Bureau International des Poids et Mesures

Consultative Committee for Mass and Related Quantities (CCM)

Report of the 14th meeting
(21-22 February 2013)
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.

M. Milton,
Director BIPM

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

as of 21-22 February 2013

President

Dr P. Richard, Federal Office of Metrology, METAS, Bern-Wabern.

Executive Secretary

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

Members

Bundesamt für Eich- und Vermessungswesen [BEV], Vienna.

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

Centro Español de Metrología [CEM], Madrid.

Centro Nacional de Metrología [CENAM], Querétaro, Qro.

D.I. Mendeleyev Institute for Metrology (VNIIM), Rosstandart [VNIIM], St Petersburg.

Federal Institute 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 Physical Laboratory of India [NPLI], New Delhi.

National Research Council of Canada- Institute for National Measurement Standards[NRC-INMS], Ottawa.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

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

Technical Research Institute of Sweden [SP], Borås.

VSL, [VSL], Delft.

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

Observers

Agency for Science, Technology and Research [A*STAR], Singapore.
Instituto Português da Qualidade [IPQ], Caparica
Laboratorio Tecnológico del Uruguay [LATU], Montevideo
National Metrology Institute of Turkey [UME], Gebze-Kocaeli.

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

The 14th meeting of the Consultative Committee for Mass and Related Quantities (CCM) was held at the International Bureau of Weights and Measures (BIPM), at Sèvres, on 21 and 22 February 2013.

The following were present: P. Abbott (NIST), M. Ballico (NMIA), H. Baumann (METAS), L.O. Becerra (CENAM), H. Bettin (PTB), W. Bich (INRIM), M. Borys (PTB), C. Buchner (BEV), S. Davidson (NPL), J. Faller (JILA), P. Farár (SMU), K. Fujii (NMIJ/AIST), G. Genevès (LNE), A. Germak (INRIM), C. Jacques (NRC-INMS), T. Kobata (NMIJ/AIST), S. Lee (KRISS), P-A. Meury (LNE), M. Nieves Medina (CEM), A. Ooiwa (NMIJ/AIST), Y.K. Park (KRISS), F. Pereira (LNE), P. Pinot (LNE-INM/Cnam), P. Richard (President of the CCM), I.A. Robinson (NPL), R. Schwartz (PTB), A.G. Steele (NRC-INMS), C.M. Sutton (MSL), J. Torres-Guzman (CENAM), K. Ueda (NMIJ/AIST), B. van der Merwe (NMISA), L. Vitushkin (VNIIM), C.J. Williams (NIST), W. Wiśniewski (GUM), J. Wright (NIST), Y. Zhang (NIM).

Observers: J. Caceres (LATU), S. Fank (UME), S.M. Lee (A*STAR).

Invited: H. Bettin (PTB), A. Elwan Eltawil (NIS), F. García-Leoro (CESMEC), K. Jousten (PTB), A. I. Kolozinskaya (NSC IM), R. Kumme (PTB), V. Loayza (INMETRO), L.Nielsen (DFM), H. Wolf (PTB), J. Wright (NIST).

Also present: R.S. Davis (*interim* Executive Secretary of the CCM), C. Kuanbayev (Executive Secretary of the JCRB), T.J. Quinn (Director Emeritus of the BIPM), E. de Mirandés, H. Fang, M. Stock, C. Thomas (KCDB Coordinator), all from the BIPM.

Excused: A. Picard (BIPM), M.E. Filipe (IPQ), Z.J. Kubarych (NIST), I. van Andel (VSL).

Dr Richard, President of the CCM, opened the meeting at 9.00 am and welcomed the delegates.

Dr Davis (*interim* Executive Secretary of the CCM) introduced Dr Stock (*interim* Director of the BIPM Mass Department), Dr Milton (Director of BIPM since January 2013) and Dr Richard (President of the CCM since November 2012).

Dr Milton welcomed the attendees. He said that the meeting would discuss historic changes to the SI. He noted that the eyes of National Metrology Institute (NMI) directors were on the Consultative Committees (CCs) and that they would be looking to the CC community for the development of strategy.

Dr Richard gave a brief history of the past CCM presidents. Dr Richard noted that he had taken over from the fourth President, Dr Tanaka, who had served for 10 years. Dr Richard has already attended seven CCM meetings, exactly half of those that had been held since the inception of the CCM. He noted that Dr Milton was attending his first CC meeting and remarked that the CCM was witnessing the beginning of a new era. Dr Richard thanked Dr Davis for his assistance in the preparations for the meeting and the help received generally since his appointment as *interim* Executive Secretary.

Dr Davidson was appointed rapporteur.

Dr Davis delivered a message from the CCM Executive Secretary, Mr Picard. Mr Picard was disappointed at not being able to attend the meeting. He thanked Dr Davis for his help and congratulated Dr Richard on his appointment to CCM President. Mr Picard hoped that the meeting would be fruitful and said he would be eager to learn the outcome.

Delegates introduced themselves and outlined their relationship to the CCM.

Dr Richard introduced a number of important topics to be presented in greater detail during the meeting: the latest version of the CCM strategy document, the latest version of the *mise en pratique* and amendments (and a template for comments on version 7 [later changed to a request for comments on version 7.1]) and the BIPM strategy for use of the international prototype of the kilogram (IPK).

The agenda was accepted without amendment.

2 CCM STRATEGY (DOCUMENTS CCM/13-2A-1, CCM/13-2B-1 AND CCM/13-08)

Dr Richard described the history of the CCM strategy document. The context of this document is Resolution 10 of the 24th meeting of the General Conference on Weights and Measures (CGPM) in 2011, which initiated a review of the role, mission, objectives, long-term strategy and governance of the BIPM. Work on this strategy document began in July 2012 with the creation of the CCM Working Group on Strategy (WGS) chaired by Dr Richard, following a directive of the International Committee for Weights and Measures (CIPM). The WGS members are all the CCM WG chairs with Dr Bich and Dr Schwartz as additional members. The first full meeting of the WGS was held in November 2012, following a web conference held in September 2012, and the first strategy document was submitted to the CIPM in January 2013. Dr Richard noted that the CCM strategy document is one of the working documents for this meeting.

The strategy document contains general information on the CCM, its achievements and stakeholders, future strategy and information on key comparisons (KCs) including the resources required to pilot and participate in KCs. Terms of reference have been amended to reflect the current (new) structure of the CCM WGs. Achievements included KCs completed and in progress, Calibration and Measurement Capabilities (CMCs) submitted, major activities and publications. Stakeholders include the metrology community (CGPM, CCs, DIs, NMIs), industry, the legal metrology community, conformance bodies and research establishments. A Future Scan includes details of the current kilogram redefinition experiments and future plans, for example measurement of density at high pressure. The rationale for various activities is outlined and it is concluded that the current set of KCs is sufficient to cover the current scope of submitted CMCs. The CCM vision includes a simplification in the CCM structure and an improvement in efficiency. A sharing of validated calculation tools and the strategy for analysing KC data across WGs (and across CCs) is proposed.

Concerning the simplification of the CCM structure, Dr Richard said the first phase was under way and the original number of WGs (14) had been reduced to 11. New WGs on the Realization and the Dissemination of the kilogram (WGR-kg and WGD-kg) had been established and would be chaired by Dr Bettin (PTB) and Dr Sutton (MSL), respectively. WGR-kg would supersede the WGSI-kg and the WGAC; WGD-kg would supersede the WGM (and its two task groups).

Dr Milton commented that this is not the first time such a strategy exercise had been undertaken by the BIPM. He also said that it was vital that the strategic vision was outlined to NMI directors and he noted that their opinions had been sought at an early stage so that national strategies could be taken into account when developing the BIPM strategy. The plan is to draft an overall strategy based on CC strategies by summer 2013 in time for discussion at a meeting of NMI Directors in October 2013.

Dr Williams asked for clarification of Section 6.1.8 of the current draft CCM Strategy V0.7 with regard to the functioning of the BIPM pool, sometimes referred to as an ensemble of reference artefacts. Dr Richard said that this was a way of describing the need for the BIPM pool and that some amendments had already been introduced to clarify the statements. Dr Richard said that he would be happy to receive proposals for amendments for a short period after the meeting.

