

Bureau International des Poids et Mesures

# **Consultative Committee for Mass and Related Quantities (CCM)**

Report of the 11th meeting  
(24-25 April 2008)  
to the International Committee for Weights and Measures



Note:

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

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

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

A.J. Wallard,  
Director BIPM

**LIST OF MEMBERS OF THE  
CONSULTATIVE COMMITTEE FOR  
MASS AND RELATED QUANTITIES**

as of 24 April 2008

**President**

Dr M. Tanaka, member of the International Committee for Weights and Measures, National Metrology Institute of Japan, AIST, Tsukuba.

**Executive Secretary**

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

**Members**

Central Office of Measures/Główny Urzad Miar [GUM], Warsaw.

Centro Español de Metrología [CEM], Madrid.

Centro Nacional de Metrología [CENAM], Querétaro.

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

Federal Office of Metrology [METAS], Bern-Wabern.

Istituto Nazionale di Ricerca Metrologica [INRIM], Turin.

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

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

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

National Institute of Metrology [NIM], Beijing.

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

National Measurement Institute of Australia [NMIA], Lindfield.

National Metrology Institute of Japan, AIST [NMIJ/AIST], Tsukuba.

National Metrology Institute of South Africa [NMISA], Pretoria.

National Physical Laboratory [NPL], Teddington.

National Research Council of Canada [NRC-INMS], Ottawa.

Nederlands Meetinstituut, Van Swinden Laboratorium [NMi VSL], Delft.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

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

Technical Research Institute of Sweden [SP], Borås.

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

**Observers**

National Metrology Institute of Turkey/TÜBITAK Ulusal Metroloji Enstitüsü [UME], Gebze-Kocaeli.

National Physical Laboratory of India [NPLI], New Delhi.

**1 OPENING OF THE MEETING;  
APPROVAL OF THE AGENDA;  
APPOINTMENT OF A RAPPOREUR**

The eleventh meeting of the Consultative Committee for Mass and Related Quantities (CCM)<sup>\*</sup> was held at the International Bureau of Weights and Measures (BIPM), at Sèvres, on 24 and 25 April 2008.

The following were present: R. Arias (CENAM), H. Baumann (METAS), L.O. Becerra (CENAM), W. Bich (I.N.R.I.M), S. Davidson (NPL), N.G. Domostroeva (VNIIM), P. Farár (SMU), K. Fujii (NMIJ/AIST), A. Germak (I.N.R.I.M), M. Gläser (PTB), Z.J. Jabbour (NIST), C. Jacques (NRC-INMS), Y.A. Kiselev (VNIIM), J.-C. Legras (LNE), E. Maczewska (GUM), J. Man (NMIA), M. Medina Nieves (CEM), P.-A. Meury (LNE), A. Ooiwa (NMIJ/AIST), P. Pinot (LNE-INM/Cnam), P. Richard (METAS), J.A. Robles Carbonell (CEM), R. Schwartz (PTB), I. Severn (NPL), R. Spurný (SMU), C.M. Sutton (MSL), M. Takamoto (NIMJ/AIST), M. Tanaka (President of the CCM), I. van Andel (NMi VSL), B. van der Merwe (NMISA), A.J. Wallard (Director of the BIPM), S.Y. Woo (KRISS), Yue Zhang (NIM).

Observers: A.K. Bandyopadhyay (NPLI), C. Dogan (UME).

Invited: H. Bauer (PTB), P. Becker (PTB), C. Buchner (BEV), H.A. Chua (A\*STAR), K. Jousten (PTB), R. Kumme (PTB), L. Nielsen (DFM), C. Santo (LATU and SIM), D. Tonui (KEBS and SADCMET).

Also present: T.J. Quinn (Director Emeritus of the BIPM); P. Barat, R.S. Davis (Executive Secretary of the CCM), H. Fang, C. Goyon-Taillade, A. Kiss, A. Picard, C. Thomas (KCDB Coordinator), L. Vitushkin (Chairman of the Working Group on Gravimetry) (BIPM).

Excused: A.K. Agarwal (NRC-INMS), V.N. Gorobey (VNIIM), S. Hurtig (SP), I. Kocas (UME).

Dr Mitsuru Tanaka (CCM President, CIPM and NMIIJ) welcomed delegates to the 11th meeting of the CCM. He said that the 23rd meeting of the General Conference on Weights and Measures (CGPM), outlining future activities of BIPM, had highlighted work in the mass area, particularly with respect to the redefinition of kilogram. Dr Tanaka said this gave added significance to the outcomes of this meeting of the CCM.

Professor Andrew Wallard (Director of the BIPM) welcomed delegates and stressed the importance of the work of the CCM, particularly with regard to the proposed redefinition of the SI unit of mass.

The agenda was approved.

Dr S. Davidson (NPL) was designated as rapporteur.

All delegates, experts, official observers, guests and BIPM attendees introduced themselves.

Dr Tanaka outlined minor changes to the agenda. Delegates from new and potential members of the CCM would make presentations giving an overview of the work of their institutes in the area of mass and related quantities.

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\* For the list of acronyms, [click here](#).

## 2 WORKING GROUP REPORTS (PART 1)

### 2.1 Report from the Working Group on Mass Standards (Dr Philippe Richard, METAS)

The last meeting was held on 18 April 2008 at the BIPM.

The terms of reference, as discussed at the working group meeting were outlined. They are:

- To study, develop and advise the CCM on issues related to mass standards.
- To define, organize and approve the necessary key comparison.
- To collaborate with the WG on changes to the SI kilogram, TG 1, TG 2 and other relevant WGs.

The meeting had 24 participants and 17 scientific reports were given, engendering much discussion. Dr Richard presented extracts from the presentations, illustrating the breadth of science discussed, these included: new automatic (vacuum) mass comparators, automation of weighing, large mass measurement, micro-mass and nano-force research, mass in vacuum data, surface studies of mass standards, cleaning of primary mass standards, storage of standards in vacuum and inert gas, magnetic coupled vacuum/air comparison system and new materials for mass standards.

Dr Davis had reported on the CIPM 2007 formula for the determination of air density, published in *Metrologia* in February 2008. Buoyancy corrections for stainless steel/platinum-iridium comparisons increase by approximately 7 µg as a result of the change in the calculated value of air density. Dr Davis suggested that, when appropriate, certificates and calibration reports state that the new 2007 formula has been used to determine air density and that this introduces a small shift in the values of all stainless steel weights.

Dr Richard presented data from CCM one kilogram key comparisons (KCs), [CCM.M-K1](#) and [CCM.M-K4](#) and linked RMO KCs, commenting that this was currently the most complete graph of equivalence in the KCDB. The status of projects [CCM.M-K1](#), [CCM.M-K2](#), [CCM.M-K3](#), [CCM.M-K3.1](#), [CCM.M-K4](#), and [CCM.M-K5](#), were outlined. Three new comparisons, [CCM.M-K6](#), -K7, and -K8, were proposed.

Dr Richard presented visions and challenges in mass metrology. Two new Task Groups had been set up:

- Task Group 1: Mass metrology under vacuum for a *mise en pratique* and
- Task Group 2: Uncertainty components due to traceability to the international prototype of the kilogram.

Other areas of importance discussed included materials for mass standards (which need to be watt balance and vacuum compatible), new reproducible techniques for the cleaning of mass standards, storage of mass standards to optimise stability and allow transfer between apparatus, mass comparison in vacuum and air/vacuum transfer of standards to provide traceability for the Avogadro and watt balance experiments, and micro- and nano-mass and force measurement.

The BEV (Austria) had been proposed as a new member of the working group and accepted by all members. The UME (Turkey) had also been proposed but, since they had not sent a representative to the meeting, membership was postponed.

Dr Tanaka asked the CCM to approve the new member – there were no objections.

Dr Tanaka asked for clarification of range of mass covered by the micro- and nano-mass and force projects. Dr Richard said that micro-mass covered weights down to 100 µg and the nano-force area covered smaller forces. Dr Tanaka commented on the importance of future research in the nano-force area.

Dr Tanaka asked for approval of the proposed new key comparisons. There were no objections.

## **2.2 Report from the Working Group on Density (Dr Kenichi Fujii, NMIJ)**

The last meeting was held on 22 April 2008 at the BIPM.

Dr Fujii presented the status of CCM key comparisons in the area of density. [CCM.D-K1](#), density measurements of a silicon sphere by hydrostatic weighing, is complete and the final report has been approved. For [CCM.D-K2](#), liquid density standards, circulation of the Draft A report is imminent. [CCM.D-K3](#), solid density standards (stainless steel), is in the planning stage and [CCM.D-K4](#), hydrometers, is planned to start this year and will draw knowledge from the RMOs on the best way to implement the comparison.

There are eight RMO key comparisons registered in the field of density and status details were presented. EURAMET had completed [EUROMET.M.D-K1](#), [EUROMET.M.D-K2](#) and [EUROMET.M.D-K4](#) and project reports had been presented and accepted. Detailed reports of [APMP.M.D-K4](#) and SIM.7.33 (hydrometry comparison) were presented at the meeting.

