refers to as a PS, although the CCT does not currently have a definition for what constitutes a “pilot study”. Dr Ballico suggested that the CCT adopt a process similar to the CCQM to formalize the status of pilot studies so that it can have a regular naming system, some mechanism for archiving the results, and procedures for publishing the results to raise the status of these comparisons to make them more useful and formal than they are at the moment.

Prof. Machin endorsed the proposal for handling this type of comparison. WG5 is measuring high-temperature fixed points to assess the world-wide status of radiometry and will then undertake measurements of  $T$ . This falls within the PS concept as described by Dr Ballico.

Prof. Wallard enquired if results of comparisons are considered in relation to the CMCs of the laboratories concerned to check for inconsistencies. Mr Strouse replied by noting the experience of WG9, whereby they would find it helpful to use some pilot comparisons that have been published to support upcoming CMCs, bearing in mind that they may not have useful key comparisons for 9-10 years. Prof. Wallard commented that pilot studies should be taken into account when considering CMCs, but his question was directed to the results of key comparisons and whether they are consistent with the declared CMCs of the labs. Dr Ballico stated that WG7 does not have a process to examine the results and compare them to the KCDB, but it could be done if required. Mr Strouse replied that this process takes place within WG8. Dr Ballico commented that the question is whether to study the CMCs that are already in place when the results of a new comparison become available. Mr Strouse confirmed that such a review process takes place within WG8.

Prof. Kühne commented that some time ago the evaluation of the uncertainty of the KCRV and the linkage of different rounds of comparisons was an issue. In 2009, at a meeting of the CCQM, Prof. Cox organized a satellite workshop on these issues. Prof. Kühne queried if there is a need for such a workshop in the field of thermometry or is the experience gained over the last 10 years sufficient. Dr Ballico replied that the linking issues are a practical matter, some laboratories used the cells from K3 and K4 as working cells in the laboratory and they accumulated many hours of use. Some laboratories did not consider that they should give the artefacts used in K3 special status, maintain them, and regularly compare them to their own primary standards so that they can make a linkage. In some cases in APMP-K3, two of the linking laboratories had indium cells that were damaged. Luckily, both laboratories had compared their cells to their national standards before and after the damage occurred so that they could connect the results, but it was fortunate that they had an internal quality and maintenance system in place. When a new key comparison or bilateral comparison is proposed, whether the lab they are choosing as a pilot has the appropriate linkage to the previous key comparison and whether their comparison results are going to be good enough to sustain the service they are going to support must be considered. It is not sufficient to recruit the participants and go ahead with the comparison, whether the linkage is going to be satisfactory for the desired purposes must be considered.

Prof. Kühne commented that K1 was one of the first comparisons, and he understood that it would be repeated. He queried if it is under way, or if there are plans to repeat K1. Dr Ballico replied that he was unsure. Prof. Kühne stated that it has been 10 years (or more) since it was carried out. Prof. Ugur queried whether we need to repeat K1. Mr Strouse replied that WG8 has not been asked to repeat either K1 or K2 at this time. Since it is within the terms of reference of WG8 to put forward key comparisons, he stated that a few requests have been discussed but not for K1 or K2. He referred to the talk on linking given in the workshop by Mr White. Mr White endorsed Dr Ballico's comments explaining that the fundamental problem is maintaining the physical state of the artefacts over a period of 10 years. This was not fully appreciated at the time the key comparison measurements were being made. For example, triple point of water cells continue to change even if they are not used, so there is a need to be concerned. Dr Ballico commented that if the physical artefacts cannot be maintained, another option is to state "the physical artefacts maintained through regular comparisons against national primary standards of that laboratory" so that a historical

linkage can be maintained. Dr Ballico queried whether the appropriate interval for the next round of key comparisons could be discussed at the meeting. He also queried whether WG8 or another Working Group could set a formal process for deciding when the next round of key comparisons should occur, canvassing the members to ascertain what interval would be suitable and practical. He stated that the CCPR carried out a similar exercise 2-3 years ago. It circulated a questionnaire asking: what key comparisons they were willing to participate in; were they willing to be a pilot; what sort of uncertainties would they support; and what was a reasonable interval for that comparison. They analyzed the information to reach a decision. If this approach was reasonable, Dr Ballico enquired who will be responsible for sending the questionnaire and analyzing the results. Mr Strouse replied that the responsibility was probably with WG8 and added that Dr Ballico was effectively requesting the development of a key comparison roadmap. Prof. Ugur stated that the scope could be expanded to include pilot studies or comparisons. He requested that an infrastructure for such comparisons be drafted for discussion within WG7 and then circulated to the CCT. He also recommended collecting information from two sources: from the general CCT membership as well as from WG8. Prof. Ugur added that when the structure for pilot studies or comparisons is developed and approved by the CCT using electronic correspondence, it can start implementing the structure without waiting for the next CCT meeting. Prof. Ugur asked Dr Ballico to prepare the structure for the pilot studies or comparisons and one or two questions regarding all types of comparisons, possibly in 3 categories, to be circulated to the CCT as soon as possible.

### **3.8 Working Group 8: Calibration and measurement capabilities**

Mr Strouse presented document CCT/10-24. There will be one membership change, with Dr Peruzzi replacing Dr Buck in June. Mr Strouse attended the WG9 meeting earlier in the week where he familiarized himself with the WG9 service categories for thermophysical properties. These categories will be placed on the KCDB as a precursor to establishing CMCs.

Mr Strouse reported some statistics relevant to the CCT: In 2009, 782 CMCs were added to the KCDB. 37 NMIs (36 countries) are currently represented within the total of 1378 CMCs. For 2010, 180 CMCs will be sent to the JCRB and fast-tracked for approval. Several hundred more CMCs are expected to be received by WG8 for approval over the course of the next few months. Recalling that the question of whether new key comparison results are reviewed with respect to existing CMCs was raised earlier in the meeting, he mentioned that WG8 has removed two CMCs for the TPW. These were from one NMI within EURAMET whose claims could not be substantiated by recent comparisons. Their entire review process will have to start again. WG8 debated whether this should be a greying-out of the CMCs or a complete removal, but greying-out was considered akin to having a non-conforming quality system that needs to be addressed. Removal of CMCs and returning them to the start of the review process seemed the only fair way to deal with the inconsistency. The process is working as anticipated and Mr Strouse was satisfied. Four review protocols, some new and some updated, will be made available on the open access section of the WG8 website. The protocol for relative humidity was awaiting final votes and should be completed in early June 2010. This is a constantly growing and evolving process.

Mr Strouse reported that one issue that has come up within the last year was the JCRB directive on traceability. NMIs must obtain traceability through another NMI for primary standards, not through the manufacturer. This has caused concern where some NMIs have purchased fixed point cells commercially and have tried to use the manufacturer's certification as proof of traceability. They have then found that they cannot do so because of the JCRB directive. He added that it is not clear that the directive is being globally disseminated. It has been approved, but its consequences do not seem to be widely appreciated. Mr Strouse explained this to the CCT to raise awareness. In this regard, he pointed out that participation in a key comparison is not an acceptable means of establishing traceability.

A second issue that concerned WG8 was CMCs versus BMCs. This and some other ILAC practices have caused confusion for some QSTF review groups over the responsibility for examining CMCs. There is disconnection between the scope of accreditation and the CMCs. Within some NMIs in SIM, those trying to get their CMCs approved have been told by their directors that the QSTF is responsible for their scopes of accreditation and CMCs. This seems to be a concept derived from ILAC, but Mr Strouse commented that the review of CMCs is clearly the responsibility of the CCT. He stated that an ILAC BMC is not the same as a KCDB CMC. The scope of accreditation is just one part of the approval process. WG8 needs to investigate the scopes to determine whether the uncertainties in the scopes match those of the CMCs.

Mr Strouse raised the issue of K3, which may become K9. This KC was presented to the RMO representatives so that it can be coordinated through them. Following the design presented by Mr Guthrie in Tuesday's workshop, the form of the proposed comparison is a collapsed star with NIST at the centre. The starting date has been postponed from November 2010 to 2011 to meet some of the financial and planning needs of the RMOs.

Prof. Wallard commented, with respect to the traceability requirement of the JCRB and other decisions by the JCRB and the CIPM that the BIPM is of the opinion that the RMO dissemination networks were not always functioning as well as they would like. After JCRB meetings, delegates are encouraged to give complete and timely debriefs of the decisions that were adopted. The JCRB Executive Secretary, Dr Mussio, always produces a list of actions and decisions very quickly after the meeting and circulates them to the RMO representatives but we do rely on the RMO representatives. One possibility being considered is to carry out an independent mailing to, for example, technical committee chairs but, when this was discussed that at the JCRB, there was a general consensus that to do so would undermine the responsibility of the RMO representatives to the JCRB. Consequently, the JCRB rejected that option. Prof. Wallard added that this lack of effective communication remains a matter of concern to him and others, particularly when they attend Consultative Committees or RMO General Assemblies. There is a lack of communication with the people who have to take actions at the working level. Prof. Wallard invited suggestions for improvement without undermining the formal role of the RMO representatives. Dr Mussio commented that after every JCRB meeting a summary of the actions and resolutions and the most important highlights is posted in the KCDB newsletter so that is available to everyone. Prof. Wallard



added that the synchronism is usually quite good and there is usually only a couple of months between a JCRB meeting and publication of the newsletter, which comes out twice per year (the JCRB meets twice per year). Dr Thomas commented that the next KCDB newsletter will be published on 10 June 2010. Mr Strouse stated that he did not receive the directive on traceability from the SIM RMO representative. Prof. Wallard thanked Mr Strouse for his comments and added that SIM is not the only RMO where this is an issue. The matter will be raised with the JCRB in September 2010.

Prof. Wallard stated that ILAC has given clear guidance to its members to move away from use of the term BMC and replace it with CMC on their certificates. There is a transition period that is under way. There is a clear top-down policy from ILAC that they should use the term CMC in the accreditation sector to avoid confusion, and they should apply the common definition developed between the JCRB, the BIPM and ILAC of the term CMC. He added that the BIPM cannot enforce what happens within accreditation bodies, nor in a sense can ILAC because it does not have that role in relation to its member accreditation bodies. Nevertheless, the policy is to move away from BMC and use the term CMC based on a common definition.