3 REPORTS OF THE WORKING GROUPS

3.1 Report of the Working Group on Mass Standards (Dr Chris Sutton, MSL) (document CCM/13-09)

The last meeting of the Working Group on Mass Standards (WGM) was held on 19 February 2013 at the BIPM headquarters. Dr Sutton outlined the aims of the WGM and the roles of the two associated Task Groups: TG1 (Mass metrology under vacuum and the technologies affecting the realization of the new definition of the kilogram) and TG2 (Uncertainty due to traceability to the IPK). During the TG1 meeting, scientific presentations had been given on: mass-in-vacuum to mass-in-air, mass stability, materials for masses, surface studies, cleaning techniques, experiments for future realization of the kilogram, mass transfer/transportation and mass metrology to support the new kilogram definition. A discussion of the draft *mise en pratique* had also taken place. The TG2 meeting had included three presentations on the analysis of historical data on the values of the BIPM prototype kilograms. Least squares analysis carried out at the DFM, modelling mass changes as dependent on time after cleaning, gave values up to 30 µg different from those assigned by the BIPM. The NRC presented initial modelling with a Kalman filter. Further work on this is necessary before results are available. The BIPM presented details of optimized fitting using a three parameter model, which confirms the values originally assigned to the copies. Future work would include the modelling of the results of the BIPM ensemble of reference mass standards.

The WGM had received presentations by: the NPL on cleaning, transfer and storage towards the new kilogram; the METAS on cleaning and surface studies (three talks); the NRC on the development of novel mass artefacts for watt balances; and the LATU on magnetic field gradients in electronic balances. The BIPM had outlined the proposal to use the IPK and the use of the ensemble of reference mass standards, the INRIM presented general mass activities and the MSL described a proposed watt balance based on pressure balances. Dr Sutton commented on the high quality of the scientific work presented. Presentations from the three meetings would be made available on the WGD-kg webpage.

The status was reviewed for each of the three current CIPM key comparisons for mass:

- CCM.M-K4: 1 kg stainless steel, results being analysed
- CCM.M-K6: 50 kg, protocol complete
- CCM.M-K7: 500 mg, 5 g, 10 g, 100 g, 5 kg (Set 3), protocol complete.

No new KCs were proposed.

Approval was sought and obtained from the CCM to form a new working group, WGD-kg, for the dissemination of the kilogram and to confirm Dr Sutton as its chair. The WGD-kg will be formed by combining WGM with Task Groups 1 and 2 and will replace the current WGM. Approval was also obtained for the members of WGM and Task Groups 1 and 2 to become members of WGD-kg.

The current status of all the realization experiments was outlined. Dr Sutton noted that the state of progress suggested that a potential redefinition is still more than two years away.

Dr Richard asked if the data analysis from TG2 would be published. Dr Nielsen (DFM) and Dr Stock (BIPM) said publication was being pursued. Dr Jacques said he would publish a summary of the Kalman filter approach.

Dr Williams asked if a consensus approach could be recommended. Dr Jacques highlighted the differences between the approaches and emphasized that they were complementary rather than considered as separate solutions. Dr de Mirandés said that a joint document outlining best practice should be considered. Dr Steele agreed that such a (consensus) document would be useful in highlighting the approaches and the current state of understanding of the uncertainty in the IPK.

3.2 Report of the Working Group on Density (Dr Kenichi Fujii, NMIJ) (document CCM/13-10)

Dr Fujii noted that the last meeting of the Working Group on Density (WGD) had been held in 2011. Terms of reference were outlined. The status of CIPM key comparisons for density was reviewed:

- CCM.D-K1: Density measurements of a silicon sphere by hydrostatic weighing (2001-2003), approved for equivalence
- CCM.D-K2: Comparison of liquid density standards (2004-2005), final report submitted
- CCM.D-K3: Density measurements of stainless steel weights (2011-), planned (questionnaire distributed and answers received from 13 NMIs)
- CCM.D-K4: Hydrometers (2011-2012), report in progress, Draft A.

RMO KCs and other bilateral comparison details were also presented. Links between KCs, SCs bilateral and international comparisons were outlined.

New KCs proposed were:

- CCM.D-K5: Comparison of volume measurements by optical interferometry
- CCM.D-K6: Comparison of density measurements by vibrating-tube densitometers

- CCM.D-K7: Comparison of density measurement under high pressures and high temperatures
- CCM.D-K8: Comparison of refractive index of liquids.

Regarding CCM.D-K6, the opinion of the WGD was that it may not be a capability of NMIs and may be conducted by ILAC and/or other interested laboratories. The WGD had also discussed how to cover the variety of CMCs from a limited number of key comparisons.

Dr Wolf had presented details of the PTB experiment on absolute measurement of the density of water. The results had confirmed the CIPM formulation for the density of water at the 1 ppm level.

Details of optical interferometric determination of ^{28}Si sphere diameter and volume at the NMIJ, the PTB, and the NMIA were outlined. A report had been published in 2011, which showed that mean diameter values measured by the three NMIs agreed at the 1 nm level.

A highlight for the WGD, in cooperation with CCM WGAC, is reducing the relative standard uncertainty of the volume measurement of silicon spheres down to 2×10^{-8}, contributing to a fundamental reduction of the uncertainty in the density standard.

Technological trends included the requirements for high-pressure and high-temperature density measurements and the need to measure refractive index and surface tension. The contribution of density measurement to the energy, environment and food industries will be increasingly important.

Dr Ballico commented on the large number of KCs and supplementary comparisons (SCs) and that there appeared to be overlap. He asked for clarification of the status of KCs and SCs. Dr Sutton said document CIPM MRA-D-05 on Measurement Comparisons in the CIPM MRA specified the requirements for KCs and SCs. Dr Stock asked about the planned comparison on refractive index and commented that the CCPR had also proposed a refractive index comparison. Dr Fujii replied that refractive index was used to infer liquid densities and this was why it had been discussed within the WGD. Dr Richard asked for cooperation between all CC WGs working in this area. He also asked about the provenance of the technological trends outlined. Dr Fujii replied that his outline reflected the demand for services from the NMIJ but that this demand reflects a more general trend. Dr Williams added that the NIST was also aware of requirements for refractive index measurements. Dr Richard asked for details of the CCM.D-K2 comparison results. Dr Fujii said agreement at the part in 10^5 level was generally achieved but one or two results were outside this range. Dr Richard asked if the non-equivalence would affect declared CMCs. Dr Fujii said this had not yet been considered.

3.3 Report of the Working Group on Viscosity (Dr Henning Wolf, PTB) (document CCM/13-11)

Dr Wolf outlined the terms of reference for the Working Group on Viscosity (WGV) and showed a breakdown of the 21 members by regional metrology organization (RMO). The last meeting of the WGV was held on 10 February 2011 at the BIPM headquarters. Seventeen NMIs have CMC entries. Key comparison CCM.V-K3 is complete and a Draft A report is expected in April 2013. A simplification which would lead to fewer CMC entries has been proposed and will be completed by 2016. RMO KCs were listed. The KCs undertaken cover the temperature range −50 °C to 150 °C and the dynamic viscosity range 0.1 mPa s to 100 000 mPa s. Comparisons

alternate between covering a broad viscosity range with a moderate temperature range and covering extreme viscosities and/or temperatures. The period between KCs is about six years with the next KC planned for 2018 and covering a moderate viscosity range and a broad temperature range.

Notable research activities included falling ball experiments for absolute viscosity measurements which are in progress at the LNE and the NMIJ. Target materials for these measurements include fuels.

WGV meetings are held every three years, although preference is given to holding meetings in conjunction with CCM meetings.

Technology trends included: absolute viscosity measurements at intermediate kinematic viscosity (1000 mm^2/s), implementing viscosity measurements under pressure up to 100 MPa, implementing viscosity measurements using viscometers other than glass capillaries (rotational viscometers are the most widely used industrial devices) and implementing viscosity determination of non-Newtonian liquids.

Dr Milton asked about non-Newtonian liquids and the technological drivers. Dr Wolf replied that the majority of liquids used in industry were non-Newtonian but they were unstable and therefore difficult to measure. Practical methods of providing traceable measurements (and equipment evaluation) in this area were being investigated. Dr Fujii commented that 90 % of liquids used in industry in Japan were non-Newtonian so this area was of great interest. Dr Davis recalled that some years ago the president of CCQM had asked about any plans within the WGV to include non-Newtonian liquid measurements.