Eleven further bilateral comparisons had been undertaken, details are:

1. Peuto A.M., Sacconi A., Mosca M., Fujii K., Tanaka M., Nezu Y., Comparison of Silicon Density Standards at NRLM and IMGC, *IEEE Trans. Instrum. Meas.*, 1993, **42**(2), 242-246.
2. Bettin H., Gläser M., Spieweck F., Toth H., Sacconi A., Peuto A.M., Fujii K., Tanaka M., Nezu Y., International Intercomparison of Silicon Density Standards, *IEEE Trans. Instrum. Meas.*, 1997, **46**(2), 556-559.
3. Chang K.-H., Lee Y.-J., Chung J.W., Final Results of Bilateral Density Comparison between NMIJ and KRISS for 1 kg Weight, *KRISS/MO-2001-058*, June 2001.
4. Bettin H., Toth H., Waseda A., Fujii K., Comparison of density difference measurements at PTB and NMIJ, *IEEE Trans. Instrum. Meas.*, 2005, **54**(2), 877-881.
5. Bilateral comparison on hydrometers calibration between INRIM-Italy and CENAM-Mexico. Status: Measurement in progress.
6. SIM.7.34-B: Bilateral comparison on volume of solids by hydrostatic weighing between CENAM-Mexico and INMETRO-Brazil. Status: Protocol in preparation (Report in progress).
7. Lorefice S., Heinonen M., Madec T., Bilateral comparisons of hydrometer calibrations between the IMGC-LNE and the IMGC-MIKES, *Metrologia*, 2000, **37**(2), 141-147.
8. International comparison of absolute volume calibrations by optical interferometers at NMIJ, PTB, and NMIA (2006-2007). Status: Measurement in progress.
9. Bilateral comparison of absolute volume calibrations by optical interferometers at NMIJ and KRISS (2006-2007). Status: Measurement in progress.

10. Bilateral comparison of absolute volume calibrations by optical interferometers at NMIJ and NIM (2008). Status: Planned.
11. Riski K., Mass and volume comparisons at MIKES – Additional results to the EA intercomparison of weights 1 mg – 100 g (Ma1) and to the EUROMET intercomparison of ceramic spheres (EUROMET 339), *Julkaisu J4/2000*.

Acceptance of CMCs had been discussed with respect to limited number of KCs undertaken in the area and the relative uncertainties of these comparisons. It had been decided that the results of CCM.M.D-K1, density measurement of a Si sphere by hydrostatic weighing (and equivalent regional KCs) could be accepted for CMCs for stainless steel density measurements since CCM.M.D-K1 was the only solid density KC available at present. However it had been decided that the results of -K1 were not sufficient to support liquid density and hydrometry CMC submissions. The acceptance of CMCs was discussed, specifically with reference to hydrometry. It had been decided that CMCs for hydrometry calibration over the temperature range 5 °C to 30 °C could be accepted despite the fact that the KC only covered calibrations undertaken at 20 °C.

Reference values of the density of water had been discussed. Dr Fujii presented a history of water density from 1927 (BIPM data) to the present. The CIPM formulation (Tanaka *et al.*) is currently used for most metrological applications in the range 0 °C to 40 °C and at pressures near one atmospheric pressure. However, the International Association for the Properties of Water and Steam (IAPWS) have produced IAPWS-95 which contains thermodynamic properties of water in the range 251.2 K to 1273 K and at raised pressure. Dr Fujii outlined the basis of this formulation and showed comparison data for various formulations for the calculation of water density. Recommendations had been drawn up with IAPWS proposing the use of CIPM formulation in the range 0 °C up to 40 °C (at atmospheric pressure). Outside this range the IAPWS formulation should be used. Additionally, the use of IAPWS formulation is recommended for the entire range if any experimental measurements lie outside range of the CIPM formulation to avoid any discontinuity in measurement results. PTB had presented details of their work on the absolute determination of water density.

Terms of reference for the working group were outlined. They are:

- To improve techniques for realizing the SI unit of density;
- To exchange information on the density standard;
- To perform CIPM key comparisons for supporting CMCs on density;
- To coordinate RMO key and supplementary comparisons for accelerating the CIPM MRA in the field of density;
- To provide guidance to accept CMCs on density;
- To coordinate activities for density measurements at NMIs; and
- To assess needs and seeds on metrology for density.

Membership of the WG was discussed and VNIIM were accepted as a member on the basis of their work on the COOMET hydrometry comparison. BEV had also been accepted as member on the basis of work on EURAMET liquid density comparison.

Dr Tanaka asked about the relative uncertainties associated with the various methods of water density determination.

Dr Fujii said that the IAPWS formulation has no clear uncertainty statements because it is derived from equations of state for water.

Dr Tanaka asked about the proposed key comparisons and asked the CCM members to approve them. There were no objections.

Dr Tanaka additionally asked for approval of new members and again there were no objections.

### **2.3 Report from the Working Group on Viscosity (Dr Harro Bauer, PTB)**

Dr Bauer explained that the Viscosity Working Group started as an *ad hoc* WG in 1999, and became a permanent working group in 2005. The Group has 18 members, with participants from all the Regional Metrology Organizations (RMOs). Fourteen of the member NMIs currently have CMCs registered in the technical area of viscosity.

The current status of key comparisons was summarized. The KC process started 1993 and to date six had been completed; one CCM KC, four regional SCs in EURAMET and one in SIM. There are currently two KCs in progress, [CCM.V-K2](#) and [COOMET.M.V-K1](#), both of which are at the Draft B stage. A further KC is planned by the SIM RMO.

Dr Bauer showed a graph illustrating the range of temperature (-40 °C to 150 °C) and viscosity (0.3 mm/s<sup>2</sup> to 1 000 000 mm/s<sup>2</sup>) covered by the CMM and regional KCs. Dr Bauer remarked that the field is well covered by the KCs already completed.

The results for [CCM.V-K2](#) were presented, only institutes with independently realised viscosity scales (i.e. not traceable to other NMIs) contributed to the calculation of the reference value. A follow-up KC [CCM.V-K2.1](#) at 100 °C is proposed to check the measurements of NMIs with discrepant or missing results at 100 °C from the -K2 comparison. Measurements will also be performed at 20 °C and 60 °C as a check on the liquid stability. Eight participants are proposed and the comparison is due to start this year.

Future KCs in the area were discussed. It is felt that the field is well covered and a period of validity of 10 years was agreed. This aligns with the recalibration period for primary standards at most NMIs. The detailed KC schedule will be discussed at next WG meeting in 3 years.

Issues in the area were outlined. The absolute measurement of viscosity is important – current traceability is to the viscosity of water. There had been a discussion about the uncertainty in the viscosity of water (The value from 1952 determined by Swindells is still used). Another issue is traceability for rotational viscometers, used to measure the viscosity of non-Newtonian fluids. This is closely allied to the area of metrology in materials properties measurements. Uncertainties are rarely quoted (except for angle and torque measurements on instruments). Uncertainties are very dependent on materials measured and on the users. Guidance on uncertainty evaluation is required. High (e.g. 100 mPa) viscosity is important in the oil industry and activities addressing this area are underway at NMIJ and PTB.

Dr Henning Wolf (Head of Viscosity at the PTB) had been proposed as the new chairman of the WG, to take over from Dr Bauer who is retiring from PTB. All WG members agreed with this nomination.

Dr Bauer said that the BEV (Austria) and INMETRO (Brazil) had been accepted as new members at the meeting.

Dr Tanaka asked the CCM to approve these new members and the proposed KCs – there were no objections.

Dr Tanaka asked the CCM to approve Dr Wolf as the new WG Chairman – there were no objections.

### **Special Presentation 1. NPLI Mass and Related Quantities Summary**

(Dr A.K. Bandyopadhyay, NPLI)

Dr Tanaka introduced a new item to the agenda: a presentation from NPLI as a potential new member of the CCM.

Dr Davis explained that this presentation was being made because NPLI is interested in changing from observer to full member of the CCM. There would also be presentations from A\*Star, Singapore, and MSL (New Zealand).

Dr A.K. Bandyopadhyay presented the background of metrology in India. The metric system was adopted in 1957, when India signed the Metre Convention. Dr Bandyopadhyay showed data on the stability of their national mass standard, number 57, and the hierarchy of mass scale at NPLI. Participation in APMP regional key comparisons was summarised; these included. [APMP.M.M-K1](#), [APMP.M.M-K2](#) and APMP.M.M-K6. The NPLI had also taken part in key comparisons [CCM.M-K5](#) and [CCM.V-K1](#). The force, hardness and torque areas were described, the force area having a 50 kN deadweight machine and a hydraulic amplification machine (1 MN). Traceability for the force, torque and hardness areas was outlined. The pressure and vacuum standards area includes vacuum orifice flow and series expansion systems. Research has been performed into controlled clearance piston cylinders and into the effect of difference pressure transmission fluid (papers in these fields have been published in *Metrologia*). Participation in pressure area CCM and RMO KCs was outlined along with a number of bilateral comparisons. In conclusion, Dr Bandyopadhyay summarised NPLI's CMCs, which had already been approved, and their participation in KC and listed their publications in this technical area.

Dr Davis outlined the approval process for becoming a full member of the CCM. This requires a formal application to the CIPM which included much of the information cover in Dr A.K. Bandyopadhyay's presentation.

### **2.4 Report from the Working Group on Force (Dr Rolf Kumme, PTB)**

The last meeting of the working group was held at CENAM on 3-5 December 2007, in conjunction with IMECO TC3 meeting in Merida (Mexico).

Dr Davis had made a presentation on “The Key Comparison Process: Theory and Practice”. The current status of key comparisons was presented.

- For [CCM.F-K4](#) (2 MN and 4 MN, piloted by the NIST), Draft A is complete and there is a proposal for Draft B.
- For [CCM.F-K3](#) (500 kN and 1 MN, piloted by the PTB), the measurements are complete.
- For [CCM.F-K2](#) (50 kN and 100 kN), Draft A is complete.
- For [CCM.F-K1](#) (5 kN and 10 kN, piloted by the MIKES), Draft B is under revision.

Data from the 1 MN comparison of [CCM-F-K3](#) were presented as an example of typical force comparison data and to illustrate the issues with data analysis. The logistics of the transportation of transfer standards were outlined and the measurement protocol discussed. The approach to dealing with drift in the transfer standard was also presented.