Prof. Wallard stated that the mismatch between accredited scopes and CMCs is becoming a “live issue” again. It was an issue 2-3 years ago when the BIPM started to work with ILAC. They were developing a policy on how accreditation of NMIs could take better account of the RMO review process. Development of the policy ran into problems because of personnel changes at ILAC. It has been taken up again and was put back on the agenda at a bilateral meeting held with ILAC in March 2010. The matter will be raised with ILAC. Mr Henson from the BIPM will be the BIPM representative and he will work with ILAC to develop a system that will be much more efficient, the aim of which is to make sure that when on-site reviews take place, they can be used by the accreditors to upgrade the scope. Often, peer reviewers and accreditors are the same people. It is hoped that a situation can be avoided whereby the NMIs that choose accreditation duplicate their efforts, the idea being that both sides of the network will share information. The accreditation reports can be made available to the technical committees in the RMOs together with the names of the assessors, and Prof. Wallard stated that issues of confidentiality raised by the accreditation bodies can be solved. On the accreditation side, once a CMC has been approved through the RMO system, it can be adopted almost immediately by the accreditation body so that the scope and CMC can be harmonized. In summary, Prof. Wallard called these arrangements with ILAC a work in progress, but there do not appear to be any major obstacles to achieving the aim of consistency between CMC claims and accredited scope. Dr Mussio stated that it is clear that CMCs from accreditation bodies and CMCs listed on the KCDB are not equal. In many of the ILAC meetings and in their General Assembly, the BIPM has stressed the distinction: accreditation is a contract between the accreditation body and the individual laboratory; but within the CIPM MRA, every signatory has a voice and can have an opinion on every CMC, it is a much more open process, and that is why the BIPM will not automatically accept CMCs from ILAC. Dr Peruzzi asked for confirmation that an approved CMC can be imported directly into a scope of accreditation, and if so, does it work in both directions. Prof. Wallard replied that this is the issue the BIPM is trying to resolve, bearing in mind that the process within the RMO-CIPM MRA system is much more comprehensive. Dr Peruzzi stated that he still finds gaps between the two. Prof. Kühne stated that this could happen only in an

ideal world. However, it is clear that each organization has a responsibility for its own method of approval. The responsibility for accreditation will always rest with the accreditor. The responsibility for the CIPM MRA will always rest with the bodies that have been created within the CIPM MRA. The idea is to make best use of the information that is created in the other process and not to duplicate it unnecessarily. He stated that decisions will always have to be made by both communities. It is a more complex issue in the world of accreditation because ILAC includes regional organizations such as EA, but within EA each national accreditation body is independent and will make decisions independently. He added that there can be no guarantee that an ILAC rule will be fully complied with by all of the world's accreditation bodies because they do not have a centralized steering capability such as the one that operates within the CIPM MRA by giving the JCRB and the CIPM decision-making roles. Dr Peruzzi explained that in carrying out CMC reviews, there are countries that argue that their entries are already approved by their national accreditation body, so that approval within the CIPM MRA is mandatory. Prof. Kühne replied that this is clearly an incorrect assertion. The idea is that when a national accreditation body uses an assessor who also fulfils the requirement for on-site visits by peers, the information should be made available to the QSTF so that their report has the equivalent information that would be produced by an on-site peer review within the framework of the RMO review. Prof. Ugur summarized that it may be necessary from the NMI's point of view to be accredited, but it is not acceptable from the BIPM point of view to simply accept the scope of accreditation without making sure that it also complies with requirements of the CIPM MRA.

Dr Fischer enquired about including customer artefacts in the review process, a point that arose during Tuesday's workshop and whether this has already been discussed for the upcoming K3 comparison. Mr Strouse requested clarification regarding what is meant by "customer artefact". Dr Fischer explained that the idea was to make the KC a blind comparison by using a customer calibration. Dr Davis stated that the question referred to Mr Guthrie's idea of using a customer calibration as part of the key comparison. Mr Strouse considered this to be a misinterpretation. Dr Davis insisted that the proposal was to measure blind; to be unaware that the measurements were part of a key comparison. Mr Strouse responded that it is difficult to make a comparison as blind as Mr Guthrie might prefer.

Prof. Wallard returned to the traceability issue. For primary standards, an NMI wishing to obtain traceability to the SI must go to another NMI whose relevant CMCs are published on the KCDB. The CIPM traceability statement does permit traceability through accredited laboratories where the uncertainty contribution of that particular calibration is small in relation to the combined uncertainty. Thus the policy does not require going to an NMI for the calibration of every instrument in the laboratory. Professor Wallard stated that this is a "good sense" approach. When the relevant technical committee looks at the CMC, the policy will be borne in mind. Mr Strouse replied that WG8 discussed the issue, and the focus was on "primary". As an example, a thermocouple is not a primary standard. In the electrical area, a precision voltmeter could be considered a primary standard because it has significant influence on the uncertainty. He added that WG8 members have noticed that some manufacturers are trying to market proprietary devices that can only be calibrated by the manufacturer, thus creating further issues. Mr Strouse stated that this is a development that must be monitored. He commented that it is not an issue in thermometry but it has been raised in the area of

high-end electronic measuring devices. Prof. Wallard stated that we are gaining practical experience as this issue evolves. He added that one of the key phrases that the BIPM is trying to emphasize is “traceability to the SI through standards realized in national metrology institutes” to help eliminate technical barriers to trade. He stated that you cannot have traceability to an institution or a building, we are really talking about traceability to the SI. Dr Davis added that the general statement sometimes needs qualification, because some important areas of metrology, such as hardness scales, are not yet fully traceable to the SI.

Dr Thomas asked Mr Strouse about the status of the new service categories for CMCs related to thermophysical quantities. Mr Strouse confirmed that the service categories have been approved by WG8. Dr Thomas enquired if this classification will be used in the next submissions of CMCs. Mr Strouse clarified that the submission of CMCs for thermophysical properties cannot occur until a review protocol has been drafted and agreed, and that WG9 was aware of these requirements.

### **3.9 Working Group 9: Thermophysical properties**

Dr Baba presented the WG9 report, CCT/10-36. He provided examples of the close relationship between temperature standards and thermophysical properties: triple points, thermal expansion (mercury-in-glass thermometers), freezing points (fixed-point cells), and spectral emissivity (radiation thermometry). Users of thermophysical properties need a precise temperature scale. Examples of where a reliable temperature scale is required are: published steam tables and other equations of state, calorimetry, thermodynamic functions of materials, thermophysical properties for low-temperature physics.

WG9 has as “terms of reference”: advising the CCT on matters related to thermophysical properties, assessing the need for key comparisons in this field, and maintaining an effective liaison with the international materials science community, including the Versailles Project on Advanced Materials and Standards (VAMAS). WG9 was tasked with producing a document on uncertainty, including a review protocol and uncertainty evaluation, and with identifying and undertaking suitable pilot studies. WG9 undertook pilot studies to understand the state of measurement standards, rather than launching immediately into a series of key comparisons.

Dr Baba stated that metrology is generally expected to contribute to environmental monitoring, health, safety, international trade, certification, science, and technology. Expectations for thermophysical properties are similar, with recent emphasis on environmental issues, including carbon dioxide emission, and the design of devices and instruments (for example, heat is a very serious issue for semiconductor devices).

Dr Baba and his colleagues are trying to establish thermophysical properties standards to meet the international needs in energy conservation, safety, trade, industry, etc. Since the list of thermophysical properties is very long, priorities must consider needs and capabilities. In 2005,

WG9 decided to start a limited number of pilot studies: thermal conductivity of insulating materials, thermal diffusivity and spectral emissivity. At the WG9 meeting, the pilot study results were presented.

1. Energy consumption in housing accounts for approximately 10 % of the energy produced, and, at present, the generation of this power contributes greatly to carbon dioxide emissions. Insulation is therefore very important. Seven laboratories participated in measuring the thermal conductivity by the guarded hot-plate method. This is a steady-state measurement, measuring the heat-flux density and the temperature difference. It is a very simple, well-defined method. The problem was that the material was rather bulky. The measurement instruments required specimens of different sizes, so the LNE (the pilot laboratory) devised a strategy for a progression of specimens. The work was very time-consuming, but all of the data have now been collected. The pilot laboratory is currently evaluating the uncertainty. The relative uncertainty is very large compared to thermometry, in the order of 1 %.
2. The second pilot study was on the thermal diffusivity of dense materials from room temperature to 1000 °C. The laser-flash method is widely used. There are many applications including coatings on superalloys and characterization of other materials used in nuclear reactors. NMIJ was the pilot for this comparison. Although the method is complicated, the principle is rather simple. The pilot laboratory prepares a specimen shaped much like a coin, about 10 mm in diameter and 1-4 mm thick. One side is heated with pulsed light. Dr Baba demonstrated the evolution of temperature with time as heat diffuses from one face to the other. Six institutes had initially planned to participate, but data is currently available from LNE, NPL, NMIJ, and NIM. Specimens were prepared of different thicknesses from isotropic graphite and Armco iron. The traceability of the results to the SI involves measurements of length, time, and temperature. A thermocouple is used for the temperature measurement, and the thermocouple and the voltmeter are calibrated to provide the necessary traceability.
3. The third pilot study was on normal spectral emissivity, with NIST serving as the pilot. There were six participating NMIs. The measurement of spectral emissivity is challenging because it depends on wavelength, temperature and direction, and different methods are used. All participants have finished the measurements. The pilot laboratory is now analyzing the data. There will be a presentation of the results at the TEMPMEKO symposium.

Dr Baba commented that the chairpersons of WG7 and WG8 attended the WG9 meeting held during the week of the CCT meeting and, as already reported by Mr Strouse, a consensus was reached regarding CMC service categories. Evaluation protocols will be prepared next. The pilot studies are being completed, and they have provided the experience necessary to draft the evaluation protocols. Therefore, WG9 must look to the future. Priorities will be established by evaluating needs. WG9 will establish internationally recognized standards for CMCs based on key comparisons or regional supplementary comparisons. The design of the strategy will be very important. WG9 has already carried out three pilot studies, but calorific values, thermal expansion, and total emissivity are also important. WG9 may decide to carry out new pilot studies. Dr Baba stated that it is important to seek collaborations with other international organizations, the private sector, and universities for thermophysical properties because the staff resources of the NMIs are very limited. Since the last

CCT meeting some progress has been made within the RMOs. Within APMP, a Working Group on thermophysical properties has been established. There is similar activity within EURAMET, and there is the prospect of similar activities within COOMET. A presentation on the results of comparisons of bomb calorimetry carried out within COOMET was made earlier in the week of the CCT meeting.

Dr Baba commented that, although thermophysical properties are most closely related to the CCT, Working Groups for density and viscosity are in the CCM. The CCL has made some supplementary comparisons for thermal expansion and there are CMCs on thermal expansion; bio-fuels and natural gas in the CCQM. Internationally, the CODATA Task Group on Fundamental Constants is a very important partner of the BIPM and CIPM, but Dr Baba stated that CODATA itself has other activities involving thermal standards or thermodynamic properties. Other important organizations in the field of thermophysical properties include ICTAC, ISO, IUPAC and the CIPM has a memorandum of understanding with VAMAS. There are three relevant international symposia: ASTP, ATPC, and ECTP. WG9 meetings coincide with these symposia.

Dr Baba stated that it is very important to expand the scope of the CCT into other fields. Thermophysical properties cannot often be measured with great accuracy, but there is nevertheless interest in being certified through the CIPM MRA with uncertainty evaluation, traceability to the SI, and comparisons that demonstrate equivalence with others. Dr Baba would like to expand the philosophy of the CIPM MRA to include other fields of metrology, and he commented that the field of thermophysical properties is a very good candidate to start that process.

Prof. Ugur enquired if there is any potential for collaboration with the CCPR regarding emissivity. Dr Baba replied that it is an important question, but there is not yet any collaboration. Prof. Ugur expressed his interest in dynamic methods. In the fields of force and pressure, these are very serious problems for industry. After analyzing the data and lowering the uncertainty, he suggested holding a session at the next CCT meeting to share the experience of WG9.

Prof. Wallard enquired about the extent of active collaboration with VAMAS. Dr Baba is a member of the VAMAS materials group and Prof. Wallard has regularly encouraged Mr Sims to send him information on areas where VAMAS is proposing comparisons. He enquired if the comparisons discussed came from VAMAS or from WG9. Dr Baba replied that he has attended VAMAS meetings, but NMI participation within VAMAS, at least regarding thermophysical properties, is very limited. When attending VAMAS meetings, he is also interested in other subjects, such as mechanical properties and particle characterization. He added that these are 'hot topics' within VAMAS, while thermophysical properties are less important.