Dr Richard asked about the drivers for simplification of the CMCs. Dr Wolf commented that dynamic and kinematic viscosities did not both need to be declared. Special entries for "reference liquids" currently existed and were not necessary and made the use of the CMCs more complicated. Dr Richard asked about the 2016 target for simplifying CMCs. Dr Wolf said it was to coincide with the completion of the relevant KC.

3.4 Report of the Working Group on Force (Dr Rolf Kumme, PTB) (document CCM/13-12)

Dr Kumme said the last meeting of the Working Group on Force (WGF) had been held in China in 2011 and the next meeting was planned for 2014 in South Africa. Draft terms of reference were outlined. Most of the technical discussions in the last meeting were related to force standards and focused on the improvement in the stability and reproducibility of force transducers.

Final reports for KCs CCM.F-K1.a and CCM.F-K1.b, CCM.F-K2.a and CCM.F-K2.b, CCM.F-K4.a and CCM.F-K4.b were agreed and published. The KCs CCM.F-K5 and CCM.F-K22, which had been conducted in the past, were agreed for provisional equivalence. CCM.F-K3.a and CCM.F-K3.b are under way and should be finished and agreed by the next WGF meeting, planned for 2014. An issue that arose for the large force range (CCM.F-K4) was that the transfer standards were large (500 kg) making transport slow and costly. Torque comparisons CCM.T-K1 and CCM.T-K1.1 were complete and published. CCM.T-K2 is under way and should be finished and agreed at the next WGF meeting. The WGF agreed that a period

of 15 years is reasonable between KCs for dead-weight machines. RMO Key and Supplementary Comparisons were listed.

No new KCs were agreed but comparisons of small force, multi-component forces and the effect of parasitic components would be investigated. A torque KC in the range below 500 N m was proposed, especially for torque steps of 20 N m and 50 N m.

Dr Baumann asked about the range for small force measurements. Dr Kumme said it was not decided but millinewton and micronewton ranges were under discussion. The provision of millinewton transfer standards would be difficult, but cantilevers could be used at the micronewton level. Dr Baumann asked about industrial requirements. Dr Kumme said for the calibration of micro-hardness machines (millinewton) and (AFM) cantilevers (micronewton) traceability measurements were required. Dr Bich added that there was a requirement from the aerospace industry to calibrate micronewton thrusters.

Dr Borys enquired about the industry requirements for dynamic force measurements. Dr Kumme said there was currently no traceability. A BIPM workshop had been held in November 2012 and an EMRP project was under way in Europe. Materials-testing machines in particular have a major requirement; a new ISO standard was published in 2012.

3.5a Report of the Working Group on High Pressures (Dr Jorge Torres-Guzman, CENAM) (document CCM/13-13)

Dr Torres-Guzman outlined the terms of reference for the Working Group on High Pressures (WGHP) and presented the programme of work for the next 5 years. He encouraged the full participation of all 19 members. The current list of members was reviewed. New membership for Dr Wüthrich (METAS) had been proposed.

The last meeting of the WGHP was held in May 2011 in Berlin and the next meeting will be in 2014. Several KCs had been completed but no KCs are currently under way. Planned KCs include those over the ranges:

- 0 kPa to 500 kPa (differential) at line pressures from 7 MPa to 20 MPa, planned for 2014
- 0 kPa to −95 kPa (negative gauge pressure), planned for 2016
- 4 MPa to 20 MPa (gauge pressure), ~2018
- 100 kPa to 7 MPa absolute and gauge (~2020).

Repetition of KCs which were over 10 years old would also be necessary. The current set of KCs was broadly felt to cover the necessary range. Careful planning and coordination of future KCs will be required to avoid interfering redundancy with the WGLP KCs.

Successes included the 5th International Conference on Pressure and Vacuum Metrology and the 4th IMEKO TC16 Conference which were held together in Berlin, Germany, in May 2011 and organized primarily by the CCM pressure WGs, IMEKO TC16-4 and the PTB. Many papers presented at the joint conference were subsequently published in two special issues of the journals *PTB-Mitteilungen* and *Measurement*. Dr Torres-Guzman highlighted the publication of the WGHP strategy document. Major issues included the limited number of active WG members.

Technological trends and challenges included: dynamic pressure measurements and dynamic pressure standards, optically based standards for static and dynamic pressures, replacement of primary mercury manometers by alternative standards – special pressure balances or oil manometers, low differential pressures with high accuracy and low line pressure, high pressure measurements (above 1 GPa) and standards for industrial high pressure technologies. Dr Richard asked if the KCs completed in 2012 had been published and what new KCs were proposed. Dr Torres-Guzman confirmed that all completed KCs had been published and four KCs were proposed. Dr Robinson asked if there was a proposal for the WGHP to investigate dynamic pressure measurement. Dr Torres-Guzman said there was but the number of members participating in this area was low at present.

3.5b Report of the Working Group on Low Pressures (Dr Karl Jousten) (document CCM/13-14)

Dr Jousten said that 20 NMIs were members of the Working Group on Low Pressures (WGLP). Meetings were typically held every three years. The last meeting was held in Berlin in May 2011 and the next meeting will be held in February 2014.

Dr Jousten presented the status of KCs. Measurements for CCM.P-K12 for leak rates in the range 10^{-14} mol/s to 10^{-11} mol/s had been made during 2007 to 2009, the Draft A report was approved in July 2010 and the final report published in December 2012. This KC will support the application of participants for CMCs in this area and the list of services had been changed recently to include a new service category for molar flow rate to accommodate these CMCs. A bilateral follow-on comparison, CCM.P-K12.1, was proposed for one participant with inconsistent data in CCM.P-K12. Measurements for CCM.P-K14 (10^{-4} Pa to 1 Pa) had been completed within one year and the Draft A report had been circulated in January 2013. CCM.P-K3.1 had been completed as a bilateral comparison between the PTB and the NIST to address issues with previous comparison results from the PTB. The Draft A report is due in May 2013. Measurements for CCM.P-K4.2012 (1 Pa to 10 kPa absolute) started in January 2012 and the comparison is due for completion in mid-2013. A protocol was under development for the ultra-high vacuum comparison CCM.P-K3.201X (3×10^{-9} Pa to 3×10^{-4} Pa). Dr Jousten illustrated that the comparisons already completed covered the majority of the low pressure range.

With regard to the leak-rate comparison CCM.P-K12, Dr Jousten discussed the comparison process which dealt with the expected linear drift in the standard due to the change in internal pressure as gas leaked out. Three analysis methods had been implemented, that of Zhang, the Largest Consistent Subset of Cox, and Bayesian Model Averaging of Elster and Toman. No consensus could be found on the best analysis method. Dr Jousten noted that the CIPM MRA Technical Supplement T2 stated "The degree of equivalence of each national measurement standard is expressed quantitatively by two terms: its deviation from the key comparison reference value and the uncertainty of this deviation (at a 95 % level of confidence)" but commented that this does not allow any statistical judgements of whether the degree of equivalence is satisfactory.

Dr Jousten commented that the wording of CIPM MRA-D-05 (Section 4.7) regarding the agreement of the participants to the Draft A suggests that all participants need to approve the draft. He suggested majority agreement rather than consensus (defined as no negative votes)

should be acceptable. The wording of CIPM MRA-D-05 (Section 4.7) may also be ambiguous regarding the Draft B stage at which CMCs could be supported by the comparison results.

New activities in the low pressure area include calibration for end users of sniffer tests to detect leaks. Other activities include: research for establishing the pressure scale (> 1 Pa, < 400 kPa) by refractive index measurement of helium (NIST), dynamic vacuum pressure measurement (EMRP IND12), cooperation between NMIs and the "rarefied gas dynamics" community to improve predictability of gas flows without calibration (EMRP IND12) and establishing traceability for partial pressure measurement and outgassing rate measurement.