For torque comparison [CCM.T-K1](#) (500 N m and 1000 N m, piloted by the PTB), Draft A is complete. Proposals for the evaluation of the results and calculation of the reference value were made in advance of the preparation of Draft B. Humidity variations were seen as a problem in the data analysis and these would be taken into account in further work on the comparison data. Comparison [CCM.T-K2](#) (10 kN m and 20 kN m) is due to start in 2008.

Future developments discussed in the areas of force and torque were discussed. The EURAMET roadmaps in the areas of force and dynamic measurement were presented. Nano-force was discussed but there was seen to be no need for a KC in this area at present. Multi-component force measurements are seen as an important area and it was decided that a pilot study, rather than a KC, should be organized. Force transducer and machine classification were seen to be useful for end users, and dynamic force and torque measurement is also an area where more work will be initiated in future.

The next meeting of the WG “Force” will be in 2010 in China or Korea. There is the possibility of additional meeting when Draft B reports become available for the four force area KCs currently underway.

A seminar on force measurement was also held during the WG meeting and presentations included dynamic force measurement and continuous calibration of force transducers.

Dr Tanaka asked for acceptance of proposed torque KC, [CCM.T-K2](#), and there were no objections. He also asked if there was any other proposed work in the area. Dr Kumme said the timescale for repeating KCs would be 15 years for deadweight machine calibrations and 10 years for the others. Dr Tanaka asked for clarification of when the 15 years period started. Dr Kumme said it would be from the completion of the KC measurement process.

Dr Tanaka asked if there were any new members of the WG. Dr Kumme said there were no new members, only contact persons had changed. Dr Tanaka asked for acceptance of Dr Kumme as permanent chair person of the WG and there were no objections.

## **2.5 Report from the Working Group on High Pressures (Dr Jean-Claude Legras, LNE)**

The last meeting of the WG was held on 21 April 2008 at the BIPM. There were 19 participants from 16 institutes, and six additional invited participants.

There was no change in membership (there are currently 20 members).

The terms of reference for the WG were discussed.

Two groups have been established to cover the full pressure range, taking into account the diversity of measurement techniques and the large scale of 18 decades: the High Pressures and the Low Pressures Working Groups (HPWG and LPWG). Taken as a whole, the HPWG takes care of the gauge and differential pressure, and absolute pressure  $\geq 100 \text{ kPa}$ . Between 1 kPa and 100 kPa, absolute pressure, the two working groups make a common agreement in consideration of the primary or secondary standards used and the transfer standard and/or unit under calibration.

The main tasks of the group are:

- To define and organize the CCM pressure key comparisons in its field of competence;
- To validate the final reports of all the comparisons before proposing their publication in the BIPM database;
- To collect the needs and the difficulties which may happen in drafting and validating the CMCs;
- To watch and anticipate for future needs of society;
- To be a forum of exchanges between the pressure experts of NMIs, through the RMOs.

Key comparisons status was presented.

- [CCM.P-K1](#) is complete and the status of the 12 regional KCs in the same range was presented.
- [CCM.P-K2](#) is also complete as is a EURAMET regional comparison over the same range.
- [CCM.P-K4](#) and a EURAMET regional comparison over the same range are complete.
- Results are available for [CCM.P-K5](#) and an APMP comparison over the same range is also complete. A EURAMET comparison is also proposed. A new comparison covering a wider range, with an improved transfer standard, is proposed to start 2009.
- [CCM.P-K6](#) has been approved for equivalence.
- Results are available for [CCM.P-K7](#) and there are nine regional KCs over a similar range.
- [CCM.P-K8](#) has been approved for provisional equivalence during the first four years of the implementation of the CIPM MRA (transitional period). The measurements were completed in 1999. A new comparison is proposed to start 2009. This will link regional KCs, which are now in progress.

Results of seven regional KCs were presented. These were [APMP.M.P-K5](#), [EUROMET.M.P-S2](#), and [EUROMET.M.P-S3](#), COOMET.M.P-S5, [EURAMET.M.P-K7](#), [EURAMET.M.P-S5](#) and [APMP.M.P-K8](#).

Activities in the RMOs APMP, COOMET, EURAMET, and SIM had been presented. Research and development in pressure metrology within EURAMET was presented by Dr Sabuga (PTB), EURAMET roadmaps were shown and the Joint Research Project on the Boltzmann constant, where the relative uncertainty of  $10^{-6}$  presents a big challenge for pressure metrology, was discussed.

The SIM area report was presented by Dr Torres (CENAM) and the APMP regional report was given by Dr Bandyopadhyay (NPLI).

Status of CMCs was discussed but there were no major areas of concern. It had been suggested that some additional information from submitting laboratories (accreditation bodies, publications etc.) would be useful.

Requirements for comparisons to support CMCs were drafted, and there were six in total.

In terms of medium- and long-term planning, it was decided that no strict periodicity should be defined for the KCs since it may depend on new developments and new standards in NMIs. It was decided to organize a maximum of one or two CCM key comparisons every 3 years. The frequency should correspond to an average periodicity of 15 years for each key comparison.

Significant developments in laboratories included the KRISS who have developed a twin pressure balance for low line pressure measurements, INMETRO who are working on large piston cylinder assemblies and LNE who are developing a primary standard for measurement (refrigerant) leaks.

Dr Legras is to retire from the LNE next month and Dr Jorge Torres (CENAM) was proposed as his successor.

Professor Wallard said he was struck by the absence of regional KCs for some of the pressure area KCs and asked if this was a problem for CMC submissions. Dr Sutton (MSL, New Zealand) said it was not really a problem. Dr Bandyopadhyay commented that the comparison at atmospheric pressure in the APMP area was awaiting the availability of large piston-cylinder device as a transfer standard.

Dr Tanaka asked that the proposed new KCs be accepted by the CCM and there were no objections. The WG had no new members and the proposed new chairman was accepted by the CCM.

## **2.6 Report from the Working Group on Low Pressures (Dr Karl Jousten, PTB)**

The last meeting of the WG was held on 22 April at the BIPM.

At present, the WG consists of 14 members. NPL had retired as a member due to devolution of its vacuum capability.

However, five new members had been accepted by the WG: A\*Star (Singapore), CMI (Czech Republic), METAS (Switzerland), NMi (Netherlands) and VNIIM (Russian Fed.). All proposed new members were either carrying out significant research in the area or had made significant contributions to the organization of key comparisons.

The terms of reference of the WG were outlined, these are:

- To advise the CCM on issues related to vacuum metrology;
- To organize comparisons for testing equivalence of national primary standards for vacuum below 1 kPa and very low gas flow (leaks) on the highest accuracy level;
- To organize comparisons for testing equivalence of national primary standards for vacuum pressures between 1 kPa and 100 kPa on the highest accuracy level when this is agreed with the CCM WG on High Pressures;
- To validate the final reports of the comparisons before proposing their publication in the BIPM database;
- To exchange information between RMOs on issues related to vacuum metrology and equivalence of national standards for vacuum and very low gas flow mainly to provide sufficient linkage between RMO and CCM WG LP key comparisons;

- To encourage and, if requested, coordinate research and development in the field of vacuum metrology to cope with the present and future needs of science, industry and society worldwide;
- To harmonize guidelines in the field of vacuum metrology related to the MRA.

The status of key comparisons was outlined. [CCM.P-K3](#) was completed in 2002 and Draft A of the final report was finally ready in 2008. The validity of the comparison was confirmed at the meeting despite some changes in the status of some of the participating laboratories. Data from the comparisons was presented and the stability of device was shown to be acceptable. [CCM.P-K12](#), a comparison of helium leak rates, had seen the withdrawal of CENAM, NPL, KRISS, as participants, but VNIIM, A\*Star and MIRS/IMT had been added<sup>1</sup>. The comparison schedule had been modified due to problems with transportation of the transfer standard. Completion of the comparison measurements is due by the end of 2008. Data on the behaviour of standard leaks was presented, Dr Jousten said that these standards were known to drift but their performance was acceptable for use as a transfer standard in this comparison.

New comparisons agreed at the meeting were detailed. Comparisons are proposed for spinning rotor gauges in the range  $10^{-4}$  Pa to 1 Pa and for capacitance diaphragm gauges/resonant silicon gauges in the range 1 Pa to 10 kPa. Dr Jousten described the proposed transfer standard for this comparison, to be provided by the NIST, and said it was significantly more stable than previous devices used.

Other issues discussed by the WG included selection of KC participants. It was commented that in the past KC quality had been compromised by having too many participants both in terms of compromising the device stability and by the diversity of uncertainty claims. Additionally it was noted that not all RMOs were active in providing linkages to KCs.

A procedure was proposed to deal with the organization of KCs. A pilot laboratory would be chosen by the WG, NMIs would apply to take part in the KC and participants would be chosen by the WG chairman and pilot laboratory. The criteria for selection would be lowest uncertainty claims, independent realisation of the scale and good metrological practice. It was stressed that participants in KCs must take part in subsequent regional KC. RMO participation in this selection process is being considered.

Planned regional KCs in the vacuum area were: APMP (1 Pa to 1000 Pa), APMP-SIM (NPLI/NIST) bilateral (70 Pa to 130 kPa) and two in the EURAMET area ( $1 \times 10^{-4}$  Pa to 1 Pa and 1 Pa to 13 kPa).

Statement from WG-LP to WG-CMC was shown with the aim of making CMCs more “user friendly” by giving details of the unit under calibration as well as the pressure range. Details of the gauge to be calibrated are given.

### **Statement of the CCM WG LP for discussion within the CCM WG CMC on CMC entries in the field of vacuum pressures**

The CCM WG LP wishing to make the CMC entries in the field of vacuum pressures more user friendly and adapted to the needs of the NMI customers and considering the relevant CIPM and

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<sup>1</sup> Participation of Associates of the CGPM in key comparisons is permitted under exceptional circumstances, and with the written approval of the CCM President.