Prof. Kühne enquired about an item in the presentation on how to establish international standards based on key comparisons. He requested clarification about whether this referred to documentary standards or a reference material. Dr Baba replied that he was considering metrological standards, not documentary standards. Prof. Kühne requested clarification of the term "international standard", normally there are national standards. Dr Heinonen suggested the term "internationally recognized".

Dr Matveyev commented on the comparison on combustion that took place between three COOMET countries and NIM, China. This was a successful comparison and there are proposals for two new heat of combustion comparisons involving a solid graphite sample and gaseous combustion calorimetry. Despite the apparent importance of the work, the proposal is absent from the work plan of WG9. Dr Baba replied that the case of benzoic acid combustion was discussed. He asked Dr Matveyev if a NMI is prepared to lead a pilot study. Dr Matveyev replied that Russia is ready to pilot the comparison and Dr Baba offered to discuss it. Prof. Ugur reminded them that it is up to the participants of the WGs to formulate the agenda of the WG meetings. WG9 is now considering the comparison. Depending on the comments of WG9, WG7 will try to classify it because it does not follow the CIPM guidelines. This will be carried out in parallel with the infrastructure for pilot studies that was discussed during the WG7 presentation. Dr Baba commented that once the infrastructure is in place, how these pilot studies are classified is accepted, and we understand how the pilot study will be used for the CMC entries, this comparison will be reviewed again. Dr Matveyev agreed with the suggestion. Prof. Ugur commented that if the comparison is to be registered as a key comparison or supplementary comparison it needs to be taken by WG9 before it starts, especially in such a new area. For key comparisons, all the steps for the comparison need to be agreed by the participants, the pilot selected, and the protocol agreed before it can start. If this is kept in mind, then the comparison will have a higher value at the end. Dr Davis commented that he understood that Dr Matveyev attended the WG9 meeting and the proposal was discussed. Dr Matveyev confirmed this but stated that it is not reflected in the 'next steps' of Dr Baba's report for WG9. Dr Ballico remarked that it is preferable to have comparisons with the highest authority, and suggested that it is preferable to register the comparisons as supplementary comparisons. This will ensure the comparison is included in the KCDB, will be visible to all, can be referred to, and will exist in the public domain. Pilot studies are not necessarily of that nature, they can be private affairs within the CCs. If possible, it is better to have comparisons operating under the JCRB guidelines for comparisons so that they attain the highest level. Pilot studies, in his opinion, should be reserved for those areas where there is a new set of services, the procedures are not set out or not uniformly agreed. He cautioned against taking the easy route and making everything a pilot study.

### 3.9.1 **Strategy: Task Group 1**

Dr Pavese presented document CCT/10-08. Since the last CCT meeting, much time was devoted to writing the terms of reference. A mission statement was prepared for the CCT based on a vision statement. The membership of TG1 came from 16 NMIs. A meeting was held on 4 May 2010 to finalize the draft terms of reference for the CCT Draft Recommendation T1 (2010). Dr Pavese requested approval of the recommendation.

Prof. Ugur summarized the process that led to creation of the Task Group. The first decision was to attach the strategy to the mission statement. This was discussed in 2009 at the CIPM, but the CIPM asked that the mission statement be prepared for approval by the CIPM. Rather than having an open-ended strategy, a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis was carried out. Two Task groups were created. TG1 has two tasks: to prepare the mission statement (which is

complete) and then formulate the methodology to develop the strategy itself. After that, the SWOT analysis will be taken into account. Given the current form of the mission statement, however, Prof. Ugur stated that a SWOT analysis may be difficult. He will discuss this with Dr Bell, the only other member of TG2. When the strategy is complete, a SWOT analysis will be performed on the entire strategy, including whether it is feasible to implement it and whether the CCT has the means and authority. If necessary, an action plan will follow. After TG1 determines the steps for the strategy, the two TGs will merge into the Working Group on Strategy (WG-S), and the WG-S will develop the strategy. Prof. Ugur commented that this is a complicated procedure, but he considers it necessary in order to produce a reliable, workable, sustainable document. Terms of Reference (ToR) for Recommendation T1 are not very elaborate within the CIPM system but, since the mission statement is under development, the CCT President suggested that the next step should be taken to outline how to accomplish the mission and, in the process, define what is meant by thermal metrology. Since the TG has approved the document, Prof. Ugur does not expect many comments. If approved, he will take it to the CIPM. Prof. Wallard commented that some wording needs to be changed before it is sent to the CIPM. He also noted that the CCQM has a document that addresses strategy and that the CCEM is developing a strategy through its Working Groups. Most CCs have strategy groups that study the TORs, the work plans, the roadmaps etc. Dr Fischer enquired about the difference between points six and seven of Recommendation T1. Dr Pavese explained that the former deals with units whereas the latter concerns quantities. Prof. Ugur will report back to the CCT following the meeting of the CIPM. He advised delegates to assume the mission statement would be accepted (see Recommendation T1 in the Annex to this report).

## **4 REPORTS OF CCT KEY COMPARISONS**

### **4.1 CCT-K6 and CCT-K8: comparison of humidity standards**

Dr Bell presented CCT-K6 and CCT-K8 and gave an overview of the comparisons underway in humidity. CCT-K6 for the mid-range (dew-points/frost points from  $-50\text{ }^{\circ}\text{C}$  to  $+20\text{ }^{\circ}\text{C}$ ) is in progress. Almost all RMO and bilateral comparisons related to K6 are complete, highlighting the fact that for CCT-K6 we need to catch up. Related comparisons within SIM were agreed and completed within the last couple of years. The definition of the K8 range, the dew-point range above K6 from  $+30\text{ }^{\circ}\text{C}$  d.p. to the upper limit of each participating laboratory, is mainly in the planning stage. For the first time, WG6 has developed a protocol designed to encourage coherence between CCT-K8 and the corresponding RMO-K8s. WG6 hopes that this will ensure that the comparisons will run synchronously. Only one of the comparisons has started, Euromet.T-K8, the others are in the planning stage. The low-range comparison ( $< -50\text{ }^{\circ}\text{C}$  f.p.) was discussed during the presentation of the WG6 report. This is not a key comparison, but it was mentioned to show that it is in progress. Although there were discussions earlier in the meeting about formalizing the status of pilot studies and comparisons, it is already formalized as a registered EURAMET project and it is unclear whether it should be formalized in any other way. The important point is that information will be gained from the comparison and lessons learned from it.

CCT-K6, is a key comparison at dew- and frost-point values from  $-50\text{ }^{\circ}\text{C}$  to  $+20\text{ }^{\circ}\text{C}$ . The comparison is of local scales of dew- and frost-point temperature of humid gas. For K6, the comparison consists of the circulation of two chilled-mirror hygrometers measured simultaneously with measurements reproduced four times. The participants decided that four reproduced measurements were sufficient, and this coincided with the recommendation given in the workshop on key comparisons held earlier in the week of the CCT meeting. In the comparison, the applied dew- and frost-point temperature based on the realization of a humidity generator at the NMI were reported. Participants also reported the reading of a PRT embedded in the hygrometer mirror once a stable reading was available from the instrument. Participants reported differences, and those differences were compared. The comparison was designed as if it had two loops. Geographically it had, with additional pilot measurements in between the two geographical loops. The loops were not run in parallel, they were in series, and so from the point of view of the analysis, it was effectively just a single loop, simplifying the analysis. The measurements are now complete. All participants completed their measurements over the last 2 years. This included measurements at VNIIFTRI, which had to be agreed, because the original participant was VNIIM. Due to reorganization within the Russian metrology system, the change of participant was proposed and agreed by the other K6 participants. Those measurements were completed successfully. The final pilot measurements were completed at NPL on both of the travelling standards. In addition, the travelling standard on loan from INTA has been returned. An additional check was made at INTA on the measurements to complement NPL's own measurements on the instrument. From the combination of the measurements made by INTA and those made at NPL, the pilot now has data on the drift of the standards over the time of the comparison. The reporting of Draft A and Draft B is not complete.

Dr Bell commented on K6, which has been a long-running comparison. The participants and protocol were agreed in 2002 and the comparison measurements took eight years to complete. There were many problems with the travelling standards, the primary cause of which was the use of old instruments. The instruments were chosen because they were known to have a stable history, but the instruments suffered a significant number of minor breakdowns which needed to be repaired. Because of the repairs, the NPL had to carry out many extra, unscheduled checks on the instruments, which added to the time taken for the comparison. Fortunately, the evidence suggests that there was no discontinuity in the performance of the instruments after any of the repairs, so the pilot does not believe that any of the repairs affected the comparison results. Being a long-term comparison, much longer than anticipated, it is a concern as to whether the instruments were sufficiently stable over the time of the comparison, but the results from both the NPL results and the INTA suggest that the amount of drift in the instruments seems within reasonable limits. Dr Bell presented a version of this information to the WG6 meeting earlier in the week of the CCT meeting, but in general was not keen on presenting half-analyzed results and so will not present that to the meeting here. She stated that indications were good for a successful comparison. Overall, she and her colleagues understood that the slow progress in completing CCT-K6 is a concern for two reasons. The first is the linking to RMO comparisons that ran at a very different time, bearing in mind that it is necessary to track the history of individual NMIs and the status of their dew-point standards if they change. The second is that RMO comparisons are out of synchronization with the original round of proposed K6 comparisons. For example, APMP-K6 began about 10 years ago and APMP is now ready to repeat



K6 while the CCT comparison has yet to be finished. This is of particular concern for APMP laboratories which, at the time of the first APMP-K6, did not have a facility and could not participate. Dr Bell commented that people who have developed new facilities are in a hurry for something to happen in the second round of dew-point comparisons in this range.

Prof. Kühne enquired when K6 will be completed and a draft available. Dr Bell will work on it following the TEMPMEKO and ISHM symposium and expects to complete the draft before the end of 2010. Dr Ballico asked if there have been discussions on how the linkages to the various RMO comparisons will be made. He enquired if there have been discussions and guidelines regarding the information that is required to maintain and demonstrate the necessary linkage and the uncertainties. He claimed that the individual RMO-K6 pilots are going to have to re-write their Draft B reports or include an addendum. He suggested that this be carried out in a coordinated manner, based on the guidelines and essential criteria. Dr Bell replied that the matter has not been discussed in detail, but she expects addenda to the existing reports rather than changing the text of the reports. She added that in EURAMET K6, which was piloted by MIKES, Dr Heinonen did an excellent job in linking three separate loops and showing how the linking could be tracked through multiple routes. This could be used as a model although it has not been discussed in detail. Dr Ballico stated that one problem is the mathematics of the linking process, the calculation of the degrees of equivalence and the linkage to a KCRV, but he maintains that there is also a second issue: what is the mechanism by which the link between those two comparisons is made and maintained. He suggested that there should be a consultation with WG7 before preparing the report.

Dr Thomas noted that some of the comparisons cited by Dr Bell are not registered in the KCDB, specifically the SIM version of K6. Dr Bell replied that it was understood that registration was required and she will bring this to the attention of her colleagues in SIM.