Dr Richard said he would prepare a document on approval of final KC reports. Dr Steele added that it should be acceptable that the conclusion of a KC was that it had been unsuccessful. He also stated that document CIPM MRA-D-05 was not prescriptive as to the (statistical) evaluation of the reference value. Dr Bich noted that 12 years ago a workshop had been held at the NPL and perhaps a further workshop or publications should be considered. Dr Milton asked about the statement that the key comparison reference value (KCRV) cannot be evaluated statistically. Dr Jousten explained that paragraph T.2 of the Supplement to the CIPM MRA suggests a fixed value for the KCRV that is valid for all participants, whereas a statistical analysis would compute reference values for different subsets of participants, followed by averaging the biases among these values. Thus no common reference value would be calculated. Dr Milton said that the issue had been met by other CCs and had not impeded the publication of the final report. Dr Jousten added that the proposed evaluation method was described in a paper submitted to *Metrologia* but the paper was not accepted for publication. Dr Milton remarked that there was a danger that expanding the KCRV uncertainty statistically could have the negative effect of making it artificially large (meaning all participants would arbitrarily agree).

3.6 Report of the Working Group on Hardness (Dr Alessandro Germak) (document CCM/13-15)

Dr Bich presented the report of the Working Group on Hardness (WGH) on behalf of Dr Germak, who was unable to attend. Two WGH meetings had been held since the last CCM meeting; 21 September 2011 coinciding with meetings of ISO TC 164 and 11 September 2012 with the IMEKO World Congress. The next meeting will either be in the Netherlands around the same time as the 16–20 September 2013 meetings of ISO TC 164 or in South Africa in conjunction with the 12th HARDMEKO Conference to be held on 3-7 February 2014. The terms of reference had been slightly revised and these were presented.

An overview of the programme of work for the next five years was presented. Hardness fields had been identified for further activities to improve the measurement traceability through development of primary definitions and organization of KCs and pilot studies. These were: instrumented indentation test, nano-indentations, dynamic hardness, portable hardness testers, hardness of elastomers, Martens hardness and Leeb hardness. It had already been decided to pursue the development of international primary definitions for Brinell, Vickers and Rockwell scales. Work had started and was due for completion during 2015. KCs for different hardness scales (HRB, HRN, HBW, HSD, HL) were planned for 2013-2020.

Membership of the WGH was outlined and no changes were proposed.

KCs under way are CCM.H-K2 for the Brinell Hardness scale (Draft A report in progress) and CCM.H-K3 for the Rockwell C Hardness scale (measurements due to start in March 2013). For

CCM.H-K2, there have been issues with the numerical aperture that are not covered by the technical protocol. The pilot laboratory has proposed a correction procedure which will be sent to participants. A pilot study on Rockwell diamond indenters is also under way (measurements in progress). Planned KCs are: Brinell (selected scales to be determined), Rockwell B scale (HRB), Rockwell superficial diamond scales (HR15N, HR30N and HR45N) and Shore Hardness D scale (HSD). A KC related to Instrumented Indentation Testing (IIT) was also suggested. It was thought that current and proposed KCs are sufficient to support all CMCs in the hardness area.

The major successes for the WGH include continuing development of international primary definitions of hardness scales (Brinell hardness scales have been well investigated) and organization of the Rockwell C KC. Issues include problems with the ill-defined numerical aperture used for indentation measurement. The main problem has been the Brinell KC; however discussion of the numerical aperture issue has been very useful for the development of the international primary definition of the Brinell scale.

Technical challenges included promotion of international cooperation among NMIs, designated institutes (DIs), RMO members and international organizations such as the International Organization for Standardization (ISO), ASTM International, the International Organization of Legal Metrology (OIML), the Versailles Project on Advanced Materials and Standards (VAMAS) and others, for improving traceability and standardization in the field. An increase in demand for traceability is foreseen in the instrumented indentation test, nano-indentations, dynamic hardness, portable hardness testers, hardness of elastomers and Leeb hardness.

3.7 Report of the Working Group on Fluid Flow (Dr John Wright, NIST) (document CCM/13-16)

Dr Wright stated that the Working Group on Fluid Flow (WGFF) meets annually in conjunction with fluid flow conferences. The last meeting was held in 2012 at the International Symposium on Fluid Flow Measurement in the USA. The next meeting will be in conjunction with FLOMEKO, 18–19 September 2013, to be held in Poitiers, France.

Guidelines for CMC and Calibration Report Uncertainties had been established (to help with inconsistencies in documents CIPM MRA-D-04 and International Laboratory Accreditation Cooperation (ILAC) policy). A six page document had been produced which could serve as a model for accredited flow calibration laboratories. Seven example uncertainty analyses were outlined in the guide.

Regarding KCs, the first round had been completed 2–3 years ago. For the second round:

- CCM.FF-K2.1.2011 for mixed hydrocarbon liquid and water flow, 5 kg/s to 60 kg/s, piloted by the VSL is scheduled to start August 2013. The protocol has been agreed.
- CCM.FF-K2.2.2011 for hydrocarbon liquid flow, 13 kg/s to 67 kg/s, piloted by the NMIJ is due to start in November 2013. Preliminary work on evaluation of the transfer standards had been undertaken.
- CCM.FF-K3.2011 for air speed, 0.5 m/s to 40 m/s, piloted by the LNE-CETIAT. The protocol had been agreed and the comparison is scheduled to start in April 2013. The first air speed comparison CCM.FF-K3.2005 using an ultrasonic anemometer (EURAMET Project 827) had shown poor agreement at certain values due to issues

with the transfer standard altering the air flow and poor application of correction procedures due to limited documentation.

- CCM.FF-K4.1.2011 for volume comparison, 100 mL and 20 L, was under way with nine out of ten participants having completed measurements.
- CCM.FF-K4.2.2011 for volume measurement by micropipette, piloted by the IPQ. Final report posted on the BIPM key comparison database (KCDB) in January 2013. An issue with the results had been the correction of the air buoyancy effect which was not applied by some laboratories.
- CCM.FF-K5.2011 for high pressure gas flow, piloted by the PTB. This comparison is scheduled to start in October 2013.
- CCM.FF-K6.2011 for low pressure gas flow, 2 m^3/h to 100 m^3/h, piloted by the CMI and the SMU. Measurements have been completed and a report is being written.

A summary of KC reports posted on the KCDB over the period since the last CCM meeting was presented.

Other issues for the WGFF included: the improvement of KC reports (shorter and in a standard format), expanding WG participation, increasing the use of electronic communication, guidelines on KC linking (via common transfer standard and/or common participants) and concern about low uncertainties claimed by commercial laboratories. Solutions to the last issue might include the publication of the results of proficiency tests, thorough ISO 17025 assessments, uncertainty guidelines and direct inter-laboratory comparisons. A rationalization of flow measurement CMC sub-categories and a protocol for CMC review was proposed.

Dr Eltawil asked about the Kenya Bureau of Standards (KEBS) participating in a petroleum flow comparison and whether any information was available. Dr Wright said information was available on the WGFF website.

Dr Ballico asked whether the protocol for CMC review would include guidelines on uncertainty calculation, saying that much information already existed and it would be good for the WG to synthesize this information.

Presentation by Dr Victor Loayza INMETRO, Brazil

(As a follow-up to INMETRO's request to become a member of the CCM, Dr Loayza provided an introduction to the relevant activities and achievements of this NMI.)

Dr Loayza outlined the mechanical areas covered by the INMETRO, the site and the administrative structure of legal and scientific metrology within Brazil. The Mechanical Metrology area consists of laboratories for Fluids, Force, Mass and Pressure. The Dynamic Fluid Flow area consists of both liquid and gas flow.

Research in the area of mass includes the effect of liquids on the long-term stability of mass standards and the magnetic characterization of the mass laboratory (space and comparators). Traceability in the fluid laboratory is provided by a silicon sphere. Research includes characterization of the density of biofuels over pressure and temperature ranges. Research in pressure includes dimensional characterization of piston-cylinder assemblies. The force area covers force, torque and hardness, research includes a collaboration with the NIST to measure adsorbed energy in a Charpy impact test to establish an international standard and a

collaboration with the INRIM to produce a 10 N to 1000 N force machine. Collaboration on dynamic force measurement with the NPL, UK, is under way.

Research in the fluid flow area includes characterizing the effect of air bubbles in domestic water meters and minimization of the measurement uncertainty of flow meters, identification of flow pattern maps for two-phase air/water flow and characterization of flow in micro-channels.