JCRB documents [CIPM/07-11](#), [JCRB-06/6](#), [JCRB-8/9](#), [JCRB-8/18](#), [JCRB-10/6\(3\)](#), [JCRB-11/7](#), [JCRB-12/06\(2\)](#), [JCRB-14/06\(2a\)](#) seeks to get approval from the CCM WG CMC on the following guidelines for CMC entries in the field of vacuum pressures.

1. CMC entries in the field of vacuum pressure shall be oriented towards the unit under calibration (UUC) and not only on the pressure scale. This means that CMC entries may have overlapping ranges.
2. In column “C” (Instrument type or method) should appear the special type of vacuum gauge to be calibrated (e.g. capacitance diaphragm gauge, spinning rotor gauge etc.). As in the past, in column “A” shall be written “absolute pressure” and in column “B” (Instrument), “vacuum gauge”. An entry in column “C” makes it clear that the given uncertainty is not only determined by the primary standard, but as well by the UUC. This entry also makes the following uncertainty values easier to understand for the reviewer.
3. Only those vacuum gauges may be considered as UUC in the CMC entries being acknowledged as having a very high metrological quality compared to the primary or secondary standard used for calibration. Only one UUC is allowed for one country having a complete overlap with another entry.
4. In column “G” and “H” (Measurement conditions/independent variable”) it shall be specified in separate lines: environmental temperature, gas species, gas purity.
5. Uncertainties, if not given by a formula, have to be given with two significant digits.
6. A laboratory that has a CMC entry or applies for such in a range that is covered by a published key comparison and has abstained from or withdrawn its participation before or during a key or supplementary comparison has to withdraw the relevant CMC entries from the BIPM database until it has successfully taken part in a key or supplementary comparison.

Future challenges in the field of vacuum metrology were described. Measurement of pressures at low temperature (for atmospheric monitoring) and the calibration of dynamic vacuum pressures for DVD/CD metalisation plants, bottle coatings etc. were identified as important areas for future research.

Regarding the terms of reference, Dr Davis commented that a unified designation for “units under test/calibration” needs to be agreed on as there appears to be some difference in the designation used by various WGs, the JCRB, the CIPM and ISO.

Dr Tanaka commented that some of the KCs currently underway were not yet registered and Dr Jousten replied that they will be in the near future.

Dr Tanaka asked for acceptance of the proposed new members of the WG and there were no objections.

Professor Wallard endorsed the proposal of restricting KC participation and said that other CCs were also doing this for reasons of efficiency and that the CIPM MRA endorsed this practice. He also underlined the necessity for KC participants to provide linkage to regional KCs.

## **2.7 Report from the Joint Pressure Working Group (Dr Karl Jousten, PTB)**

The last meeting of the WG was held on 22 April at the BIPM.

Dr Jousten explained that the purpose of the WG was to provide liaison between the HP and LP

WGs. Proposals for the interface between the two WGs had been discussed. There were three potential approaches involving divisions at either 100 kPa, or 1 kPa, or by use of force/area and other technology. The pros and cons of the 3 approaches were outlined. A fourth approach had been proposed with WGLP responsible for absolute pressures below 1 kPa, WGHP for pressures above 100 kPa, and both WGs making a common agreement on absolute pressures between 1 kPa and 100 kPa. This approach was agreed and a decision was made to give WGLP responsibility for the 1 Pa to 10 kPa absolute KC.

The meeting decided to organize the 5th CCM Conference on Pressure and Vacuum Metrology in the week before the next CCM meeting in 2011. The venue will be PTB, Berlin and it was proposed to merge this conference with the IMEKO TC16 (pressure) conference.

No common statement was made on CMC entries as the WGHP agreed that high pressure CMC entries are satisfactory.

Dr Davis commented that there are precedents for conferences organized jointly by a CC working group and another organization such as IMEKO.

### **3 POSSIBLE REDEFINITION OF THE KILOGRAM**

#### **3.1 Resolution 12 of the 23rd CGPM, November 2007 (Dr Richard Davis, BIPM)**

Dr Davis introduced this topic by referring to CGPM Resolution 12, publicly available on the BIPM website. He commented that although the meeting had been held in November 2007, the Resolution had been proposed and circulated many months in advance. The Resolution encourages NMIs to: pursue experiments relevant to the kilogram redefinition, prepare a *mise en pratique*, explain new definitions to end users, initiate an awareness campaign to alert end users of impact. Potentially the Resolution also allows the use of international prototype of the kilogram and/or its official copies, although the advice of the CIPM would be required to clarify this point. Dr Davis referenced a presentation by Prof. Ian Mills to the CGPM since it is important to this issue and post dates the drafting of Resolution 12. The presentation is available on the CCU web page. Dr Davis showed the historic CODATA values for Planck constant and highlighted the current discrepancies between the watt balance and Avogadro experimental results. The CCU is unanimous that discrepancies must be resolved before redefinition. The CCU favours fixing the Planck constant in the kilogram redefinition, but changes should await the Resolution of outstanding discrepancies. Words for the new definition and *mise en pratique* should be considered over the next two years. Dr Davis contrasted the drift in kilogram standards (with a maximum value of about 75 µg) with the discrepancy in current Avogadro and watt balance realisations (1100 µg) and with the NPL and NIST watt balance values for Planck's constant (with a discrepancy equivalent to 300 µg). Dr Davis said that the CCU were (unofficially) reluctant to accept the 20 µg uncertainty stipulated by the CCM for the level required for the redefinition, feeling that this value was too low.

### **3.2 Report of the Working Group on the Avogadro Constant and IAC (Dr Peter Becker, PTB)**

Dr Becker presented highlights of the International Avogadro work since 2001.

In 2001 a single crystal of enriched  $^{28}\text{Si}$ , of weight 190 g was successfully grown. In parallel, a result for the Avogadro constant based on measurements with natural silicon reached a relative uncertainty of  $3.1 \times 10^{-7}$  in 2003. That same year, the CIPM endorsed a new project based on enriched  $^{28}\text{Si}$  to continue the Avogadro-based approach to the kilogram redefinition and/or realisation. In 2007, 4.8 kg of enriched  $^{28}\text{Si}$  was grown and from this ingot two spheres have been produced.

Dr Becker outlined the international collaboration on this work and detailed the specific areas of responsibility of the participants.

The growth of the  $^{28}\text{Si}$  crystal and the production of two spheres at NMIA were explained in detail. Preparation of other samples from the crystal, for purity and lattice spacing measurements, was also described. The oxygen and carbon content of the new crystal are greatly reduced compared with previous natural silicon samples. The enrichment process has resulted in a crystal which is 99.994 % pure  $^{28}\text{Si}$ . The Institute for Reference Materials and Measurements (IRMM) had made measurements which showed a lower enrichment level but there are potential problems with their measurement process due to the presence of natural silicon in the measurement apparatus. Other methods for the measurement of molar mass are being investigated.

Dr Becker described the measurements necessary to characterise the silicon spheres. Positron annihilation is used to assess the spheres for voids, lattice parameter comparisons are underway. Photoluminescence is used to detect hydrogen in the silicon and laser scattering topography has also been used to detect voids. The density of samples from the  $^{28}\text{Si}$  ingot shows good homogeneity and confirms a value of 0.999 94 for the purity of the silicon. Determination of the molar mass represents the biggest challenge to sphere characterisation. A new approach to determination of the molar mass using Isotopic Dilution Mass Spectrometry (IDMS) was described.

An update of the present uncertainty levels and the future required levels was presented. Current diameter measurements give a repeatability of 0.3 nm, and the recently completed mass comparison gave an uncertainty of 3  $\mu\text{g}$ . Molar mass determination needs to be reduced by an order of magnitude (this is the reason for using enriched  $^{28}\text{Si}$ ) otherwise all uncertainty components are near the levels required.

A timeline for future measurements was outlined; the first Avogadro number, with native oxide, will be determined by October 2008 based on measurements made by PTB and NMIJ. A thermal oxide will then be grown on the sphere and the Avogadro constant will be re-determined in mid 2009. The project is due for completion at the end of 2010.

### **3.3 Progress of other work towards a possible new definition of the kilogram (Dr Zeina Jabbour, NIST)**

Dr Jabbour reviewed the principle of the watt balance; the apparatus balances electrical and mechanical power. It has two measurement modes; weighing and moving, this eliminates the

need to measure magnet and coil parameters. Five balances are currently active or under development at the LNE, METAS, NIST, NPL and the BIPM.

NPL have an equal arm balance and use a permanent magnet. They have used weights of silicon and gold-plated copper. The current relative standard uncertainty is  $66 \times 10^{-9}$  but their value for Planck's constant ( $h$ ) shows a  $308 \times 10^{-9}$  discrepancy with the value obtained by NIST. Updates to the balance have recently been made in the areas of resistance measurement, interferometry, the Josephson Digital to Analogue Converter (JDAC) array. An uncertainty target of 2 parts in  $10^8$  target has been set for the end of 2008. A Mark III balance has been designed but will not now be implemented.

The NIST watt balance works with a wheel and knife-edge arrangement and uses a superconducting coil. The current relative uncertainty is  $34 \times 10^{-9}$  but recent measurements at half load (500 g) have shown an offset in the calculated value for  $h$ .

Dr Jabbour presented data illustrating the current discrepancies between the Avogadro and watt balance results and between the different watt balance experiments.

The METAS watt balance is based on a commercial mass comparator and uses a permanent magnet. It has a capacity of 100 g and the current reproducibility is about 1 part in  $10^7$ .

The LNE experiment involves the movement of the mass comparator as a whole rather than just the coil. It has a capacity of 500 g. LNE are presently consolidating the individual sub-systems and making investigations into suitable alloys for watt balance compatible mass standards.