Dr Bell gave details of CCT-K8, which was agreed at the last CCT meeting. It will cover the humidity range above that addressed by K6: dew-point temperatures from +30 °C to a maximum of +95 °C. In practice, participants will measure up to the limit of their capabilities. There is flexibility because the NMIs vary in how high their standards operate. Participation in CCT-K8 has been agreed, initially from within the normal CCT channels. Where there were too many participants from a particular RMO, WG6 has gone back to the RMO to request a smaller group of NMIs after deciding on the balance of representation from each RMO. APMP participants are MSL, A\*STAR and NMIJ. For COOMET the participant is VNIIFTRI. There are five participants from EURAMET, partly weighted by the fact that the pilot is in EURAMET and partly because there is a greater intensity of activity within EURAMET. The participants are INTA (pilot), E+E, INRIM, NPL and PTB. The participants from SIM are NIST and INTI. Prof. Wallard asked about E+E, the participant from Austria. Dr Bell replied that E+E has been designated by the BEV for humidity. E+E is a hygrometer company, so that is an unusual situation. Dr Bell is familiar with this laboratory and stated that they are careful in separating their designated institute role from their commercial role. Prof. Ugur noted that INTI is no longer a member of the CCT. Dr Davis stated that we have a precedent in that MIKES was not a member of the CCT when MIKES participated. For CCT-K6, MIKES was nominated by EURAMET. Prof. Ugur stated that this is a source of confusion. At the last CCT meeting, it was difficult accommodating CENAM in a key comparison and much effort

was required to include CENAM as quickly as possible so that they could participate. A decision is needed on whether this is under the authority of the CIPM or the CCT. If it is the CCT, a uniform policy will be needed so that, from now on, this policy is applied to all of the key comparisons, whatever the decision. Prof. Ugur did not favour either approach, but he insisted on having a consistent policy. Dr Davis stated that the CCM (for which he is also executive secretary) covers more than 10 areas of metrology, largely unrelated to each other, so WGs typically have members that are not members of the CC. Members of the WG are allowed to carry out key comparisons organized by the WG. He commented that there is flexibility given to the CCs [see paragraph 6.5 of [CIPM-D-01](#)]. Prof. Wallard stated that the participants of key comparisons should be members of the CCT, but the way to deal with that would be to arrange a key comparison as a bilateral between NIST and INTI. Dr Davis noted that there have been CC key comparisons under the CIPM MRA that have included Associates of the General Conference as participants. This is not routine, but it has been allowed if such participation “adds value” to the comparison. He added that INTI joined the CCT comparison at a time when they were an official observer of the CCT. MIKES joined K6 when they had no formal relationship to the CCT. Dr Bell added that MIKES joined because of their importance as the pilot of EURAMET.T-K6, and their status within the CCT did not reflect their importance within EURAMET. Dr Davis commented that this illustrated his point about added value. Dr Bell replied that, in the case of MIKES, the added value was very clear. Mr Strouse questioned the SIM list because he was under the impression that INTI was not on that list, although he was pleased that they were participating. Dr Bell replied that she was aware there may be two contradictory messages that people have received regarding INTI’s participation. She suggested that this should be clarified after the meeting. It was also clear that NIST and INTI have already had a bilateral for K6, and there is a plan for a SIM version of K8, which she assumed INTI will participate in. She pointed out that it was normally a requirement to have a minimum of two linking laboratories. At the time that WG6 organized K8, INTI was the correct choice but Dr Bell suggested that this is negotiable. At the time the participants were selected, INTI was clearly a CCT participant with observer status. Prof. Ugur stated that in the past laboratories that were not members of the CCT have been included and other CCs follow the same procedure. Until the CIPM has made a definite decision on this matter, an issue which Prof. Ugur will raise with the CIPM in October 2010, he suggested that this case should be allowed and that the proposal is pursued. He also suggested the policy is that, until the CIPM decides otherwise and disseminates the information to all CCs and everyone follows the rules, it is possible to proceed this way, providing the communication between SIM and the pilot, with respect to INTI, is solved. Prof. Wallard suggested that the matter be followed up outside the meeting. Dr Bell stated that the participants of K8 will remain open to receiving that information.

Dr Bell provided further details of K8. There will be two travelling standards to be measured simultaneously at multiple times in the same way as K6. New instruments belonging to INTA will be upgraded to the satisfaction of the pilot before the comparison begins. The protocol is being written, but because all of the protocols are being written together for K8, that will be a straightforward process and it is hoped that the participant’s measurements will start before the end of 2010. Prof. Ugur thought that it had been agreed to have at least two participants from each RMO. He enquired if there is a problem with COOMET and SIM. Dr Bell replied that there is much less humidity activity within COOMET. Dr Ballico stated that the two links normally required in a regional comparison can include a linking laboratory from another region. Dr Bell added that

VNIIFTRI is possibly the only laboratory within COOMET which is able to participate. Mr Strouse stated that there is only one NMI in SIM able to measure a dew-point of +95 °C. Two more are able to measure up to +60 °C dew-point. Dr Bell explained that the principle was to begin near the top of the K6 range and to finish at the upper limit of each NMI's capabilities. Comparisons at intermediate values should be sufficient to support CMCs. Dr Ballico enquired how the KCRV will be calculated. Dr Bell explained that every participant will measure at common points. Each dew-point will be considered an independent population. Prof. Ugur asked when the protocol will be completed. Dr Bell expects to finish it before the end of 2010.

## **5 REVIEW OF WG TASK DEFINITIONS, ROLES, RESPONSIBILITIES AND OPERATIONAL PROCEDURES**

Prof. Ugur enquired if there are any issues involving Working Groups, Task Groups, or comparisons. Dr Davis commented that, for WG7, the membership includes the pilots from previous comparisons. That was considered a good idea at the launch of the CIPM MRA, but commented that some of those pilots have retired or have taken on responsibilities outside the thermometry area in the intervening years. There is a mechanism for recruiting new people, in that they are piloting a new key comparison, but there is no mechanism for removing people who are no longer active. Prof. Ugur asked for this discussion to be deferred until the afternoon when the membership of WG7, WG8 and the Strategy Task Group will be discussed. Prof. Ugur thanked the chairs of the Working Groups, including Dr Ripple as past chair of WG1, also the pilots of the ongoing and potential comparisons.

Prof. Ugur stated that even though it had been decided to discuss this agenda point by correspondence, he considered that this method was not satisfactory. He preferred not to change the ToRs of the WGs this time unless there was a very strong preference to do so, because, once the strategy is decided, the ToRs and, possibly, the structure of the WGs will have to be revisited. He proposed that the delegates limit their proposals to changes that are essential for the next two years.

Prof. Ugur has received one proposal from the PTB regarding WG1, to which there were no objections. Dr Fischer stated that the PTB proposal was to task WG1 with continuing to update the Supplementary Information for the ITS-90 *and* the PLTS-2000.

Prof. Ugur commented that no decision could be made regarding the roles, responsibilities and procedures at this stage, pending the outcome of the strategy exercise. Prof. Ugur stated that, as far as he was aware, there were no requests to change the ToRs for any of the remaining 8 WGs. Prof. Machin wanted to clarify WG5s task list by adding the phrase "recommending comparisons relevant to WG5" because there is nothing to state that it was within the role of the WG. Prof. Ugur commented that this role is already implicit but could indeed be included. He added that the first two points in the WG5 ToR will be clarified. Prof. Ugur proposed that when the changes are complete

they should be made available on the website. Dr Davis commented that the grammatical changes will be made immediately and the other changes after approval of this report. Prof. Ugur stated that if the CCT agreed with the roles, responsibilities, and procedures, the composition of the WGs can be discussed later.

## 6 DISCUSSIONS ON ITS-20XX

Prof. Ugur invited comments on the ITS. He noted that this item is on the agenda of every CCT meeting, but this is the first time that perturbations to the system by changing the definition of the kelvin will be considered. Even though WG4 and the TG-SI have studied the consequences of changing the definition of the kelvin, Prof. Ugur suggested that, as a separate check, the plenary meeting should discuss the consequences for the ITS and other temperature scales such as PLTS-2000. He suggested beginning the discussion immediately and, if necessary, creating a small group to answer questions that cannot be answered during the plenary CCT.

Prof. Ugur posed the following question. We have primary experiments that are used for the determination of the Boltzmann constant. When we determine the Boltzmann constant, the same experiments can be used to measure the temperature. Is this assumption correct? Let us assume that we have a measurement at the TPW. We make a measurement. If we keep the ITS as it is now, the temperature is fixed in the ITS but, as was discussed earlier in the meeting, the thermodynamic temperature is identical to  $T_{90}$  at the triple point of water. So what do we measure? We have fixed  $k$ , and so it has zero uncertainty. If we measure anything at all, it seems that we can only measure the uncertainty of the TPW.

Prof. Kühne made an analogy with the redefinition of the kilogram. At the moment, the international prototype is exactly 1 kilogram with no uncertainty. This can be thought of as corresponding to the definition of the TPW. The exact temperature of the TPW is known thermodynamically and in the ITS-90, but these are two completely separate issues. Focusing on Prof. Ugur's question, Prof. Kühne mentioned thermodynamic temperature. When the value of the Boltzmann constant is fixed, the thermodynamic temperature of the TPW is the same as it was before but, the exact moment the definition is in place, the uncertainty of the determination of the Boltzmann constant jumps to the thermodynamic temperature of the TPW, but only on the thermodynamic temperature TPW, not on the ITS-90 temperature. All the ITS-90 fixed points, including the TPW, remain as they are and continue to have no uncertainty. The fact is that  $T - T_{90}$  changes because  $T - T_{90}$  at the moment was zero, with zero uncertainty at the TPW. The very day the change happens, the difference will still be zero but with an uncertainty: the uncertainty of the Boltzmann constant determination. In answer to Prof. Ugur's question, when you use an experiment such as acoustic gas thermometry, an absolute thermometer is used and the Boltzmann constant is known so it is possible to make a re-determination of the TPW – of the thermodynamic temperature. Depending on the uncertainty of the experiment, it will also be possible to determine other thermodynamic

temperatures with uncertainties. These uncertainties will not depend on the uncertainty of the Boltzmann constant because that has no uncertainty and is fixed, but will exclusively depend on the uncertainty of the primary thermometer, but it will have no influence on ITS-90.

Prof. Ugur replied by stating that he understood the basic issue. He added that it would be possible to ignore the thermodynamic temperature and stick to the ITS-90. This would be adequate as long as everybody used the same scale and the same method of computing uncertainties. He queried if this assumption was justified. A discussion followed and Prof. Ugur sought an analogy between the ITS-90 and other scales which may be used in other areas of metrology, perhaps in mass metrology.

Prof. Ugur concluded that the fundamental question is: what are we going to do with the ITS-90 temperature scale. Dr Heinonen responded that in his opinion there was no major change. He added that the ITS will still be close to thermodynamic temperature, so the situation will be the same as now: the change of definition will not require any special action. The scale will have to be kept close to thermodynamic temperature. Prof. Machin stated that the situation is very clear to him. ITS-90 is a recipe book, we follow the recipe and we get ITS-90. It is very straightforward, the fixed points are defined, and they have zero uncertainties. If people want thermodynamic temperatures, the situation is also very clear. We can now use the WG4 document to generate thermodynamic temperatures. However, in his experience the vast majority of people do not care. As for the differences between  $T$  and  $T_{90}$ , this particular issue seems far away from what needs to be discussed in detail at the moment.

Prof. Ugur summarized the discussion by remarking that there is no problem for the time being. If a problem occurs, the CCT can deal with it. Prof. Machin added that, if people really want thermodynamic temperature, they will *know* that they want it. Dr Hermier stated that nowadays there are no special demands requiring a change to the scale. Changing the scale for no benefit to the users would be very unwelcome. With no identified needs up to now pushing for a change, he was in favour of keeping the scale unchanged. Prof. Ugur agreed that this seemed to be the consensus.