Dr Richard asked about the research into the effect of liquids on the long-term stability of mass standards. Dr Loayza said the project looked at the effect of hydrostatic weighing in FC40 and water on the post-measurement stability of mass standards. Results showed FC40 provided a cleaning action on the mass standards and the standards showed good stability afterwards. Dr Richard asked about staffing levels and the number of scientists; Dr Loayza replied that the division consisted of 40 staff with 15 (research) scientists.

Dr Richard thanked Dr Loayza and added that he would discuss the membership request with the CCM Chairs in order to formulate a recommendation for the CIPM.

3.8 Report of the Working Group on Gravimetry (Dr Leonid Vitushkin, VNIIM) (document CCM/13-17)

Dr Vitushkin recalled that the Working Group on Gravimetry (WGG) was established in 2003. The WGG has held two meetings since the last meeting of the CCM; at UME TÜBITAK on 29-30 May 2012 and at the BIPM headquarters on 18 February 2013. The terms of reference, updated in January 2013, were presented. The list of members was given; only four of the member institutes had declared CMCs. A proposal from KRISS for membership (with Dr In-Mook Choi as delegate) had been received and is now recommended by the WGG to the CCM.

End users of reliable gravity measurements were discussed. These include NMIs and DIs (for watt balance experiments, for gravity networks and for geodetic-geophysical research), geodesy and geophysics organizations for global and local gravity models, and service providers for engineering geology, hydrology, geological exploration, and for monitoring reserves of natural resources, including minerals, hydrocarbons and water.

Measuring techniques in absolute gravimetry currently in use and under development were discussed. Fifty-nine FG5 and 31 A-10 commercial gravimeters exist around the world. China, Italy, Japan, the Russian Federation and the USA are developing absolute gravimeters. Cold atom gravimeters are being developed at the LNE and by a French commercial company (μQUANS). China, Germany and the USA are also developing cold atom gravimeters.

The first comparison of gravimeters at the BIPM took place in 1989 (8 gravimeters took part) and the latest comparison was in 2009 (21 gravimeters took part, 11 as part of the first KC and 10 as a pilot study). Results of the Scientific North-American Comparison of Absolute Gravimeters (NACAG-2010) in the Table Mountain Geophysical Observatory (Longmont, Colorado) in October 2010 were presented. A further comparison is scheduled and could possibly be organized as a SIM regional comparison. An APMP Regional comparison of absolute gravimeters will be organized at the Changping Campus (NIM, China) in 2015. The next KC of absolute gravimeters is planned for 2017; the WGG recommends to the CCM that the NIM host the comparison at the Changping Campus with the NIM as the Pilot laboratory. A proposed EURAMET comparison will take place between 2015 and 2017.

The WGG meeting in Istanbul in May 2012 had addressed the issues related to selection of the site for the 2017 KC of absolute gravimeters and had discussed scientific issues related to the technical protocol for the comparisons of absolute gravimeters. Actions arising from this meeting included:

- Preparation, discussion and adoption of the "Guide to evaluation of the sites for comparison of absolute gravimeters" (document CCM-WGG/12-12 in open access).
- Exchange of opinions and voting concerning the realization of the procedure for the selection of the site for the 2017 KC and the selection by voting for one of two proposed sites. Sites were proposed by the LNE (France) and by the NIM (China).
- Requests for official applications from the LNE and the NIM and the evaluation of these applications within the WGG have been analysed. It was concluded that both sites fulfil the requirements to host the comparison.

The majority of the WGG members voted in favour of the NIM, China, as the site for the 2017 KC of absolute gravimeters.

The first draft of the document "Guidelines for preparation of WGG recommendations to CCM of the sites for KCs" was prepared and distributed among WGG members on 8 December 2012. This document is aimed to complement CIPM MRA-D-05 regarding the organization of KCs. Future activities include the establishment of a focus group to oversee further developments of this guide. A focus group will be established to produce guidelines on uncertainty calculations in absolute gravimetry.

Dr Pereira made points regarding the functioning of the WGG. The LNE had applied to host the 2017 KC of absolute gravimeters several times. At the WGG meeting held at the UME, Turkey, in 2012, a selection procedure was proposed in agreement with Mr Picard but was not pursued. No minutes of the 2012 meeting were released and the 2011 minutes were not released in a timely fashion. Concerning membership of the WGG, attendees at the meetings have not been consistent with the official members approved by the CCM. This is of particular concern with relation to the voting process. Dr Richard replied that he had invested a lot of time in investigating these issues since the start of his presidency. He said the list of members had been incorrect but this is currently being updated. Regarding the voting for the 2017 KC site, Dr Richard had examined the votes and had approved the outcome based on this evidence but agreed that the process was not correct. Dr Vitushkin noted that the points raised by Dr Pereira had been made and discussed within the WGG. He added that that the initial call for volunteers to host the 2017 KC was made by the then CCM President, Dr Tanaka. This call gave rise to the subsequent discussions within the WGG.

Dr Steele said that Natural Resources Canada (NRCan) had benefited greatly from the work of the WGG and this had been useful in assisting with the NRC watt balance experiment.

Dr Richard asked how many NMIs or DIs are expected to submit CMCs in gravimetry during the next two years. Dr Vitushkin said that it was the choice of the individual participants. Dr Richard asked about the scientific outcome of the 2009 pilot study. Dr Vitushkin said the study had produced ideas on how future comparisons in the area should be organized. Dr Sutton noted that the pilot study had helped to determine the metrological characteristics of the FG5.

Dr Richard noted that stakeholders had identified that the uncertainties of KCs were not low enough with relation to the performance of the instruments. Dr Vitushkin said the typical standard uncertainty was 2.4 μGal but could be up to 10 μGal. All FG5 instruments had similar systematic errors so accounting for correlation of results was difficult. Prof. Faller commented that the work of the WGG had benefited metrology in gravimetry by discovering uncertainty contributions that had been insufficiently appreciated. Dr Robinson said that the UK gravimetry community had benefited widely from the results of comparisons.

3.9 Report of the Working Group on the Avogadro Constant (Dr Horst Bettin, PTB) (document CCM/13-18)

Dr Bettin said that the Working Group on the Avogadro Constant (WGAC) was established in 1995 (initially as an *ad hoc* WG) and since then had met annually. The last meeting was held in June 2012 and the next meeting has been proposed for September 2013. Membership was outlined. The NIST and the NRC had been invited to become members so that all NMIs participating in the re-started International Avogadro Coordination (IAC) would be members of the WGAC. Dr Bettin noted that with the merging of the WGSI-kg and the WGAC into a new WG for the realization of the kilogram (WGR-kg), membership and terms of reference will need to be reviewed.

The relationship of the Avogadro constant to the kilogram and to the Planck constant was reiterated.

The contributions of the various institutes to the IAC were outlined and for most quantities the results are based on measurements obtained by three or more institutes. An exception is the lattice constant, which is currently only measured by INRIM, although PTB is establishing a facility. Recent results of watt balance and X-ray Crystal Density (XRCD) experiments were presented.

Highlights included the publication of a special issue of *Metrologia* and a new experimental value for N_A with a relative uncertainty of 3 in 10^8. An EMRP collaborative project (SIB-03) had been initiated with the goal of resolving the discrepancies between the current experiments to determine the value of the Planck constant.

A five-year programme for reducing the uncertainty in the measurement of N_A was outlined. This includes: manufacture of spheres with out-of-roundness below 20 nm and improved measurements of volume, surface characterization, lattice parameter and molar mass. The programme includes confirming results for the lattice parameter measurement, expanded measurements of impurities in the silicon spheres and new traceability to the IPK. New samples of enriched ^{28}Si had been ordered by the PTB for the production of four new spheres. The target is a relative uncertainty in N_A of 1.5×10^{-8} by the end of 2015.

Dr Bettin outlined the process of realizing the new kilogram by the XRCD method, as the Avogadro experiment is now known. For each realization, surface layer characterization is necessary, and will take about one week. Volume measurements, requiring about one month's work, will only be required every few years. The lattice parameter, crystal perfection and isotopic composition remain constant. The uncertainty in changes to the mass of the surface layer is equivalent to about 3 μg and so Dr Bettin said that a characterized sphere could potentially be used for monitoring the stability of the IPK, even by using a sphere made of

natural silicon. Dr Bettin noted that technological trends in the XRCD method are towards higher accuracy with fewer and simpler apparatus and/or methods.