Dr Jabbour gave details of the European Metrology Research Programme (EMRP) Joint Research Project (JRP) e-MASS. This involves collaboration between the METAS, LNE and INRIM on aspects of the watt balance experiment.

In the BIPM watt balance experiment, the weighing and moving phases occur simultaneously, this reduces the sensitivity of the apparatus to changes in magnet and coil parameters. The project proposes the use of a cryogenic magnet and a superconducting coil. Currently the apparatus is working under ambient conditions and has been designed for a 100 g load.

### **3.4 Progress of other work towards a possible new definition of the kilogram (Dr Michael Gläser, PTB)**

Dr Gläser outlined the ion accumulation experiment at the PTB which is coming to a close. The principle of operation of the experiment was described. The apparatus consists of an ion source, a dipole magnet which separates bismuth ions and a collector for the ions. Currently the ion current in the collector is 2 mA to 3 mA but it is not constant over a 24 hour period. The current is monitored every 50 ms. From September 2005 to January 2008 the mass of ions collected over a period of about 3 days was increased from 30 mg to 323 mg. A mass of 108 mg, accumulated in 2007 gave a relative uncertainty of  $2.7 \times 10^{-4}$  in the atomic mass unit ( $m_u$ ) with a deviation of  $4.2 \times 10^{-4}$  from the published CODATA value. Data from the latest accumulation of 323 mg is currently under evaluation.

Dr Bich (INRIM) asked what was the consistency of data over the history of the experiment. Dr Gläser said that most results have been compatible with CODATA values and, for those that were not, reasons for the discrepancies had been identified.

### **3.5 Report from the Working Group on Changes to the SI kilogram (Dr Philippe Richard, METAS)**

The second meeting of this WG was held on 17 April 2008 at the BIPM.

Dr Richard outlined the WG membership. There were three new members, Dr Michael Borys (PTB), Dr Lars Nielsen (DFM) and Dr Gérard Genevès (LNE).

The terms of reference of the WG were presented. These are:

- To advise the CCM about issues concerning the redefinition of the kilogram;
- To consider the impact on mass metrology of a new definition of the kilogram (and its *mise en pratique*);
- To monitor the results of relevant experiments by following progress of the different projects (individual, regional and international) with a view to how a *mise en pratique* at the level of 1 kg might best be achieved;
- To solicit and collate comments from a wider scientific community on the wording of the future definition and on the *mise en pratique*;
- To coordinate and assist the work of the WGM Task Groups, within and between the regions.

There had been technical presentations on the NPL, METAS, LNE and BIPM watt balances and on the International Avogadro Project.

Coordination of future activities was discussed. Each member of WG has been assigned a specific task to ensure liaison with all interested external parties.

Dr Tanaka asked for acceptance of the new members of the WG and there were no objections.

### **3.6 Report from Task Group 1 of the CCM Working Group on Mass Standards; Mass metrology under vacuum for a *mise en pratique* (Dr Stuart Davidson, NPL)**

Dr Davidson was reporting on the meeting on behalf of the TG1 Chairman, Dr Michael Borys.

The first meeting of this TG was held on 21 April 2008 at the BIPM.

The rationale for setting up this TG was presented in terms of the CCM's reply to the CIPM Recommendation 1 (2005) "Preparative steps towards new definitions of the kilogram": with particular reference to the stated requirement for transfer and storage of weights under vacuum or in inert gas.

The 18 members of the TG were listed, as were the six members of the steering committee.

Provisional terms of reference for the TG had been agreed at the meeting. These are

- Evaluation of the available experimental results from the watt balance and Avogadro experiments with a special emphasis on the necessary vacuum mass metrology;

- Identification of requirements on mass metrology for a practical realisation of a new definition;
- Organization of international comparisons and evaluation of the results;
- In coordination with TG 2, identification and evaluation of the uncertainty inherent in the *mise en pratique* for the kilogram when a new definition is proposed to the CGPM.

The TG had also agreed on a list of objectives which were to make recommendations in the areas of mass standards (material, shape, surface, etc.), weighing in vacuum, transfer between vacuum and air, storage (vacuum, inert gas, air), transport and cleaning procedures.

A questionnaire had been circulated and the capabilities of the TG members in the field had been gathered and were presented at the meeting.

The results of a comparison of silicon spheres weighed in vacuum had been presented and the TG had agreed the necessity for collaboration between the members to ensure compatibility of equipment developed of the transfer of weights under vacuum.

### **3.7 Report from Task Group 2 of the CCM Working Group on Mass Standards: Uncertainty components due to traceability to the international prototype of the kilogram (Dr Lars Nielsen)**

The first meeting of this TG was held on 21 April 2008 at the BIPM.

The 19 members of TG 2 were listed together with the 5 members of steering group.

Dr Davis had given an introduction to the subject and explained the requirements of the TG. The uncertainty of the mass of the international prototype of the kilogram,  $K$ , is zero by definition. The issue is whether the stability of the artefact and in particular the lack of repeatability of cleaning process should be taken into account when assessing the uncertainty in  $K$ . Dr Davis presented data relating to the cleaning of primary mass standards and to the relative stability of official copies of  $K$ .

The terms of reference for TG2 were agreed. These are to report to the WGM and the CCM on the following:

- The present uncertainty to which the unit of mass can be disseminated from the international to the national prototypes;
- Methods for evaluating the correlation between the measured mass values of the prototypes of the kilogram;
- Recommendations for additional measurements which would allow an improved uncertainty evaluation. These measurements may involve use of the international prototype or its official copies;
- In coordination with TG1, identification and evaluation of the uncertainty components inherent in the *mise en pratique* for the kilogram when a new definition is proposed to the CGPM.

A plan for future work was decided which included collection of historical calibration data for kilogram prototypes, setting up a model for deterministic and random changes in the mass of a kilogram prototype (relative to the international prototype), adjustment of parameters in a model

using historical calibration data and prediction of future mass values of a kilogram prototype using model and adjusted parameters.

#### **4 RECOGNITION OF THE CONTRIBUTIONS OF RETIRING MEMBERS (President Mitsuru Tanaka)**

Professor Wallard explained that Dr Tanaka would spend a few minutes to present certificates to three individuals who had made outstanding contributions to the work of the CCM during their careers. Certificates were awarded to Dr Harro Bauer, to Dr Michael Gläser and to Dr Jean-Claude Legras. These were bestowed on behalf of the Director of the BIPM and the President of the CCM for services to the CCM and to furthering the goals of the Metre Convention.

#### **5 WORKING GROUP REPORTS (PART 2)**

##### **5.1 Report from the Working Group on Hardness (Dr Alessandro Germak, INRIM)**

The WG meets annually and the last meeting was held on 22 November 2007 at the AIST in Tsukuba (Japan), in conjunction with the HARDMEKO 2007 Conference.

The members of and participants in the WG were reviewed.

At the last meeting, news from the NMIs was presented. New equipment had been developed at INMETRO (Brazil), NCM (Bulgaria), NIM (China), NPLI (India), CENAM (Mexico), NIMT (Thailand), UME (Turkey) and NIST (USA). NPL (UK) had closed their activities in the field of hardness.

New definitions of the Rockwell C hardness scale were outlined, the majority of NMIs had adopted the definitions, however a few problems had been encountered with their implementation and thus minor revisions to the definitions were proposed to address these problems.

New definitions for the Vickers and Brinell hardness scales are being developed and a survey of NMIs working in this area is underway.

The status of key comparisons was outlined. The three comparisons [CCM.H-K1.a](#), comparisons [CCM.H-K1.b](#) and comparisons [CCM.H-K1.c](#) had been approved for equivalence. The measurements for [CCM.H-K2](#) were completed in 2004, Draft A was produced in 2005 and an update in Draft A is underway since the results need to be corrected for the numerical apertures of the individual measurement systems used by the participants. CCM.H-K3, a new Rockwell C comparison, is proposed and four pilot laboratories will organize the comparison by RMO area.

Pilot studies on nano-hardness and diamond Rockwell indenters were proposed.

The terms of reference of the WG were outlined. They are:

- To advise the CCM on matters relating to hardness;
- To improve harmonization of primary standards developing new definitions and/or organizing pilot studies;
- To organize key comparisons for supporting the CIPM MRA;
- To produce working documents for the evaluation of uncertainty;
- To maintain good links and interface with the hardness community (IMEKO TC5);
- To provide formal liaison among organizations involved in the standardisation (ISO TC164/SC 3, OIML TC10/SC5).

Strategic planning was discussed. Future requirements identified included traceability for traditional scales and developing and disseminating primary standards in the areas of non-metallic materials, new scales (Martens) and nano-indentation.

Professor Wallard asked what the reaction had been from the standards organisations to updates in the scale definitions. Dr Germak said there was continuous liaison with industries and these bodies and their input was taken into account when developing metrological standards.

## **5.2 Report from the Working Group on Fluid Flow (Dr Masaki Takamoto, AIST/NMIJ)**

The last meeting of the WG was held on 17-18 April 2008 at the BIPM.

The status of key comparisons was outlined.

Results of [CCM.FF-K1](#), [CCM.FF-K3](#), [CCM.FF-K4](#), [CCM.FF-K5.a](#), [CCM.FF-K5.a.1](#), [CCM.FF-K5.b](#) and [CCM.FF-K6](#) are published in the KCDB. Draft B of [CCM.FF-K2](#) is in preparation.

Membership of the WG was outlined, contact persons had change but the member NMIs remained the same.

Reports from APMP, COOMET, EURAMET and the SIM were presented at the meeting.

A workshop on KCs had been held, with five presentations followed by discussions, on the matters of interest to the membership.