Prof. Kühne enquired about the necessity of informing users of temperature-measuring instruments that there is a difference between thermodynamic temperature and  $T_{90}$  temperatures. At the moment, most of the temperature calibrations carried out by NMIs and accredited laboratories are done so according to  $T_{90}$ . In the future, over a large temperature range, that will continue to be the case, but increasingly, as has already started in radiation thermometry at higher temperatures, there will also be instruments measuring thermodynamic temperature directly. In the future, it is possible that there will be instruments working in the same temperature range, one type of instrument giving thermodynamic temperature and another giving  $T_{90}$ . There is a risk that this will happen soon, and if it happens there will be confusion about what is actually meant by temperature. Prof. Machin stated that ITS-90 has been disseminated for 20 years and users are not confused that they have not been informed whether it is  $T$  or  $T_{90}$ . The vast majority of people do not know and do not understand the difference. Prof. Kühne enquired what would happen if you calibrate an SPRT for a customer, do you say that it is  $T$  or  $T_{90}$ . Prof. Machin confirmed that it is  $T_{90}$ . Prof. Kühne stated his understanding was that when you calibrate at the moment, you inform users that it is a  $T_{90}$  calibration, and that will

continue in the future. If it is not  $T_{90}$ , then it must be stated that it is  $T$ , thermodynamic temperature, so that there cannot be confusion. Dr Hollandt requested confirmation of what was said and added that both  $T$  and  $T_{90}$  calibrations are already carried out at the PTB.  $T$  measurements of a high-temperature blackbody can be done with filter radiometers and provide radiation thermometers with high-temperature calibration. So far, it is not undertaken for customers because this is not covered in the present *mise en pratique* but PTB hopes to be able to officially start in the near future. Therefore, the PTB reports  $T_{90}$  in its calibration certificates (by going back to the Au point). In the future, PTB would like to have both possibilities. Dr Hollandt added that it should be stated in the calibration certificate whether it is  $T$  or  $T_{90}$ . It will not have any practical significance for users, but being an NMI it should be possible to distinguish between  $T$  and  $T_{90}$  in our calibration certificates, he says. Dr Hollandt does not foresee any practical problems. Dr Hermier agreed and suggested that  $T$  or  $T_{90}$  can be reported but he did not think that customers should be offered a choice between  $T$  or  $T_{90}$  calibrations. He suggested that we should wait for requests from customers. He explained that, if a NMI were to issue a certificate in  $T$  to a customer who then compared this with a previous certificate in  $T_{90}$ , the customer will notice that the calibration with  $T$  has a larger uncertainty than the one for  $T_{90}$ . The customer will not understand this, Dr Hermier stated.

Dr Fischer proposed that the *mise en pratique* is prepared allowing both methods, ITS-90 and thermodynamic temperature. Temperature is then disseminated and the situation is revisited after five years. If there is any confusion, NMIs can recalculate  $T$  into  $T_{90}$ . A temperature can be realized in terms of thermodynamic temperature and if the customer is not accustomed to it, they can recalculate in terms of  $T_{90}$  because the conversion is available. Prof. Machin endorsed Dr Fischer's proposal. The uncertainties under discussion are significantly smaller than the ones the customers use and require and there will not be a problem for more than five years. Prof. Ugur agreed and stated that this is probably the route to follow.

Prof. Ugur questioned whether thermodynamic experiments which will get down to the 1 ppm range in 2-3 years will be too complicated for daily purposes. Mr Liedberg replied that regardless of how people choose to measure temperatures, they need traceability to their local NMI or an NMI that is a signatory to the CIPM MRA. NMIs will not be excluded by this change. Mr White commented that the only people able to tell the difference between  $T$  and  $T_{90}$  were all seated in the room. Dr Davis added "at least we know who they are, because some of them are in their labs actually doing it". Mr Hill recalled the comment from Dr Moldover (NIST) that the differences between  $T$  and  $T_{90}$  will not necessarily show up until you have people that are able to make measurements, such as thermophysical properties, so accurately that they are sensitive to all of the little kinks and bumps and variations. Having a difference between  $T$  and  $T_{90}$  leads to a kelvin that varies in size as a function of temperature (an odd way to look at it, Mr Hill admitted) could transfer into bumps and wiggles in thermophysical properties. As far as Mr Hill can tell, especially in light of Dr Baba's presentation, the accuracies involved are so far removed from what we are able to do in temperature that it is very unlikely such features would be detected, so the practical consequences are unforeseeable in the near future, if not within the distant future. Prof. Machin reminded the CCT that  $T_{90}$  is only an approximation to  $T$  anyway. There is no prohibition on measuring  $T$  if someone wishes to do so. He stated that Dr Quinn made the same point. Prof. Wallard commented that in the real world when calibration certificates are produced and claiming traceability to the SI, the CMCs are

always  $T_{90}$ . He enquired whether there are any CMCs for  $T$ . Dr Peruzzi stated that there is another case, that of the PTB disseminating PLTS-2000. The PTB has a CMC for calibrating superconductive devices from 50 mK to 1000 mK, and in that case there is no ITS-90. Prof. Wallard responded that he was thinking of examples within the range where most real-life users measure temperature, not at the extremes. Dr Hollandt stated that he would not rule out, in the future, the PTB having CMC entries in the high-temperature range based on thermodynamic temperature because smaller uncertainties will be achieved this way. Although this will not be significant for the user, we will have this method available. Prof. Wallard claimed that it will be a very specialized class of user who is actually interested in the thermodynamic temperature rather than a certificate which is for practical purposes. Dr Davis replied that users generally want a small uncertainty – that is what we all want and that is why ITS-90 exists. Dr Yoon commented that, at high temperatures, the biggest user for  $T$  is internal to NIST because this  $T$  is used to determine the temperature of a high-temperature blackbody that is used to assign the spectral irradiance of lamps that are used to calibrate remote-sensing satellites. Remote-sensing satellites require traceability to thermodynamic units and not to a conventional unit because global-change processes are thermodynamically driven. Internal requirements are the most stringent for  $T$  at NIST. Prof. Ugur observed that the current market for thermodynamic temperature is practically zero, except internally at NIST. Dr Yoon added that if you are off by 0.5 K at 3000 K, this corresponds to 0.5 % change in the spectral irradiance at 250 nm. This can be seen very clearly by satellites that look at the UV spectrum of solar irradiance, for instance. Due to the fact that they can see this and they would like even lower uncertainties, to determine the competing models for global climate change, if you had lower uncertainties as described by Dr Fox (NPL) during the WG5 meeting, it would be possible to come to an understanding of how the climate will change much earlier than the 50 or 100 years that it takes, so that these values can be acted on to mitigate their consequences. Dr Yoon continued by stating that if you wait too long, the ‘tipping point’, as it is called will be passed, and we cannot do anything.

Prof. Ugur enquired what the probability was for one of the primary methods of measuring thermodynamic temperature being commercialized, except for radiation thermometry which is, more or less, already commercialized. Is there a chance that in the next 5 years or 15 years we will see a market emerge? Prof. Machin stated that NPL has a small project to develop a practical acoustic thermometer based on the thermodynamic method for industrial processes, and that it could potentially be commercialized. He added that the uncertainty is larger. Prof. Ugur asked if we can imagine what might be the case 10 years from now when the uncertainties will be lower and he asked Prof. Machin why the NPL is building such equipment. Prof. Machin replied that he was not at liberty to discuss the applications. Mr Strouse added that Dr Moldover has plans to develop a small acoustic gas thermometer to calibrate SPRTs, but that it is probably far in the future. Prof. Kühne stated that practical temperature scales were developed because thermodynamic thermometers were too slow, too inaccurate and too difficult to operate. As soon as somebody makes a breakthrough and can commercialize and build thermodynamic thermometers which have the small uncertainties of practical thermometers and are inexpensive, they would eliminate the need for practical scales. The practical scale is only the method we have in order to achieve the reproducibility in temperature measurement that industry requires. Prof. Ugur added that it will eventually disappear through natural evolution.

Prof. Ugur summarized the discussion by stating that there is general contentment with the existing system and that the CCT is happy to let the technology evolve and it will react to changes whenever it considers it necessary to do so.

## 7 COMPOSITION OF THE WORKING GROUPS

Prof. Ugur announced that, following final polling of CCT delegates during the last break, the selection of the chairperson for WG1 has been decided. Dr Fellmuth of PTB will be the new chairperson. Dr Fischer stated that Dr Fellmuth is prepared to fulfil the responsibilities and expressed thanks for the trust placed in Dr Fellmuth's abilities.

Prof. Ugur enquired if a vice-chairperson is required in case of absences or resignations. Prof. Wallard replied that this is not normally done but added that it was up to the CCT President and the CCT delegates. Prof. Ugur stated that the matter can be raised at the next meeting, if necessary.

Dr Davis discussed the membership of the WGs and indicated where he has questions. These are cases where e-mails addressing WG membership were not received by him in advance of the meeting. Through an active exchange with the delegates, existing memberships are confirmed and withdrawals and additions are registered with Dr Davis. Prof. Ugur stated that, as far as he knows, all of the chairpersons will be continuing. Dr Davis commented that the recent rules of the CIPM (see [CIPM-D-01](#)) state that the chairs should be renewed or changed at least every four years. Therefore it was useful for the CCT to discuss this by email correspondence before meetings. In response to a question from Dr Merlone with respect to the TG-SI, Dr Davis asked Dr Fischer if the TG is open to new members. Dr Fischer replied that the TG is open to new members, as long as they work. Dr Davis asked if anyone else wished to join, but no new members were forthcoming. Prof. Ugur enquired if the same system will be used next time, considering the savings in time at the plenary. There was little response, so Prof. Ugur declared that the correspondence mechanism will be tried once more. Mr White commented that for routine matters the correspondence method works well but it might be a different situation next time, depending on the recommendations from the strategy TG.

Prof. Ugur commented on membership of WG7. Entry into WG7 is automatic but leaving is not defined. He queried whether pilots should be accommodated indefinitely, or whether a timespan should be applied to the pilots, for example, three terms. Dr Ballico stated that it is important to have members of WG7 who are experienced in the running of the previous comparison so that they can comment on the linkage for the next set of comparisons. In that sense, the membership is really not so much of laboratories but of actual individuals who were involved in conducting the comparison and the preparation of the report. Members who are no longer at the NMI or who have retired should be removed from the list. However, most of the comparisons are still ongoing or being continually



linked. For example, K3s are run every couple of years. The K6 linkage is about to start, so it is useful if the people who were involved in K6 were around for the comparison. As long as it is possible to remove those members who are unable to actively contribute, that will be an improvement, he commented. Mr Strouse stated that if K4 were to be run again by a different pilot lab, at the conclusion of that second round the first person might step down to allow the new K4 person to take over, facilitating a transition. Prof. Ugur noted that individual memberships exist and there are no rules. If anyone wants to join WG7, until now it has been allowed. It is just a matter of logistics, and he commented that it is up to WG7, especially the chairperson, to decide if he is satisfied with the size of the group.

Dr Ballico stated that most of the work is handled electronically. He posts reports and requests everyone to review it and post their reviews on the message thread. In the chairman's report (CCT/10-28) active members were indicated. Seven members actively participated in the reviews. Some members did not participate in any reviews over a period of two years. This could however be due to there being no comparison that corresponded to their area of expertise. He stated that the situation is basically satisfactory, but members should not join unless they intend to work. He will not accept members who only intend to observe. The expectation is that people are prepared to devote their time to performing the reviews. He noted that, within the last two years, there were 15 documents to review, and some of these were 100 pages in length. When the a new protocol is submitted, it will be posted and reviewed to ensure that it complies with the CIPM MRA guidelines, makes some suggestions about linkage, the choice of the pilot, the calculation of uncertainties, and the methodology. Other criteria to be examined include whether the protocol is equivalent to the linking comparison and does it serve the needs of the participants. There will be some correspondence. He observed that most of the work occurred in the review of Draft B. EURAMET K6 was a good example, being 120 pages in length. The WG7 members would produce a list of comments and each of these comments will be followed-up with the pilot.