4 ACTIVITIES OF THE WORKING GROUP ON CHANGES TO THE SI KILOGRAM (DR BETTIN) (DOCUMENT CCM/13-18)

Dr Bettin then introduced the Working Group on changes to the SI kilogram (WGSI-kg) which was established in 2006, initially as an *ad hoc* WG. He said that the WGSI-kg currently has 11 personal and *ex officio* members. Meetings of the WGSI-kg were held on 19 February 2013 and 10 May 2011. Terms of reference for the WGSI-kg were outlined. Aims for the next five years are to: prepare a final version of the *mise en pratique* for the redefinition of the kilogram and to organize linking weighings to the IPK, a KC before redefinition, CMCs for primary realizations of the kilogram, and criteria for new experiments to realize the kilogram. During the last two years, the WGSI-kg had prepared a draft *mise en pratique* and organized a workshop on this topic at the BIPM in November 2012, which is covered in detail in the next section. A support group has been established for calibrations more closely linked to the IPK.

Dr Bettin introduced the new Working Group on the realization of the kilogram, WGR-kg, which replaces WGSI-kg and WGAC. The membership of WGR-kg is essentially the combined membership of WGAC and WGSI-kg, as well as a representative from each institute with a watt/joule balance experiment. Dr Bettin said that the first meeting of WGR-kg would be held in September 2013 during the kilogram workshop of the EMRP project "kNOW". Separate technical meetings for the watt balance and XRCD projects may be organized by WGR-kg if required.

Dr Steele asked about the scope of the new WGR-kg in relation to the WGSI-kg. Dr Richard said that the WGR-kg would focus on developing the *mise en pratique* rather than the technical aspect of the realization experiments. Dr Bettin noted that Dr Robinson should be invited to the meeting even though the NPL no longer has a watt balance. Dr Jacques asked about the 3 μg uncertainty contribution due to the oxide layer on the silicon spheres. Dr Bettin said it was the estimated uncertainty based on measurements of the oxide-layer growth.

4.1 Report on the Workshop on the *mise en pratique* of the new definition of the kg (Dr Bettin) (document CCM/13-19)

Dr Bettin reported that 55 participants from 25 institutes attended the workshop, which was held at the BIPM headquarters on 21–22 November 2012. Presentations included the status of watt balance and XRCD experiments, EMRP projects on the new kilogram, current maintenance and dissemination of the kilogram, and reports of WGM Task Groups 1 and 2. Views on the *mise en pratique* from various perspectives were presented, including watt balance and XRCD experimenters, NMI Directors for institutes both with and without primary realization projects and external opinions from organizations such as the OIML and the CECIP.

Dr Bettin summarized the current and predicted uncertainties from watt balance and XRCD experiments. Regarding current maintenance and dissemination, this work had been undertaken by Task Group 2 to analyse stability data on the BIPM prototypes. Inconsistencies of up to 30 μg from the BIPM derived values had been calculated in relation to a least squares model used to analyse the weighing data.

CCM conditions for the redefinition were discussed and the level of 2 in 10^8 was thought to be broadly realistic. There was a wide range of opinions regarding the timescale for redefinition. There was no consensus on the minimum number of realizations necessary following the redefinition of the kilogram, but it was agreed that a KC of potential realizations will be necessary before the redefinition.

Regarding the *mise en pratique*, the necessary comparison requirements before and after the redefinition have been agreed. Dissemination from a single realization was discussed as was the status of the BIPM pool of 1 kg reference artefacts with respect to the KCRV. The use of an "ensemble-world", made up of pools maintained at participating NMIs and the BIPM was discussed, but with no agreement to pursue this idea further. The possibility of realizations at values other than 1 kilogram was recognized. Stakeholders for the redefinition work were discussed.

Dr Williams asked about the rationale of having a "Key Comparison" prior to a redefinition. Dr Richard said it was a question of wording but this issue would be addressed later.

Dr Quinn, BIPM emeritus Director, clarified that the decision on the redefinition is the sole responsibility of the CGPM, which will base its decision in part on proposals from the CCs. Dr Steele added that stakeholders include the entire SI community, not just the mass community.

4.2 First discussion of the latest draft of the *mise en pratique* of the new definition of the kilogram (document CCM/13-20)

Dr Davis noted that v6.3 was based on comments received on v5.2, and that these comments were submitted as mark-ups on the original Word document. This method was cumbersome and lacked transparency. Suggested changes to v6.3 were submitted on a template, which it was decided was a better method that should be continued for future draft versions. The key comments received were summarized. These were:

- To simplify the document
- To emphasize that the realization could be made at values other than a kilogram
- To make clear the difference between the IPK, the mass unit and the realization of the unit.

The main text is now eight pages long including references.

Key points from the WGSI-kg meeting were:

- Is v7.0 clear enough?
- Is the wording for the nominal value of realization now acceptable?
- Is the distinction between uncertainty and relative uncertainty now clear?
- Does the final linking of the IPK with the primary realization constitute a KC?

Additionally

- Many references cited in v7.0 do not exist – a special edition of *Metrologia* is proposed
- A new template for v7.0 (CCM/13-06D) exists – comments should be sent to Dr Bettin (copied to Dr Davis) by 30 April 2013[1].

Dr Steele endorsed the use of a template. He suggested that a KC among realizations of the kilogram would still be necessary after redefinition but also that the mechanism for relating these KCs to both the primary realizations and the BIPM ensemble of 1 kg artefacts needed to be better defined. Dr Stock said it was intended that the BIPM ensemble would act as a "flywheel" for the maintenance of the reference value over the short term (a few years). Dr Williams said that the value of the ensemble would be fixed relative to the realization experiments when the value of the Planck constant was fixed and emphasized that primary realizations could occur at values other than one kilogram. Dr Davis emphasized that the primary realizations only needed to be state of the art (at the nominal value of realization). Dr Quinn emphasized the difference between the comparison used to fix *h* and those for the subsequent dissemination of the mass scale. Dr Steele made specific comments on v7.0 regarding the use of the acronym ERMS and took issue with the following paragraph. Dr Steele said the advantages of the use of an ensemble should be outlined in the document as this was essential for a wider audience of the *mise en pratique*.

4.3 Possible recommendations of the CCM to the CIPM

Dr Schwartz outlined the motivation for an update to remove any ambiguity from the existing Recommendation CCM G1 (2010), to take into account comments and recommendations from stakeholders and to reflect on the ongoing experiments on redefinition, maintenance and dissemination.

He noted that Resolution 1 of the 24th meeting of the CGPM (2011) asked CCs to consider practical, commercial and legal metrology implications of redefinition. Important stakeholders (OIML, CECIP) have submitted position statements to the CCM expressing reservations regarding a premature redefinition. Additionally, experimental work is ongoing and the recommendations should reflect the current state of these experiments. Draft Recommendation G1 (2013) is proposed in working documents CCM/13-03 and CCM/13-03A. The aim has been to remove ambiguity while retaining the previous conditions for redefinition. Changes were outlined and discussed and the initial draft went through several revisions. Dr Richard thanked Dr Schwartz for his work and said the process has been a major improvement on the preparation process of the preceding CCM recommendations on this topic. Each amendment was discussed in turn.

At the beginning of the session on 22 February 2013, Dr Richard remarked that he was very satisfied with the discussions that had taken place the previous day. Draft 3.0 of CCM Recommendation G1 (2013) had been circulated and would be discussed before lunch and further under item 11.

[1] Shortly after the meeting was adjourned, minor corrections were made to v7.0. The new v7.1 was recirculated with an updated template, but with the same deadline for submitted comments.

5 REPORT OF THE WORKING GROUP ON CMCS (DR SUTTON, MSL) (DOCUMENT CCM/13-21)

Dr Richard explained that the Working Group on CMCs (WGCMC) would be merged with the new Working Group on Strategy (WGS). Dr Sutton said that the most recent meeting had been held in May 2011. The WGCMC had been formed in 2005 at the request of the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB) to facilitate the inter-regional CMC review process. Dr Sutton outlined the terms of reference and membership of the WGCMC and noted that a list of current RMO TC chairs is available on the JRCB website (see JCRB Directory). A draft document on comparisons necessary to support CMCs, covering density, fluid flow, force, gravimetry, hardness, mass, low pressure, high pressure and viscosity had been prepared in 2008 and was made available on the WGCMC website. However, in practice the broader criteria in Section 3 of the document CIPM MRA D-04 were followed, or a bilateral KC was arranged, because timely KC results were often not available.