A decision list has been produced containing nine key points. There are:

- KCRV calculations should include the uncertainty of the transfer standard.
- Use the recommendations of SP regarding documentation, transportation and logistics for travelling standards. For instance, where possible, transport should be arranged by the pilot with a single company.
- Make a checklist of potential transfer standard influences and uncertainty sources.
- Participants should review preliminary test results for meter characterization before starting KC measurements. Characterization needs to occur in more than one laboratory.
- Participants must show detailed uncertainty budgets at the start of the KC.
- Develop a template or guideline for KC protocol for pilots to use as a reference.
- Share costs of constructing the transfer standard, and consider sharing labor costs.

- Consider use of largest consistent subset for determination of KCRV.

A design suggested by SP for the transportation box for flow meters was presented and schedule for CCM and RMO WG meetings for the period 2007-2010 was shown.

### **Special Presentation 2. Update on developments at National Metrology Centre A\*Star, Singapore (Mr Chua Hock Ann, A\*Star)**

This presentation was given by Chua Hock Ann, as A\*Star is a prospective new member of CCM. A\*Star is the Agency for Science, Technology and Research in Singapore. Mr Chua outlined the national research and development framework in Singapore. He presented an organizational chart of A\*Star which includes research institutes in a number of sectors and the Singapore National Metrology Centre. The Mission Statement of Science and Engineering Research Council was outlined, the council includes technical areas of electronics, infocomms, chemicals and engineering.

The strategy is to group a number of the research institutes in a new facility this year. The National Standards and Conformance Network was presented, as were details of Singapore's National Measurement System.

Mr Chua highlighted the main technical areas within the NMC. The national standard kilogram has changed by about 25 µg over 4 years, details of A\*Star's mass comparators were given. A\*Star has force facilities up to 2 MN and vacuum, medium and high-pressure calibration facilities. Participation of Singapore in pressure comparisons was detailed.

Recent development initiatives were presented and included research in the areas of nanometrology, MEMS, biomedical and health, infocomms, time and frequency. A vacuum mass comparator has been ordered and will be commissioned in the new laboratory.

Primary low gas flow metrology (for leak detectors and micro gas flow meters) is being developed. A bilateral comparison with NMIJ has been undertaken and the results will be published at the APMP conference this year. A\*Star are developing a primary high vacuum standard set up using continuous expansion system. Additionally air speed metrology standards are being developed and laser doppler anemometer and wind tunnel facilities are under development.

Lists of recent publications and participations in comparisons were presented.

### 5.3 Report from the Working Group on Gravimetry (Dr Leonid Vitushkin, BIPM)

The last meeting of the WG was held on 24 August 2007 at the VNIIM. The WG was set up in 2003. The membership of the WG was outlined, UME being recommended as a new member. The WGG consists of a mixture of metrologists and geophysicists. The following terms of reference were established at the last meeting:

- To draw up appropriate protocols for the comparison of absolute gravimeters.
- To organize periodic comparisons of absolute and relative gravimeters and related workshops.
- To draw up procedures for the evaluation of the results of these comparisons, including standardized procedures for data processing.
- To make proposals for ongoing work on gravimetry at the BIPM.
- To advise the Consultative Committee, and through it the CIPM, on matters related to absolute gravimetry.

The WG discussed the difficulty of finding gravity stations where the value of  $g$  is stable. New sites were being developed at the NIM (China) and in Guadalajara (Spain). The most prevalent instrument used is produced by micro-g in the USA. However there is no primary standard for  $g$  in USA. Only four CMCs in the area of gravimetry have been declared, all within EURAMET.

The date of the next gravimetry comparison had been agreed as October 2009 and it will take place at the BIPM. The next meeting of the WG will be at the beginning of 2010 when results of comparison can be presented.

The WG meeting had seen a presentation from UME on national absolute and practical  $g$  measurements. The NIM presented details of their new gravimetry site and mechanical absolute gravimeter. The Spanish institute for geophysics presented details of a site for absolute  $g$  measurements.

Details of seventh international comparison of absolute gravimeters (ICAG 2005) were presented. There were 19 participants and two types of instruments used (free fall and rise and fall) and both commercial and in-house constructed instruments took part. The main issue was the analysis of uncertainties. Results will be presented in the near future.

Details of IAG symposia held in 2007 and 2008 were given and the Global Geodetic Observing Systems action plan (2005) was presented.

Dr Richard asked about the link between uncertainties reported in the last ICAG comparison and the CMC submissions. Dr Vitushkin said that the evaluation of uncertainties was complicated and several different models were available. Real expanded uncertainties of 5 microgal were the realistic limit of what could be achieved. Dr Claudine Thomas commented that the four CMC entries claimed uncertainties of about 10 microgal.

## 6 THE BIPM KEY COMPARISON DATABASE (Dr Claudine Thomas, BIPM)

Dr Thomas outlined the means of access to the KCDB, which is a publicly available website maintained by the BIPM. One hundred eighty (180) laboratories in all are participants in the CIPM MRA, from 45 Member States and 25 Associates. There are 614 KCs and 173 SC registered in the KCDB. The number of new comparisons being registered is broadly constant with 40 new KCs and 20 new SCs registered each year. There are now over 1000 graphs of equivalence in the KCDB. Dr Thomas stressed that detailed data is only available for KCs, and for SC only a copy of the final report is linked to the database.

The CMCs approved by the JCRB, the method of access and illustrations of typical entries were shown. Over 20 000 CMCs have been published, with 600 being added over the last year. A data page is available with a range of statistics relating to CMCs. Dr Thomas stressed that CMCs need to be supported by an approved Quality System. Statistics on visits to database are increasing with time. The latest usage data are difficult to assess due to hits by the “robots” used by search engine providers but plans are in place to exclude these hits. An average figure for hits is approximately 16 000 per month for Appendix C of the KCDB (CMCs) and slightly less for Appendix B (KCs and SCs). The *KCDB Newsletter* is issued twice yearly and the next issue (No. 9) is scheduled for June 2008.

## Special Presentation 3. The Measurement Standards Laboratory of New Zealand (MSL): Activities in mass and related quantities (Dr Chris Sutton, MSL)

This presentation was given by Dr Sutton as MSL is a new member of the CCM.

MSL has about 30 professional staff, and their range of activities was presented. Re-branding of the laboratory includes a new logo to more clearly identify New Zealand’s NMI.

Areas of research were illustrated, including mass stability and cleaning. Many cleaning methods have been evaluated. Ultrasonic cleaning in ethanol, the Soxlet method using ethanol, boiling in water and the Soxlet method using water have all been used, with the Soxlet ethanol combination proving the most repeatable.

The development of automatic weighing systems was described. A method for the analysis and linking of international measurement comparisons developed by Dr Sutton and published in *Metrologia* was described. Density determination of standard weights by variations in air density was explained. A check on the consistency of the density of water at MSL measured using an NMIA solid density standard was also presented. This density value was found to be consistent with the value calculated from the measured isotopic composition of the water.

Gas operated pressure balances and the evaluation of short-term repeatability was outlined. Analysis of damped oscillation behaviour indicates that the short-term repeatability of these devices is at the level of 1 part in  $10^8$ . The use of gas operated pressure balances for absolute and differential pressure measurements was described.

An evaluation of the Newtonian gravitational constant  $G$  had been performed, with two MSL measurements contributing to the CODATA 2002 value.

Future research may include investigation into the use of watt balances in a (low frequency)

oscillatory calibration mode. This has the potential to reduce the physical size of the balance, and the size of magnetic field region required and to improve immunity to vibration. Also use of twin pressure balances for watt balance operations was proposed.

#### **Special Presentation 4. Metrological situation at the BEV at the Mass and related quantities section (Dr Christian Buchner, BEV)**

This presentation was given by Dr Buchner as BEV is a potential new member of CCM.

Highlights from the fields of mass, density, force and hardness were presented. In the mass area automatic systems for the calibration of weights in the ranges 1 mg to 10 g, 10 g to 1 kg and 1 kg to 20 kg have been developed. Within the density area automation of hydrometry and the fundamental density apparatus for liquid and solid density determination has taken place. An automatic handling system for determination of the volume of OIML Class E1 weights up to 1 kg has also been developed. A volume comparator for weights of 1 kg to 50 kg has been developed based on 3 different weighing cells of capacity 1 kg, 10 kg and 60 kg.

In the force area a small (10 N to 1  $\mu$ N) automatic deadweight force machine has been developed. The beam arrangement allow tension and compression forces to be applied and a low force transducer comparison is proposed with NPL and PTB. For hardness measurements an automated hydraulic controller and automatic positioning of the indenter have been implemented.

An outline of new buildings for BEV was given. New laboratories are planned for mass, density, micro-force, pressure and viscosity. The new facilities will be complete in 2010. Additionally a new laboratory for macro-force is proposed. Deadweight machines of capacities 2 kN and 250 kN will be designed and built. A new 1 kg prototype balance will also be constructed, based on a Sartorius load cell.

#### **7 RECENT ACTIVITIES OF THE METRE CONVENTION (Dr Pedro Espina, BIPM)**

Dr Espina outlined the membership. Fifty-one States are signatories of the Metre Convention and there are 26 Associates of the CGPM (five new Associates have been added over the last year). An overview of the RMO structure was given and changes in the African area were detailed. A new RMO, AFRIMETS, will cover the whole of Africa and will include the current RMO (SADCMET).

Actions from the JCRB 18 (May 2007) and JCRB 19 (September 2007) meetings were presented. A Unification of CMC and BMC definitions had been agreed on. CMC will now be universally used and will include ILAC accredited values. A seminar was held at JCRB 18 in May 2007 to explain process of CMC submission to six NMIs who have signed the CIPM MRA but have yet to submit CMCs.