Prof. Ugur commented that the only proposal concerned the suggestion that if a comparison is repeated, the new pilots replace the old pilots, if they are different people. Dr Ballico replied that the first proposal is that members who are no longer members of their NMI or are no longer actively operating in that field should step down from the WG. Prof. Ugur added that, in the case of a repeated key comparison, the new pilot should replace the original pilot. Dr Fischer mentioned the withdrawal of the PTB member of WG7. Dr Davis commented that the withdrawal referred to Dr Tegeler, who drafted a key comparison report, but is now retired. Dr Ballico accepted the withdrawal, and reiterated that it is important that the list of members reflects the resources available to do the job. At the moment, it appears that there are 15 people, but in fact there are only about six people who are available to carry out any reviews. Mr Hill noted that the BIPM CC directory is out of date. Dr Davis replied that he is aware that both the web pages and the CC directory need updating. Dr Ballico suggested approaching the labs to confirm that the members are available to carry out reviews. Prof. Ugur queried the status of Dr Rusby (NPL). Prof. Machin replied that Dr Rusby is still very active and if he is required as a member of WG7, Prof. Machin is certain that Dr Rusby would be willing to contribute. Dr Ballico confirmed that Dr Rusby was one of the people who undertook some of the reviews and his continued participation would be appreciated. Prof. Ugur queried whether anyone else wanted to join WG7, other than the pilots. Mr White

commented that the chairman of WG3, who is an *ex-officio* member of WG7, has been omitted from the list.

Prof. Ugur noted that members of WG8 are not elected. Each RMO nominates its own representative. Therefore, apart from the change in representation from EURAMET, which was noted earlier, no action was required. Prof. Pokhodun commented that the work of WG8 is very sensitive because it affected every institute. He noted that there are strong and amicable relations among the members. Prof. Pokhodun mentioned that it had been a great pleasure to be a member of the WG and he thanked the chairman for his excellent leadership.

Prof. Ugur initiated the discussion on the Working Group on Strategy (WG-S). Since TG1 is nearing completion of its work, Prof. Ugur suggested that it is time to organize the WG on Strategy and elect a chairperson. Prof. Ugur noted that ToR for the WG-S already state the conditions for membership. There was no opposition to these conditions so Prof. Ugur proposed constituting the WG-S, even though it will not begin working until TG1 completes its tasks and its final report is approved by the CCT by correspondence. There were no objections. Prof. Ugur stated that one member is allowed per laboratory. He suggested that names can be sent by e-mail to Dr Davis with a copy to Prof. Ugur, since there is no need for CCT approval. Dr Davis commented that many people have already volunteered for the WG and listed the names that he has received so far: Dr Ballico, Dr Fischer, Dr Heinonen, Dr Yamazawa, Prof. Machin, Dr Pavese, and Mr Sparasci. Mr Strouse asked to be added to the list and Dr Merlone expressed his interest in joining. Dr Davis stated that an NMI could have two members if Prof. Ugur wished to make the chair of the WG an *ex officio* member. Prof. Ugur commented that, to ensure continuity, the core people will continue, including Dr Davis, Dr Pavese, and himself. Dr Davis noted that Prof. Ugur's initial idea was to have the chair of TG1 as a member. Currently it is Dr Pavese. Dr Davis thought that another member can be allowed from INRIM and Prof. Ugur had no objections. Prof. Machin stated that he has no objection to Dr Merlone joining the strategy group and thought that he will be an excellent member. Prof. Ugur's vision is that the core people will implement the methodology developed by TG1. He added that the members of the CCT, and in some cases of people who are outside of the CCT in research areas which are not yet represented in the CCT, may give their opinions on the strategy.

Prof. Ugur called for nominations to the chair of the WG on Strategy. Mr Strouse was nominated as chairman. He accepted and there were no objections.

Dr Bell queried why there are only two members of TG2, herself and the CCT President. Prof. Ugur stated that others were welcome but did not volunteer. He believes it would be useful to have more support for TG2 and would like to have two more members, especially candidates that have conducted a SWOT analysis by correspondence. Prof. Ugur commented that anyone wishing to volunteer for TG2 should send an e-mail to Prof. Ugur or Dr Bell.

Prof. Ugur queried the practice of establishing task groups (TGs) within WGs. He asked for clarification of the procedure to establish TGs within WGs and to establish the membership. Prof. Machin replied that within WG5 it was an informal process. There was a recognized need to

write the *mise en pratique* for the kelvin. Dr Yoon replied that establishment of a task group was proposed and volunteers were requested. Usually only a few people volunteered. The task group does not exist anymore because the job is finished. Prof. Ugur suggested that either this procedure is made more formal and extended to all of the CCT or such volunteer groups should be renamed to avoid confusion with the 'formal' TGs that are officially established by the full CCT. Dr Davis suggested the term 'working party'. With no substantive objections, Prof. Ugur declared that WGs are free to establish working parties as they find appropriate and they can handle the tasks, the membership, and selection of the chairperson within the WG.

## 8 OTHER BUSINESS

Dr Bell commented on the BIPM Forum. WG6 has used the BIPM Forum in the past. Her experience, and that of others, was of mixed success. Dr Bell contacted Dr Miles (BIPM Editor and Webmaster) in advance of the CCT meeting to find out if there had been any changes to the forum since some users had abandoned using it because of difficulties. There is a plan to introduce new software to operate the BIPM Forum. The new software will allow IT staff to view the status of subscribers to the forum and messages that are sent. This was not possible in the past, with reported problems being difficult to track at the BIPM. With the new software, the situation will change and it is feasible that the forum will work as intended. Alerts will be changed to draw attention to the need to subscribe to a topic. On pages where information is shown, colour highlighting or stronger visual signs can be used to show whether or not a user has subscribed to a topic. It was never clear whether there was a functional problem with the software in the past, or whether there was a difficulty with users being able to subscribe successfully and reliably to topics. The other issue regarding the change from one software package to another is that the chairs of each WG will need to identify how much of their back history needs to be migrated between the old software and the new. Mr Strouse reported that WG8 has been successfully using the software for all the purposes intended, but suggested that it may be because of the small size of the group. Dr Davis added that one of the features of new software is that there will be no limit to the size of files that can be handled. He commented that the problems are usually related to subscribing, but added that using a computer with a different architecture, different OS, or different browser may cause problems that are unanticipated by the BIPM IT staff. Dr Thomas, who is the KCDB coordinator and a non-voting member of WG7, stated that the software has been problematic but there is now a chance to introduce something much better. She considered the forum to be very useful because it keeps all information about each key comparison in one place. At the end of a comparison, the report is downloaded from the discussion forum when Dr Ballico indicates that it is appropriate to do so. If a file or an e-mail is lost, a copy is always kept safely in the forum, and Dr Thomas added that it would be very useful if all CCs used such a discussion forum. Dr Ballico commented that it has been working fairly well, but better knowledge of who subscribed to a forum would be useful. There have been delays in approving reports because members have apparently not received messages, and it was necessary to resort to e-mail. With respect to the archive, Dr Ballico stated that it is important to maintain the full history because it is essential from a quality system point of view to have the

documentary evidence of due process occurring for some of the formal approval processes. This is also the case for WG8.

## 9 NEXT MEETING

Prof. Ugur suggested that the CCT should meet every two years. Mr Strouse replied that March 2012 is the date of the next Temperature Symposium to be held in Anaheim, California, USA. Prof. Kühne stated that March is a difficult month for the BIPM because of other international meetings, the CIPM bureau meeting and normally a JCRB meeting and that May would be a better month. Prof. Kühne commented that April is normally the month for the CCQM, and he would prefer to spread the meetings over several months. He suggested that the date should not be fixed during the CCT meeting, instead it should be left to the BIPM to assess the calendar and make a suggestion. Prof. Wallard noted that the CIPM needs to approve the date. Prof. Ugur summarized that the suggestion is for mid-May 2012. Mr Hill commented that when he began attending the meetings of the CCT they were held in September and suggested that it might be preferable to split travel to the symposium in the second quarter and the CCT in the latter part of the third quarter. Prof. Ugur did not favour this suggestion, claiming that it leaves little time to prepare the minutes and the CCT report in advance of the CIPM meeting, so this would be quite stressful for the *rappporteur*, the Executive Secretary, and the President of the CCT. He would prefer at least three or four months of time to prepare the minutes of the meeting. Prof. Machin suggested that two year's time will provide a good opportunity to review progress with the Boltzmann constant. Prof. Ugur queried the format of the meeting and asked if delegates are satisfied with 1.5 days for the CCT plenary meeting, a half-day plenary workshop on a topic to be decided and two days for WG and TG meetings. If so, he proposed that the workshop be scheduled for Thursday morning, with the CCT plenary meeting beginning in the afternoon. He suggested that papers should be submitted two months prior to the meeting and elections should be completed by e-mail prior to the meeting.

[Note: Subsequent to the adjournment of the CCT meeting, the dates of 21-25 May 2012 have been reserved by the BIPM for the next CCT meeting.]

## 10 REPORTS TO THE CIPM AND CGPM

Prof. Ugur asked Prof. Kühne about the deadline for the CCT report to the CGPM meeting in 2011. Prof. Wallard replied that documentation for the General Conference begins to be disseminated during the preceding December-January. This includes the convocation, part of the CIPM President's report, and the proposed programme of work of the BIPM. The written reports of the CC Presidents would normally be completed three months or so in advance of the CGPM. Prof. Ugur requested that chairs of WGs, TGs and pilot laboratories provide him with a report by the end of

April 2011. He spends a considerable amount of time producing his report and the accompanying oral presentation. Prof. Kühne mentioned that the CC reports require translation into French and that takes a considerable amount of time because there are 10 reports to be translated, so it would be advisable to have the President's reports submitted by the end of April 2011. Prof. Ugur requested the members of the CCT send him their WG, TG, and pilot reports by the end of March 2011. He added that he will try to remind people to send the reports.

Prof. Ugur explained that, as for his report to the CIPM, he has the written reports of the WGs from this meeting. In March 2011, he will receive the inputs from the CCT for his report to the CGPM.

## 11 CCT MEMBERSHIP APPLICATIONS

Prof. Ugur stated that an application for membership of the CCT has been received from IPQ. He will propose to the CIPM that IPQ, which is at present an observer, should become a full member. He commented that the CCT decided that any new applicants should make a 10-15 minute presentation followed by discussions. The CCT membership will then express their opinions. Based on those opinions, Prof. Ugur will take the issue to the CIPM. The planned presentation from NIS, Egypt, has been postponed because the responsible person was unable to attend the CCT meeting. The presentation has been rescheduled for the next CCT plenary meeting. Prof. Ugur has two questions for new applicants: why do you think you deserve to be in the CCT and how can you contribute to the CCT. These are also valid questions for the existing members as well, because as Dr Fischer stated earlier, the CCT prefers members who intend to work. Prof. Ugur stated that there is a need for members of WGs and TGs who really contribute to the system and added that the CIPM is considering what actions to take if some CC members or observers consistently fail to contribute (an issue for all CCs, not just the CCT).