Dr Sutton noted that the rate of CMC submissions was roughly constant at about one set of CMCs per month and that these were efficiently reviewed by the RMO TCs/WGs. He added that fewer problems are now being encountered with the submission and review process than five years ago.

Dr Ballico asked about the Draft procedures for CMC review. Dr Sutton said that document CIPM MRA D-04 outlined comparison requirements for CMC submissions.

Mr Shih Mean Lee asked about the variation in presentation of mass CMCs. Dr Sutton said one issue with mass is that mass CMCs are needed for various user communities (e.g. mass metrology and pressure-balance metrology). EURAMET and APMP had followed a similar format in presenting CMCs for ranges of mass values. Dr Richard said other RMOs could follow this format to promote consistency. He also remarked that under the new WG structure, individual CMC issues would be dealt with by the relevant WG chairs and the JCRB secretariat.

6 REVIEW OF WORKING GROUP MEMBERSHIP AND CHAIRS

Dr Richard outlined the new structure of the WGs.

The Working Group on the Dissemination of the kilogram (WGD-kg) will be chaired by Dr Sutton and is a merging of the previous WGM and its two Task Groups. The Working Group on the Realization of the kilogram (WGR-kg) will be chaired by Dr Bettin and is a merging of WGSI-kg and WGAC, with members to be added from the watt balance community. The Working Group on Strategy (WGS) is chaired by the CCM President, Dr Richard, and now includes WGCMC, WGKC, the chairs of all other CCM working groups and additional members chosen by the chair.

New WG members were approved by the CCM as follows: WGHP, METAS (Dr Wüthrich); WGR-kg, MSL (Dr Sutton); WGG, KRISS (Dr In Mook Choi); WGAC, NIST and NRC.

Dr Steele commented that perhaps the WGR-kg may be a misleading title since the redefinition has not yet taken place. Dr Richard said that this could be reviewed when the terms of reference were developed. Dr Williams agreed with this proposal. Dr Robinson noted that he had been invited to become a member of the WGR-kg by its chair, Dr Bettin.

7 RMO AND JCRB ACTIVITIES REGARDING TECHNICAL COMMITTEES IN THE MASS AREA

7.1 JCRB Report to the CCM (document CCM/13-22)

Mr Kuanbayev, on secondment from KazInMetr (Kazakhstan) noted that he had been JCRB Executive Secretary since December 2012. He presented highlights of the 28th and 29th meetings of the JCRB including the key resolutions and actions. A proposal for a web-based platform for CMC review was made and is being investigated by the BIPM. A workshop on the CMC review process, with the aim of improving the efficiency of the process, will be held on 18–19 March 2013 at the BIPM headquarters.

Changes to the CIPM MRA documents, particularly CIPM MRA-D-05, were outlined. Member States and Associates of the General Conference were listed. Tunisia became a Member State in February 2012. Botswana, Namibia, Oman and the Syrian Arab Republic became Associates of the CGPM during 2012. Representatives of institutes from Botswana, Namibia, the Syrian Arab Republic and the European Space Agency (ESA) had signed the CIPM MRA during 2012. A Memorandum of Understanding between the BIPM and the International Atomic Energy Agency (IAEA) had been signed in June 2012.

Dr Wright asked about changes to the CIPM MRA documents regarding monitoring the impact of comparisons (Action 29/3) and the responsibility of KC pilots to alert NMIs (along with the JCRB and RMO TCQS chair) regarding discrepancies between CMCs and KC results. Mr Kuanbayev replied that, as mentioned in his presentation, updated procedures to monitor the impact of comparisons are given Section 9 of document CIPM MRA-D-05, Version 1.3 (approved by the CIPM in October 2012). Dr Sutton mentioned the issue which was raised at the WGS meeting regarding the wording of Section 7.2 of CIPM MRA-D-05 (approving SCs), saying early approval should be encouraged. Dr Thomas said the issue was that an additional six-week period (for comment and editorial control) was required after the relevant RMO Technical Committee had recommended the approval of the Final Report. Dr Richard asked if there were plans that would require Designated Institutes to publish CMCs within a certain amount of time after their having been officially designated. Dr Thomas said there were no such plans.

7.2 Reports on TCM and TCFF activities in AFRIMETS, APMP, COOMET, EURAMET, SIM

AFRIMETS (document CCM/13-23)

Dr Eltawil reviewed the regional sub-divisions of AFRIMETS (EAMET, MAGMET, SADCMET/MEL, CEMACMET, SOAMET and NEWMET). It was noted that many areas were only just establishing metrology networks. A TC-M working group meeting had been held in Kenya in 2011 which included a training workshop. In 2012 the TC-M working group meeting was held in Benin and included a training workshop on uncertainty calculation and CMC review. AFRIMETS includes four States Parties to the Metre Convention (Egypt, Kenya, South Africa and Tunisia) but only two of these Member States have published CMCs. However, Egypt, Kenya and Tunisia are applying for new CMCs. Two regional KCs are under way: AFRIMETS.M.P-K2 (Pressure measurements, 10 kPa to 120 kPa absolute) which is in progress and SADCMET.M.M-K5 (Comparison of mass standards 200 mg, 1 g, 50 g, 200 g and 2 kg) with the report being prepared. Four SCs are in progress. Dr Eltawil outlined the participation of the various AFRIMETS members in key and supplementary comparisons, including participation in comparisons organized by other RMOs.

APMP (document CCM/13-24)

Dr Kobata outlined the activities covered by the TCM. Dr Kobata had taken over as TCM chair from Dr Sam-Yong Woo (KRISS) in December 2012. In Mass, a pilot study for National Prototype Kilograms has been completed and a report is being prepared. In pressure, a Draft A report is being written for APMP.M.P-K9 (10 kPa-110 kPa absolute). Gauge pressure comparison APMP.M.P-K13 (50 MPa-500 MPa) is under way and measurements are in progress. The protocol for vacuum comparison APMP.M.P-K14 (0.1 mPa-1 Pa) is being prepared. In density, a Draft A report is being written for hydrometer comparison APMP.M.D-K4. In force, measurements are in progress for APMP.M.F-K2.a and APMP.M.F-K2.b (50 kN and 100 kN) and a protocol is being developed for APMP.M.F-K3.a and APMP.M.F-K3.b (0.5 MN and 1 MN). APMP.M.F-K4.b (2 MN) has been approved for equivalence and has been published.

New comparisons proposed are in mass, APMP.M.M-K5 (200 mg, 1 g, 50 g, 200 g and 2 kg), and in vacuum, APMP.M.P-K4 (1 Pa to 10 kPa). A torque pilot study at 1 kN m has been organized by the KRISS supported by APMP TC Initiative 2012. A hydraulic pressure project has been organized by the NIMT, as a follow-up project to finish the 100 MPa pressure comparison exercise. Possible future KCs proposed are a 50 kg comparison requested by the NIM, an AFM cantilever stiffness comparison requested by the CMS-ITRI, Brinell Hardness and Vickers Hardness comparisons proposed by the NPLI, a 1 Pa to 10 kPa differential pressure comparison at 100 kPa line pressure requested by the NMC/A*STAR, and a 0.1 MPa to 10 MPa hydraulic pressure comparison requested by the NIM.

In other activities, recent technical peer reviews of NMIs in the region were summarized (the NMIA, the MSL, the KRISS, the MUSSD, and the NMIJ). TCM workshops and conferences were held at the APMF 2011 in China and the IMEKO World Congress 2012 in the Republic of Korea. The 6th APMP Pressure and Vacuum Workshop had been held in New Zealand on 23-24 November 2012. The 12th and 13th TCM meetings had been held in Japan in 2011 and

New Zealand in 2012, respectively. The next meeting will be held in Chinese Taipei in November 2013.

The President asked about the pilot study on National Standard Kilograms in platinum iridium. Dr Sungjun Lee said the pilot was the KRISS in collaboration with the NPL. Dr Davidson said he had seen the results which showed discrepancies but these had been identified as issues with the densities used for the buoyancy correction. Dr Davis added that EURAMET had carried out a similar study of National Standard Kilograms a number of years ago, piloted by the NPL.