Details of World Metrology Day on 20 May 2008 were given. The theme is “metrology in sport”, to tie in with the 2008 Olympics.

Details of BIPM Summer School 2008 were presented. Dr Thomas is the scientific secretary. Dates are the 29 June to 11 July 2008. The maximum registration, 93 students (90 present), has been achieved, and there are three Nobel laureates among the lecturers.

Dr Espina's secondment as JCRB secretary comes to an end in May 2008 and he will be succeeded by Prof. Luis Mussio of LATU (Uruguay). However, NIST has renewed Dr Espina's secondment to the BIPM in order for him to take on new duties.

Dr Tanaka thanked Dr Espina for his contribution to the JCRB over the last three years.

This concluded the first day's session.

Dr Tanaka welcomed the delegates to the second and final day of the CCM meeting.

## **8 RMO ACTIVITIES REGARDING TECHNICAL COMMITTEES IN THE MASS AND FLOW AREAS**

### **8.1 EURAMET RMO mass activities (Dr Stuart Davidson, NPL)**

Dr Davidson presented information on the change over from EUROMET to EURAMET and the reasons for this change.

Details of KCs and SCs in the EURAMET area were given and results were presented for EUROMET.M.M-K4 and EUROMET.M.P-S3 and EUROMET.M.P-S4.

The transfer of six guidance documents from European Accreditation (EA) to EURAMET was outlined and details of the last EURAMET TC-M meeting were presented. The meeting was held in Bucharest (Romania) in March 2008 and over 80 delegates from 31 countries participated. Details of the current status of EUROMET CMCs were also given.

Dr Davidson outlined the iMERA roadmapping exercise used to outline research strategy in the EURAMET area. He presented four roadmaps in the areas of mass, pressure, force and dynamic measurement. New collaborations and comparisons within EURAMET were also presented.

Dr Tanaka asked about EA.EURAMET guides and who they were aimed at. Dr Davidson said that they were aimed at end users but had also been adopted by a number of accreditation bodies as the basis for technical assessment of laboratories.

Dr Tanaka asked about industry's involvement in the roadmapping process. Dr Davidson said that input from industrial had essentially relied on the contacts of the individual NMIs with their countries industrial user.

Professor Wallard commented that we need somehow to estimate the uncertainties associated with the best existing devices (for CMCs) and asked whether EA/EURAMET guides could help with this. Dr Davidson said this was not the aim of the guides and assessment of state of the art in the metrological areas would need to be made by consultation with the relevant instrument manufacturers. Dr Chris Sutton commented that assessment of instrumentation state of the art in a particular field is best done by the relevant WG.

## **8.2 SADCMET RMO mass activities (Mr Benjamin van der Merwe, NMISA)**

Mr van der Merwe presented the report from SADCMET in the absence of Mr David Tonui, who had been called away. Membership of SADCMET was outlined. The RMO contains few developed economies and only the southern African area is covered. A new RMO, AFRIMETS, was proposed in 2006 as a pan-African RMO, will be proposed as the new RMO for the African region at the JCRB meeting at the end of April. The status of regional comparisons was outlined (mass force volume). Further comparisons in mass and volume are proposed. Results of [SADCMET.M.M-S1](#) were presented.

## **8.3 APMP RMO mass activities (Dr A.K. Bandyopadhyay, NPLI)**

The make up of the CMC review committee was shown. The number of CMCs submitted over the last 2 years was presented, as was the status of CMCs reviewed for other RMOs and within APMP. Details of last Technical Committee meeting, held in conjunction with APMF-2007 in Sydney (Australia), were given. The next meeting will be held in conjunction with the 4th APMF Pressure and Vacuum workshop at KIM LIPI in Indonesia. Details of the Developing Economies (DEC) programme were outlined, a workshop had been held after APMF-2007, Dr Bandyopadhyay illustrated the links between NMIs giving guidance and those receiving training. Research and development in the region was outlined. Details of active and proposed KCs were given. Results for [APMP.M.P-K6](#) and [APMP.M.P-K7](#) were presented as were details of [CCM.P-K4](#) and a number of bilateral comparisons. Dr Bandyopadhyay commented that the use of the term unofficial for non key comparisons was seen to devalue the validity of the work.

Dr Davis suggested the use of the term “Pilot Study” for an international comparison that is outside the framework of the CIPM MRA but which is needed nevertheless. This terminology has been adopted by other CCs, most notably the CCQM.

## **8.4 APMP area flow activities (Dr Masaki Takamoto, AIST/NMIJ)**

Dr Takamoto reported on behalf of the APMP TCFF chairman. The review team for CMCs was outlined; CMCs are divided into six categories with two NMIs making up the review team for each category. Key Comparisons in the fluid flow area were listed. [APMP.M.FF-K1](#) (water flow) and [APMP.M.FF-K3](#) (air speed) are expected to start mid-2008. [APMP.M.FF-K4](#) (volume) started in July 2006 and Draft A of the final report is being prepared. [APMP.M.FF-K6](#) (low pressure gas flow) has started and completion of the measurements is due in August 2008.

## **8.5 COOMET area flow activities (Dr Masaki Takamoto, AIST/NMIJ)**

Dr Takamoto reported on behalf of the COOMET TC-flow chairman. The TC was set up in 2000 and currently has 17 participating laboratories. Meetings are held annually. A number of comparisons focusing on the areas of oil and gas flow measurement have been undertaken. New projects for water flow and further gas flow comparisons are proposed.

## **8.6 EURAMET area flow activities (Dr Masaki Takamoto, AIST/NMIJ)**

Dr Takamoto reported on behalf of the EURAMET TC-flow chairman. The last meeting was held in Berlin this year. There were 52 participants from 26 countries and the meeting was held over three days. Seventy projects have been registered. There were some issues with CMCs and KCs which had been discussed at the meeting and presented to the CCM Working Group on CMCs earlier in the week.

## **8.7 SIM area mass activities (Dr Claudia Santo, LATU)**

Dr Santo outlined the structure of the SIM Mass Working Group. There are 34 member countries divided into five sub-regions. Of the members 21 are signatures of the MRA. An issue in the area is the wide range of capabilities among member laboratories.

The structure of sub working groups and the chairmanship of each was presented.

Training activities within the RMO were described. This activity is important due to range of capabilities of laboratories in the region. Activities have included a mass workshop at LACOMET in November 2007 and a density workshop at CENAM in November 2006. Four workshops in the area of pressure and vacuum had also been held. Training in torque and a triangular cooperation between PTB Germany, INN Chile and ANDIMET has provided training in the force area. SIM has also produced technical guides in a number of areas.

Details of comparisons were presented. A significant number of comparisons have been undertaken and published in conferences proceedings but not registered with the KCDB. This issue will be addressed in the near future. There have been over 20 comparisons in mass area, three in volume and density, several in pressure and vacuum and about 10 in the area of force.

Status of CMCs was outlined by technical area, and the submission and review process for CMCs was outlined.

## **8.8 SIM area flow activities (WG10 flow) (Dr Roberto Arias, CENAM)**

The scope of the WG was outlined. There are 6 technical areas and the WG has a membership of 34.

A summary of CMCs and future submissions was presented. Comparisons [SIM.M.FF-K4](#) and [SIM.M.FF-S4](#) (volume) are underway and three new comparisons are planned (for low pressure air flow, water flow and kinematic viscosity).

Key areas of research and development were summarised. INMETRO are constructing a facility for air speed measurement which is due to be completed in July 2008. They are also developing a facility for oil flow measurement. NIST is planning to perform calibrations for large natural gas flows using rented Colorado Experiment Engineering Station Inc. (CEESI) Iowa facilities with NIST personnel continuously involved. A new flow measurement facility for liquid hydrocarbons is being constructed at CENAM.

## 9 WORKING GROUP REPORTS (PART 3)

### 9.1 Report from the Working Group on CMCs (Dr Chris Sutton, MSL)

The last meeting was held on 23 April 2008 at the BIPM. The membership of the WG consists of WG chairs and representatives from all the RMOs. Dr Sutton presented the background to the WGCMC, its terms of reference, and its main roles.

An update from the JCRB had been presented by the JCRB Executive Secretary, Dr Espina. This included the plan to consolidate the many JCRB documents and the agreement between the CIPM and ILAC to unify the definitions of the terms Calibration and Measurement Capability (CMC) and Best Measurement Capability (BMC) which in future will all be referred to as CMCs.

The current state of BIPM mass area CMCs had been discussed. Currently there are no BIPM CMCs. The WG had unanimously agreed that it was essential for BIPM to have CMCs in the KCDB in order to provide for traceability of the mass scale and for mass to become part of CMC system.

Brief reports had been presented by RMO TC chairs.

Dr Davis had raised the issue of including device uncertainty in CMCs and referred the meeting to several documents that are available on the JCRB open access part of the BIPM website including [CIPM/07-25](#). He reported that Note 5 of this document requires CMC uncertainty statements to incorporate agreed-upon values for the best existing device.

The WGLP had proposed more “user-friendly” CMCs orienting entries towards instrumentation rather than just values. This was accepted as good practice by WG-CMC and seen to be beneficial in giving more information to CMC users and making it easier to identify the uncertainty associated with the performance of the device under test. An example of the implementation of this CMC format was given from the vacuum area. The WG-CMCs Chair noted that this proposal from the WGLP was consistent with a subsequent agenda item to expand the classification of services.

Dr Davis commented that if column C in the CMC table was used to describe the instrument then this could be searched for by end users when accessing the CMC database.

Dr Bauer reported that WGV planned to simplify viscosity CMCs.

Concerning supporting information for CMC submissions, the WG accepted that, given long delays in the completion of some KCs and the problems some NIMs are having gaining access to KCs, information other than KC results is still acceptable (see [JCRB-14/06\(2a\)](#) for guidance). Dr Sutton stressed this other information must be publicly available. A draft document outlining comparisons necessary to support CMCs is available on WG website.