Prof. Ugur summarized his recommendations for 2010. As far as he is aware there are no new applications. He added that in his view, after a laboratory has been admitted to the CCT as an observer, and depending on their activities within the WGs and comparisons, a presentation is no longer needed. The CCT President intends to follow this unwritten rule. Dr Davis commented that MIKES is currently an observer, but had applied to become a member. Prof. Ugur commented that an agreement with MIKES is already in place with respect to the next steps. Dr Davis suggested that it would be helpful if current observers express a desire to become a full member, should they wish to do so. Prof. Ugur commented that in practice there is very little distinction between observers and full members. The issue of participation in comparisons will probably be resolved by the CIPM. The only remaining formality is on paper, so his view is that observers should feel no pressure to become full members. However, if they do wish to become members, then the paperwork is very important.

Prof. Ugur enquired if there are likely to be any new applications to join the CCT. Dr Davis replied that no such requests have been received.

## 12 RECOMMENDATIONS TO THE CIPM

Recommendation T1 was approved by the CCT delegates earlier in the meeting. Recommendations T2 and T3 are still pending.

Prof. Ugur called for discussion of Recommendation T3, which concerns the relationship between the CCT and the WMO. Dr Merlone explained that the basis for the current discussion was the suggestion to turn CCT/10-09 into a Recommendation to the CIPM. The recommendation came through WG2 since it was felt that the instrumentation used for meteorological and climate studies fell within the scope of WG2, but Dr Merlone commented that it was decided to write the recommendation in a more general way. He discussed the improvements to the draft recommendation that were made during the meeting of the CCT. It was noted that the WMO had signed the CIPM MRA. The CCT, CCQM, and CCPR were specifically mentioned at the WMO/BIPM workshop, but the draft recommendation was left in a more general form without explicit reference to the particular CCs that are likely to be involved. Five bullet points have been defined taking into account the results of the meetings and also some projects involving the NMIs. Several CCT delegates requested clarification regarding the wording, especially as it may prove problematic for translation into French. Dr Merlone explained that some terms are jargon commonly used by the WMO, for example “long terms and wide scales”. Prof. Kühne noted that T3 is a recommendation from the CCT to the CIPM, and informed the meeting that there was a similar recommendation from the CCQM to the CIPM. He expects the CIPM to draft a resolution that will be put before the CGPM for adoption by the member states. The text, or at least the ideas, from both recommendations will be merged into one draft resolution. Discussions on the wording continue, specifically concerning the phrase “climate change and monitoring communities”. Recommendation T3 was approved (see Appendix to this report).

Dr Fischer presented an improved version of Recommendation T2, highlighting the modified section to the delegates. After a brief discussion, Prof. Ugur concluded that the CCT was satisfied with the wording and congratulated Dr Fischer for the good work. Recommendation T2 was approved (see Appendix to this report).

## 13 ADJOURNMENT OF THE MEETING

Prof. Wallard reminded the delegates of World Metrology Day on 20 May 2010 ([www.worldmetrologyday.com](http://www.worldmetrologyday.com)) and asked the members to relay any news of local events so that they can be added to the BIPM database. Prof. Ugur thanked the members, the chairs of the WGs and TGs, the pilot laboratories, and the *rapporteur*. He thanked Dr Davis especially for his hard work and expressed his pleasure and honour for having had the opportunity to work with him, and stated that he had benefited very much from having Dr Davis within the CCT. Prof. Ugur also stated that he is looking forward to working with Mr Picard at the next meeting of the CCT in two years. He noted that Prof. Wallard will be leaving as well, but that it would be nice to see him at the next CCT, much like Dr Quinn. Prof. Ugur is looking forward to working with Prof. Kühne as the new Director of the BIPM. Since the CCT has decided to hold the next CCT meeting two years hence, Prof. Ugur expects to be back again with the new CCT President-elect and they will work together for a smooth transition.

## **RECOMMANDATIONS DU COMITÉ CONSULTATIF DE THERMOMÉTRIE PRÉSENTÉE AU COMITÉ INTERNATIONAL DES POIDS ET MESURES**

### **RECOMMANDATION T 1 (2010) :**

#### **Mission du CCT**

Le Comité consultatif de thermométrie (CCT) recommande au CIPM d'approuver la description de ses missions présentée ci-après.

Les missions du CCT sont de :

- s'assurer que les unités du SI utilisées pour exprimer les valeurs des grandeurs se rapportant à la métrologie thermique sont réalisées et disséminées dans le monde entier de façon uniforme et adéquate, afin d'établir et de maintenir la compatibilité de l'ensemble des mesures en promouvant leur traçabilité au SI,
- conseiller le CIPM sur toutes les questions scientifiques ayant des incidences sur la métrologie thermique, y compris sur les activités du programme scientifique du BIPM dans ce domaine, et vérifier que les actions requises par le CIPM à ce sujet sont bien mises en œuvre.

La métrologie thermique comprend les domaines de la température, de l'énergie thermique (chaleur), de l'humidité et des propriétés thermophysiques.

Pour remplir ses missions, le CCT :

- émet des recommandations sur la définition et la réalisation de l'unité de température du SI - le kelvin, des échelles de température, et des grandeurs dérivées se rapportant à la métrologie thermique,
- informe les laboratoires nationaux de métrologie et leur recommande d'engager des recherches dans le domaine de la métrologie thermique, afin de s'assurer que le SI est correctement mis en œuvre, en particulier en ce qui concerne le kelvin et sa définition, ainsi que les unités des grandeurs dérivées se rapportant à la métrologie thermique,
- informe les laboratoires nationaux de métrologie et leur recommande d'engager des recherches dans le domaine de la métrologie thermique, afin de s'assurer qu'ils répondent aux besoins en constante évolution de la communauté scientifique, des entreprises et de la société,
- s'engage dans des concertations officielles et, lorsque cela est nécessaire, établit des collaborations avec les parties intéressées afin d'identifier les besoins et les défis métrologiques actuels et à venir, et facilite la mise en place de solutions interdisciplinaires appropriées,
- met en place les activités requises par le CIPM MRA en matière de métrologie thermique, telle que la supervision des comparaisons clés et des aptitudes en matière de mesures et d'étalonnages,



- conseille les utilisateurs de la métrologie thermique afin qu'ils réalisent et disséminent correctement le kelvin et les unités dérivées se rapportant à la métrologie thermique, en utilisant notamment les méthodes appropriées d'évaluation de l'incertitude pour les mesures concernées,
- conseille les utilisateurs de la métrologie thermique sur les mesures effectuées dans le domaine de la température, de l'énergie thermique (chaleur), de l'humidité ou des propriétés thermophysiques, et notamment sur les méthodes appropriées d'évaluation de l'incertitude,
- joue pour ses membres le rôle d'un forum d'échange d'informations techniques et scientifiques sur leurs activités et leur permet d'établir de nouvelles collaborations,
- identifie et collecte les résultats qui démontrent la valeur des progrès effectués dans le domaine de la métrologie thermique, et les transmet aux parties intéressées,
- accomplit toute autre mission requise par le CIPM en matière de métrologie thermique, tel qu'indiqué dans la section « Responsibilities of Consultative Committees » du document CIPM-D-01.

## RECOMMANDATION T 2 (2010) :

### Considérations sur une nouvelle définition du kelvin

Le Comité consultatif de thermométrie (CCT),

*rappelant* le précédent rapport qu'il a présenté au CIPM en 2007 (*Report to the CIPM on the implications of changing the definition of the base unit kelvin* - [TG-SI/docs05](#)),

#### *considérant*

- les discussions qui en ont découlé lors des 24<sup>e</sup> et 25<sup>e</sup> sessions du CCT en 2008 et en 2010,
- les récents progrès des expériences entreprises afin de déterminer la valeur de la constante de Boltzmann,  $k$ , évoqués lors des 3<sup>e</sup> et 4<sup>e</sup> ateliers *Progress in Determining the Boltzmann Constant* organisés en 2008 et en 2009, ainsi que
- les progrès d'autres expériences permettant d'établir la mise en pratique de la nouvelle définition du kelvin qui existe déjà et que l'on étend à présent afin de couvrir les mesures directes de la température thermodynamique,

#### *notant*

- que diverses expériences, telles que la thermométrie acoustique à gaz, la thermométrie à gaz par mesure de la constante diélectrique, la thermométrie à bruit de Johnson, la thermométrie à rayonnement total ou la thermométrie par mesure de l'élargissement Doppler, constituent des voies distinctes pour déterminer la valeur de la constante de Boltzmann,
- qu'en ce qui concerne les expériences actuellement en cours visant à mesurer  $k$ , deux années supplémentaires sont nécessaires avant que CODATA ne puisse recommander une valeur robuste pour  $k$  avec une incertitude-type relative réduite d'un facteur de l'ordre de deux par rapport à l'incertitude actuelle,  $u_r$ , d'environ  $2 \times 10^{-6}$ ,

- qu'une fois le kelvin redéfini, une incertitude-type relative de  $1 \times 10^{-6}$  pour  $k$  correspondra à une incertitude-type d'environ 0,25 mK de la température du point triple de l'eau,

*appréciant* les considérables progrès des expériences en cours pour déterminer la valeur de la constante de Boltzmann afin d'accroître la confiance vis-à-vis de la valeur actuelle,

*recommande*

- d'obtenir une incertitude-type relative de la valeur de  $k$  de l'ordre de  $1 \times 10^{-6}$ , fondée sur des mesures obtenues à partir de différentes méthodes de thermométrie primaire, avant de procéder à la redéfinition du kelvin,
- d'inclure à ces mesures, dans l'idéal, au moins deux méthodes fondamentalement distinctes, telles que la thermométrie acoustique à gaz et la thermométrie à gaz par mesure de la constante diélectrique, et de les corroborer par des mesures obtenues à partir d'autres méthodes, telles que la thermométrie à bruit de Johnson, la thermométrie à rayonnement total ou la thermométrie par mesure de l'élargissement Doppler,
- d'adopter la valeur recommandée par CODATA pour la constante de Boltzmann.

### **RECOMMANDATION T 3 (2010) :**

#### **Sur les mesures liées au climat et aux observations météorologiques**

Le Comité consultatif de thermométrie (CCT),

*considérant*

- que la collection de résultats concernant la température moyenne à la surface du globe est essentielle pour comprendre les mécanismes du changement climatique,
- que le changement climatique a de profondes répercussions sur différents aspects de la vie sociale, politique et économique,
- qu'il est nécessaire d'améliorer la qualité des résultats collectés en assurant la traçabilité mondiale des mesures requises pour les études climatiques et les observations météorologiques, comme l'ont demandé les utilisateurs de données sur le climat et tel que cela a été exprimé lors de l'atelier commun au BIPM et à l'OMM intitulé « Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty », qui s'est tenu à Genève en mars 2010,
- que la signature du CIPM MRA par l'OMM conduira celle-ci à avoir des relations plus étroites et à collaborer avec la communauté de la métrologie thermique,
- que la recherche et l'analyse coordonnée sont des pré-requis à la mise en place d'un réseau mondial de données traçables de référence, nécessaire au développement de modèles plus précis du changement climatique,

*recommande*

- d'encourager les laboratoires nationaux de métrologie et la communauté scientifique, en particulier les métrologistes spécialisés dans le domaine de la température, à se préparer à

affronter de nouveaux besoins, perspectives, projets et activités liés à la traçabilité, l'assurance qualité, les procédures d'étalonnage et les définitions des grandeurs utilisées dans les études climatiques et les observations météorologiques,

- d'inciter les laboratoires nationaux de métrologie et les institutions météorologiques à entretenir des relations solides, aussi bien au niveau local que national ou international,
- d'encourager les laboratoires nationaux de métrologie à travailler avec les réseaux météorologiques appropriés afin de mettre en place une structure de surveillance de résultats traçables sur le climat s'inscrivant sur le long terme, de grande envergure, et fondée sur les meilleures pratiques métrologiques,
- d'étudier les moyens les plus efficaces pour que les Comités consultatifs ayant des activités liées au climat et à l'environnement coopèrent afin de parvenir à une stratégie commune pour répondre aux besoins exprimés par la communauté météorologique,
- d'encourager les Comités consultatifs à informer leurs groupes de travail des besoins en matière de mesures, d'étalonnage et d'assurance qualité exprimés par les communautés travaillant sur le changement climatique et sa surveillance.