Professor Wallard commented on BIPM measurement capabilities and uncertainties. These are available in some form on the web or via certificates issued, however this information is not always easily accessible. At the request of the CIPM, a BIPM Task Group has already been set up to investigate how the approach to uncertainty statements of the BIPM can be unified and validated.

Dr Sutton commented that a CMC entry for the BIPM would be the most useful way to address this issue.

Dr Tanaka pointed out that Dr Sutton is the interim chair of the WG-CMCs and proposed him as permanent chair given his good work in the area; there were no objections.

## **9.2 Report from the Working Group Chairpersons meeting (Dr Mitsuru Tanaka, NMJJ)**

Dr Tanaka outlined the topics of discussion at the WG chairpersons meeting; membership, key comparison periodicity and terms of reference were all discussed.

New technical areas in each of the WGs were discussed, as were CMC issues. An improvement to the reviewing process for CCM and RMO KCs was proposed with two people reviewing each KC report; the WG chair and another person from a different WG, chosen by the Executive Secretary in consultation with the WG chairs. Strategic planning presentations were given by the WG chairs and it was commented that the EURAMET roadmaps may prove useful as a basis for strategic planning in the technical areas. The CIPM initiative in material metrology was presented and discussed.

## **10 MATERIALS METROLOGY ACTIVITIES IN THE CCM (Dr Mitsuru Tanaka, CIPM)**

Tasks which the CCM must address include:

- Identification of areas within material metrology (MM) where there is a need for traceability (the Hardness Working Group was given as an example of an area where this issue had been successfully addressed).
- Cooperation with international activities and with other interested bodies such as IEC, ILAC, ISO, OIML, VAMAS etc.

Dr Tanaka gave examples of measurements such as Young's modulus, hardness, tensile strength, thickness of surface layers, sizing of nano-particles where metrological traceability could be provided by the CCM.

A report by Dr Seton Bennett (NPL) to the CIPM had outlined areas where each CC could provide measurements for material property measurements. Seven quantities had been recommended, where measurement traceability could be addressed by the CCM. These were: hardness, modulus, strength, toughness, fatigue, creep and viscosity.

Eight VAMAS technical working groups with measurement issues relating to the CCM were identified. These are:

- TWA3: Ceramics for structural applications
- TWA5: Polymer composites
- TWA17: Cryogenic structural materials
- TWA20: Residual stress

- TWA22: Mechanical properties of films
- TWA29: Nano-mechanics
- TWA31: Residual stress in welds
- TWA32: Dynamic modulus measurement

The Recommendations of the AHWGMM/CIPM were presented. These are:

1. The Working Group recommends that the CIPM should sign a Cooperation Agreement with VAMAS in order to ensure an ongoing dialogue and actions with a view to identifying key traceability issues affecting the accuracy and repeatability of the measurement of materials properties.
  2. The Working Group recommends that the CIPM should instigate a further review in 3 or 4 years time to evaluate the progress made and determine what further action, if any, is required.
- 3-5. CCs should set up WGMMs, Joint WGMM for CCM and CCL.
6. The Working Group recommends that materials WGs established by CCs should encourage participation of all important stakeholders, including ISO/IEC, ILAC and VAMAS.
  7. The Working Group recommends that NMIs should support materials metrology in their work programmes in order to implement and disseminate best practice in the measurement of materials properties.
  8. The Working Group recommends that NMIs should encourage their staff to participate actively in the work of materials working groups.

Details of the potential national calibration hierarchy for materials metrology were given and an example was drawn from the area of tensile testing machines. It was noted that the CCM needs to gather information from end users and develop reliable methods for materials measurement.

Proposals for future materials metrology activity in the CCM were outlined:

Phase 1: 4/2008 – 10/2009, driven by AHJWGMM

1. Dialogues between relevant CCM WGs and VAMAS TWAs, identifying quantities with respect to needs & seeds.
2. Investigation of the national calibration hierarchy for each quantity and study how to demonstrate its performance.
3. Formation of Joint Task Group for the quantity.

Phase 2:

1. Coordination of Pilot Studies.
2. Improvement of the procedure for measurement and calibration.
3. Expanding the scope of object materials.
4. Elaborating the technical standard for measurement and calibration.
5. Establishing or harmonization in CRM.

Professor Wallard commented that Dr Tanaka had provided a good summary of activities in the area and of the CIPM Recommendations. A draft Memorandum of Understanding with VAMAS has been drawn up. The suggestion is to use the existing CC structure to investigate development

in this area, rather than setting up a new CC.

Professor Wallard noted that BIPM needed to be kept informed of new areas of activity within the CCs so that the requirements for KCs in each area can be considered. He gave the example of nanotechnology as an emerging area where KCs could become necessary.

Dr Tanaka added the example of dynamic measurement and advised looking at the EURAMET roadmaps as a source of information on emerging technology requirements.

## 11 WORK AT THE BIPM

### 11.1 Overview (Dr Richard Davis, BIPM)

Dr Davis presented the work of the Mass section at the BIPM from 2005 to date. The work of the Section included calibrations of mass (1 kg), density and magnetic susceptibility for Member States. There is also a capability for calibrations at atmospheric pressure; this has been validated by a supplementary comparison with LNE. The last service is only available internally.

Coordination of the International Avogadro project and related work was presented. This included the production of prototypes and related surface artefacts. Additional work on air density towards production of the CIPM-2007 formula and measurement of magnetic properties of materials including work for the European Space Agency (ESA) were also highlighted. A new collaboration with NPL on cleaning primary mass standards using UV activated ozone is also underway. Initially, this programme will last three months, ending in June 2008.

The Newtonian constant  $G$  had been measured and it was noted that material properties are crucial to this experiment. Measurements for the BIPM Chemistry section included the calibration of built-in weights for a balance with magnetic suspension.

Dr Davis identified the staff responsible for calibrations, International Avogadro work, magnetic properties, the watt balance (treated administratively as a special project), and gravimetry (located administratively in the Time, Frequency and Gravimetry section).

Within the context of the International Avogadro Coordination, a renovation of the laboratory space had taken place. It was noted that capabilities for magnetic properties measurement were initially developed because modern balances have electromagnetic servo-control and nonmagnetic alloys of stainless steel do not always meet their specification. There are also issues with the very large magnets used with watt balance experiments. Tests on an ESA proof mass of a platinum-gold alloy had recently been made. The material was thought to have a theoretical susceptibility of zero (but the measured value was finite).

Future challenges in the area included; fulfilling the mission given to the BIPM in the Metre Convention, pilot KC [CCM.M-K4](#), development of a *mise en pratique* for new definition of the kilogram (with CCM WGM TG1 and TG2), completion of the IAC and advance the BIPM watt Balance.

## 11.2 Mass determination in the framework of the IAC; BIPM watt balance (Mr Alain Picard, BIPM)

Mr Picard noted that participants in the IAC needed to determine the mass in vacuum of silicon spheres to an uncertainty of 5 µg. This highlighted the need to take into account physi-sorption and chemi-sorption on the spheres surface.

Physical water vapour adsorption was discussed. A large discrepancy in silicon sorption corrections between NPL, NMJ and BIPM, had been noted. There is a need to calibrate the sphere in vacuum, but this means desorption of platinum-iridium also needs to be known.

Air density determination and the new CIPM-2007 formula was discussed. The new formula reduces the uncertainty in air density determination to  $34 \times 10^{-6}$ . However it was noted that the use of buoyancy artefacts potentially improves this uncertainty to  $25 \times 10^{-6}$ , making no assumptions about the composition of air.

Mass stability data between air and vacuum measurements for silicon sphere was presented. Uncertainties in air of 14.3 µg could be achieved. It is calculated that measurement in vacuum (using platinum-iridium sorption artefacts) can achieve an uncertainty of 5 µg. Evaluation of chemi-sorption on silicon spheres is to be performed by baking the sphere at 500 °C in vacuum. Data for mass comparisons of silicon spheres in vacuum were presented. Results show that the target uncertainty of 5 µg has been achieved.

Progress on the BIPM watt balance was presented. It was recalled that Dr Jabbour had already shown the general principles of watt balances. The novel features of the BIPM watt balance include:

- Weighing and moving measurements being made simultaneously;
- A superconducting coil and a cryogenic magnet. This gives the benefit of no coil resistance, essential for a simultaneous measurement of current and induced voltage, and improved temperature stability of the magnetic field,  $B$ ;
- Dynamic alignment, with all degrees of freedom under servocontrol.

The physical design of the balance was shown. Results at present give a repeatability of 4 parts in  $10^4$  in air. Plans for the future development of the balance were outlined.

Dr Jousten asked what level of vacuum was used for the silicon sphere comparison and commented that differences in vacuum may explain the discrepancies between the findings presented for different NMIs.

Dr Fujii commented on variable sorption effects for silicon in vacuum.

## 12 RECOMMENDATIONS TO THE CIPM

Dr Sutton suggested that the recommendation for BIPM to declare mass CMCs should be proposed to the CIPM. Professor Wallard said the issue would be addressed but did not envision the need for a formal Recommendation. He assured the Chair of the WG-CMCs that the views of the WG will be conveyed to the CIPM, since both he and Dr Tanaka attend CIPM meetings.

Professor Wallard thanked Dr Tanaka for presiding over the CCM meeting.

Dr Tanaka thanked the Director and staff of the BIPM for their work in preparing for the CCM meetings and throughout the year.

Dr Tanaka formally closed the meeting.

Dr S. Davidson, rapporteur

revised October 2008

**APPENDIX G 1.**

**Working documents submitted to the CCM at its 11th meeting**

Working documents submitted to the CCM at its 11th meeting are on restricted access