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

### **RECOMMENDATION T 1 (2010):**

#### **Mission of the CCT**

The Consultative Committee for Thermometry (CCT) recommends that the following mission statement be approved.

The mission of the CCT 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 includes temperature, thermal energy (heat), humidity and thermophysical properties.

This mission is achieved through:

- providing recommendations for the definition and realization of the SI unit of temperature, the kelvin, and of temperature scales, and of derived quantities relevant to thermal metrology;
- informing and recommending research on thermal measurement to the NMIs to ensure the appropriate development of the SI, especially in relation to the kelvin, including its definition, and that of the units of derived quantities relevant to thermal metrology;
- informing and recommending research on thermal measurement to the NMIs to ensure that they continue to meet the developing needs of science, enterprise and society;
- undertaking formal consultation and where appropriate collaboration with stakeholders to identify current and future metrological needs and challenges, facilitating the development of appropriate and cross-disciplinary solutions;
- implementing duties required by the CIPM MRA relevant to thermal metrology, including oversight of key comparisons and CMCs;
- providing appropriate guidance to all thermal metrology users for the proper realization and dissemination of the kelvin and derived units relevant to thermal metrology, including methods for evaluating uncertainty in the relevant measurements;
- providing guidance to all thermal metrology users for the measurement of temperature, thermal energy (heat), humidity and thermophysical properties, including methods for evaluating uncertainty;

- acting as a forum for the exchange of scientific and technical information about the activities of its members and create opportunities for collaboration;
- identifying, collating and transmitting to stakeholders evidence of the value of developments in thermal metrology;
- implementing any other duties required by the CIPM relevant to thermal metrology, as stated in the document “Responsibilities of Consultative Committees”.

## RECOMMENDATION T 2 (2010):

### Considerations for a new definition of the kelvin

The Consultative Committee for Thermometry (CCT),

*recalling* its previous Report to the CIPM in 2007, entitled “Report to the CIPM on the implications of changing the definition of the base unit kelvin”, [TG-SI/docs05](#), and

#### *considering*

- further discussion at its 24<sup>th</sup> and 25<sup>th</sup> meetings held in 2008 and 2010,
- recent progress in experimental determinations of the Boltzmann constant,  $k$ , as reported at the 3<sup>rd</sup> and 4<sup>th</sup> International Workshops on Progress in Determining the Boltzmann Constant held in 2008 and 2009 and
- other experimental progress allowing a *mise en pratique* for the new definition of the kelvin already established and presently extended to cover direct measurement of thermodynamic temperature,

#### *noting*

- that various experiments, such as acoustic gas thermometry, dielectric constant gas thermometry, Johnson noise thermometry, total radiation thermometry and Doppler broadening thermometry represent distinct routes to determining the Boltzmann constant,
- that the experiments currently underway to measure  $k$  need another two years before CODATA can recommend a robust value for  $k$  with a relative standard uncertainty about a factor of two smaller than the current  $u_r$  of approximately  $2 \times 10^{-6}$ .
- that a relative standard uncertainty of  $1 \times 10^{-6}$  in  $k$  corresponds to a standard uncertainty of about 0.25 mK in the temperature of the triple point of water after the redefinition,

*appreciating* the considerable progress of ongoing experiments to determine the Boltzmann constant in order to improve confidence in the present value,

#### *recommends*

- that before proceeding with the redefinition of the kelvin a relative standard uncertainty of the value of  $k$  of order one part in  $10^6$  be obtained, based on measurements applying different methods of primary thermometry,

- that these measurements ideally include at least two fundamentally different methods such as acoustic gas thermometry and dielectric constant gas thermometry and be corroborated by other measurements such as Johnson noise thermometry, total radiation thermometry or Doppler broadening thermometry,
- that the CODATA recommended value be adopted for the Boltzmann constant.

### **RECOMMENDATION T 3 (2010)**

#### **On climate and meteorological observations measurements**

The Consultative Committee for Thermometry (CCT),

*considering that*

- global average temperature records are essential in understanding how the climate is changing;
- the consequences of these changes have deep impacts on different aspects of social, political and economic life;
- the need exists to improve the quality of data collection by assuring worldwide traceability in measurements involved in climate studies and meteorological observations, as expressed by climate-data users and during the recent WMO-BIPM joint workshop on "Measurement Challenges for Global Observation Systems for Climate Change Monitoring: Traceability, Stability and Uncertainty " (Geneva March 2010);
- the signing of the MRA by WMO will lead to closer liaison and cooperation with the thermal metrology community;
- research and coordinated analysis is required to build up a worldwide network supplying traceable baseline data sets, needed to develop more accurate models for climate change;

*recommends*

- to encourage NMIs and the scientific community, especially temperature metrologists, to be prepared to face new perspectives, needs, projects and activities related to the traceability, quality assurance, calibration procedures and definitions for those quantities involved in the climate studies and meteorological observations;
- to support a strong cooperation between NMIs and Meteorological Institutions at local, national and international levels;
- to encourage NMIs to work with the relevant meteorological networks to support a monitoring framework for traceable climate data over long temporal terms and wide spatial scales based on best practice metrology;
- to consider the most effective means by which CCs involved in climate and environmental activities should cooperate in order to establish a common response to the stated needs of the meteorological community; and
- to encourage CCs to alert their relevant Working Groups to the measurement, calibration and quality assurance needs of the climate change and monitoring communities.

**APPENDIX 1.****Working documents submitted to the CCT at its 25th meeting**

Open working documents of the CCT can be obtained from the BIPM in their original version, or can be accessed on the BIPM website:

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

Documents restricted to Committee members can be accessed on the [restricted-access](#) CCT website.

## Document

## CCT/

- |                            |  |
|----------------------------|--|
| 10-01                      | Draft Agenda (2) -- 7 March 2008, 1pp.   |
| 10-02/rev1                 | Abstracts of CCT Workshop (revised), G.F. Strouse, 4pp.  |
| 10-03                      | ITS-90 Inconsistency for standard platinum resistance thermometers in the sub-range 0 °C to 419.527 °C, S. Jianping and K. Zhiru (submitted by NIM), 6pp.                              |
| 10-04                      | A suggestion of controlling ITS-90 inconsistency in the SPRT range, K. Zhiru <i>et al.</i> (submitted by NIM), 19pp.   |
| 10-05                      | A comment on the proposed new definition of the temperature unit based on the Boltzmann constant, F. Pavese, 2pp.  |
| 10-06/rev2                 | Status of progress towards the determination of the relationship between neon triple-point temperature $T_{tp}$ and isotopic amount composition $22x$ , F. Pavese <i>et al.</i> , 8pp. |
| 10-07                      | How well founded are the temperature-based discussions concerning the environment? - A challenge for the CCT, F. Pavese, 2pp.  |
| 10-08                      | Proposals for establishing a CCT strategy, F. Pavese, 8pp.   |
| 10-09                      | Temperature metrology needs for climate studies, A. Merlone and G. Lopardo, 5pp.   |
| 10-10                      | About the extrapolation at 77 K for SPRTs calibrated in the 83 K - 273 K temperature range, Y. Hermier <i>et al.</i> , 3pp.  |
| <a href="#">10-11</a>      | Index of refraction effects in blackbody temperature measurements, A.A. Gaertner, 4pp.   |
| <a href="#">10-12/rev1</a> | Realisation and dissemination of thermodynamic temperature above the silver point (1234.93 K), G. Machin <i>et al.</i> (WG5), 31pp.  |
| <a href="#">10-13</a>      | MeP-K direct methods, G. Machin <i>et al.</i> (WG5), 6pp.  |
| <a href="#">10-14</a>      | MeP-K Indirect methods, G. Machin <i>et al.</i> (WG5), 4pp.  |
| <a href="#">10-15/rev2</a> | Working Group 4 Report to CCT; 05 May 2010, J. Fischer, 3pp.   |

- [10-16](#) Task Group on the SI (TG-SI) Report to CCT, J. Fischer, 2pp.
- [10-17](#) Extension of thermodynamic temperature data up to 36 K with dielectric-constant gas thermometry using  $^3\text{He}$ ,  $^4\text{He}$  and Ne as measuring gases, C. Gaiser and B. Fellmuth, 3pp.
- 10-18 Report of Working Group 6 on Humidity Measurements to the 25th meeting of the CCT, 2010, S. Bell, 2pp.
- 10-19 A procedure for estimating ideal freezing temperatures using the gradient of the freezing plateau, J.C. Greenwood *et al.*, 12pp.
- 10-20 Uncertainties in the extrapolation of SPRT calibrations in the ITS-90 below the triple point of argon, 83.8058 K, R. Rusby, 3pp.
- [10-21](#) Extrapolation of the ITS-90 down to the boiling point of nitrogen from the triple point of argon, T. Nakano and O. Tamura, 7pp.
- [10-22](#) Direct cell comparison for evaluation of impurity effect in fixed-point realization, J.V. Widiatmo *et al.*, 4pp.
- [10-23/rev](#) The resistance ratio criteria of PRTs as interpolating instruments for ITS-90, K. Yamazawa *et al.*, 4pp.
- 10-24 Working Group 8 Report to CCT: May 2010, G. Strouse, 2pp.
- [10-25/rev1](#) CCT - WG5 Activity Report to CCT, G. Machin, 4pp.
- 10-26 DRAFT OUTLINE of the *Mise en pratique* for the definition of the kelvin, D.C. Ripple (submitted by NIST), 4pp.
- 10-27 The roles of the *mise en pratique* for the definition of the kelvin, D.C. Ripple *et al.* (submitted by NIST), 14pp.
- 10-28 Report on the activities of the CCT-WG7 June 2008 - April 2010, M. Ballico, 3pp.
- 10-29 Report Presented to the CCT by Working Group 1: May 2010, D.C. Ripple, 2pp.
- 10-30 Study on the realization of the superfluid transition temperature of helium in the past ten years, L. Peng (submitted by NIM), 8pp.
- 10-31 Working Group 2 report to the CCT, May 2010, H. Liedberg, 2pp.
- 10-32 Further supporting material regarding extrapolation from Ar TP down to 77 K, P.M. Steur, 1pp.
- 10-33 Working Group 3 Report to CCT: May 2010, D.R. White, 11pp.
- 10-34 Possible consequences of the redefinition of kelvin and recommendation to CCT and CIPM, A.I. Pokhodun, 2pp.
- [10-35/rev1](#) The discontinuity in T90 at the triple point of water, R. White, 5pp.
- 10-36 Working Group 9 report to CCT (Draft), May 2010, T. Baba, 2pp.
- 10-37 CCT Workshop “Design and Implementation of Key Comparisons”: Abstracts & Presentations W. Guthrie, P.M. Harris, R. White, M. Heinonen, 4pp.
- [10-38](#) Minutes of CCT-WG5 Meeting, G. Machin, 8pp.