COOMET (documents CCM/13-25 and CCM/13-25a)

Ms Kolozinska outlined the main tasks of the COOMET TC1.6: the implementation in the COOMET member-countries of the CIPM MRA, planning, organization and methodological support of COOMET key and supplementary comparisons in the field "Mass and related quantities", organization and realization of COOMET projects concerning establishment and improvement of measurement standards or new measurement and calibration methods in the field "Mass and related quantities" and generating proposals of cooperation projects in the field "Mass and related quantities". The structure and membership of TC 1.6 were also presented.

The 16th and 17th meetings of COOMET TC1 .6 had been held in 2011 and 2012 in the Russian Federation and Azerbaijan respectively. Two training workshops had been held; the first on *Mass Measurement Uncertainty* (5-6 October 2010, Tbilisi, Georgia) and the second on *Pilot comparison in the field of mass* (24–26 May 2011, Astana, Kazakhstan).

The status of COOMET comparisons is as follows:

- COOMET.M.M-K5, Draft B report in progress.
- COOMET.M.M-K8 (50 mg to 2 kg), technical Protocol is under development.
- COOMET.M.P-K14, completed and published in 2012.
- A planned pressure comparison in the range from 1 MPa to 10 MPa has yet to be finalized.
- COOMET.M.H-K1.b and COOMET.M.H-K1.c on Vickers Hardness have been completed.
- COOMET.M.H-K1 on Vickers Hardness has been completed.
- COOMET.M.H-K2 on Brinell Hardness is in progress with the Draft B report currently being prepared.
- A planned Rockwell and Super-Rockwell Hardness comparison has yet to be finalized.
- COOMET.M.F-S1 (Seven loads, 20 kN to 2000 kN), Draft B report being prepared.
- COOMET.M.F-S2 (Eight loads, from 10 kN to 100 kN), Draft A report being prepared.
- COOMET.M.T-S1 (Four torques 100 N.m to 2500 N.m, CW and CCW), measurements in progress.

COOMET has eight CIPM MRA signatories; two are member states and six are associates. A total of 85 CMCs have been declared, mainly by the Russian Federation. New CMC submissions were outlined.

The President asked about the training programmes and how they were organized. Ms Kolozinska said the training was in the framework of a COOMET-PTB programme of training in association with the host laboratory.

EURAMET (documents CCM/13-26 and CCM/13-26a)

Dr Nieves Medina presented a summary of EURAMET TC-M projects by technical area and by type (comparison, research, traceability and consultation). The majority of the projects were in mass and pressure. Of the 144 registered projects, 107 had been completed. Overall, 34 RMO KCs and 23 SCs had been organized. Of these, 12 KCs and 8 SCs were in progress. Fourteen other (non-comparison) projects deal mainly with research. Project 1205, a review of Calibration Guide 18 for Non-automatic weighing instruments, was unusual as it included collaboration with stakeholders as well as 17 NMIs.

EMRP projects involving TC-M were outlined. In the EMRP 2010 call, three projects were funded:

- High pressure metrology for industrial applications (1.6 GPa at 0.05 % uncertainty)
- Traceable dynamic measurement for mechanical quantities to fulfil industrial requirements
- Vacuum metrology for production environments (partners include industrial companies).

Workshops had been held for each of these projects in June 2012, October 2012 and April 2012, respectively.

In the EMRP 2011 call, two projects had been funded:

- SIB03 kNOW: Realization of the awaited definition of the kilogram – resolving the discrepancies, with a goal of achieving consistency between watt balance and XRCD experiments at a relative uncertainty not larger than 5×10^{-8}.
- SIB05 NewKILO: Developing a practical means of disseminating the new kilogram, with a goal of ensuring the continuity of the practical realization and dissemination of the mass unit between existing and new realizations of the kilogram.

In 2012, one project had been funded: SIB63 Force traceability in the meganewton range, to fulfil industrial requirements in civil engineering, materials testing, wind power systems, the off-shore industry, the aviation industry and aerospace. The project will start in 2013 with a primary goal of extending primary force standards up to 50 MN.

Dr Baumann asked about the establishment of a TC-Gravimetry in EURAMET and the current status. Dr Nieves Medina said the issue would be discussed at the next TC-M Contact Persons meeting. Dr Baumann commented that interested parties should be able to attend the meeting. Dr Davis asked about the research project on floats in mercury columns and whether it was a pressure related project. Dr Nieves Medina said yes, to which Dr Davis asked about the future of mercury columns. Dr Nieves Medina commented that this was a decision for the individual institutes rather than the RMO. Dr Sutton asked about the mass SCs and why KCs had not been carried out. Dr Nieves Medina replied that the nominal values of the masses had been chosen by the participants as the most efficient way to complete the comparison. Dr Richard commented that the project on dissemination from the kilogram would be of interest to WGD-kg.

Dr Nieves Medina noted that this was dissemination by sub-division and build-up rather than at the kilogram level *per se*.

SIM (document CCM/13-27)

Mr García-Leoro, SIM MWG7 Chair, explained that the WG was divided into five sub-working groups for Mass, Force and Torque, Pressure, Density, and Hardness. Overall, MWG7 has 93 contacts from 30 countries of the five SIM sub-regions. Mr García-Leoro presented details of SIM comparisons. Since 2001, 43 have been registered in the KCDB and the rate of registration has increased from two per year in 2003 to about eight per year now. Ongoing comparisons include SIM.M.M-S9 - Determination of the susceptibility and magnetic polarization of weights by means of the susceptometer method and SIM.M.F-S3 - Supplementary Comparison of Instrumented Charpy Impact Machines. Workshops on magnetic properties, liquid density and absolute pressure had been held.

SIM includes 15 signatories of the CIPM MRA, 12 of which have CMC submissions. Planned activities were presented and included workshops, internships and filling current gaps in CMCs. Mr García-Leoro commented that the new requirement 7.2 of document CIPM MRA-D-05 regarding the approval of RMO reports of Supplementary Comparisons seemed to be difficult to fulfil in practice. He proposed that the control should perhaps be applied to the Draft A or B, rather than to the final report.

Mr Abbott asked about the motivation behind the measurement of the susceptibility of mass standards. Mr García-Leoro said it was an issue for the calibration of and acceptance criteria for the weights, particularly those manufactured from lower quality stainless steel. Dr Bich said the issue had previously been raised by the SIM. He said that the feeling of the majority of RMOs was that it was not necessary to establish CMCs for this in the mass area. Dr Sutton confirmed that CMCs were not deemed necessary as the results were not reported in the calibration certificates. Dr Borys asked how the results of the susceptibility measurements would be used in the measurement model when local magnetic field strength was not used. Dr Davis commented that if it were thought necessary to report susceptibility on calibration certificates, it may set a precedent where surface roughness - where international recommendations also exist - would need to be reported. The President said that the view that the CCM does not recommend the submission of CMCs in this area could be taken back to the SIM. Dr Steele emphasized that while CMCs may not be necessary, the measurements and dissemination of knowledge about the measurements was important. The President suggested including other RMOs and the CCM in the proposed SIM workshop on the redefinition of the kilogram.

Report on Activities within Regional Fluid Flow Technical Committees

Dr Wright presented an overview of Fluid Flow activities in the APMP, COOMET, EURAMET and SIM regions (document CCM/13-28).

The APMP TCFF annual meeting was held on 5–6 December 2011 in Kobe, Japan, and included a workshop on liquid flow calibration facilities and a distillery tour. Current APMP CMCs were summarized. Six APMP KCs had been completed and published (APMP.M.FF-K1 to

APMP.M.FF-K6) and one was planned (APMP.M.FF-K2.a for hydrocarbon flow). Of the six completed KCs, all but APMP.M.FF-K2 had been linked to the relevant CCM KC.

COOMET TC 1.4 meetings were held in the Ukraine (2011) and in Germany (2012). Three supplementary comparisons are in progress (COOMET.M.FF-S2 to COOMET.M.FF-S4) and two are proposed (hot water and natural gas flow rate). New facilities in the Russian Federation for water, hydrocarbon and multi-phase flow were described. Two projects related to gas flow measurement had been completed, with a third proposed.

EURAMET TC-Flow has 31 Contact Persons and 57 flow experts divided into sub-groups for Gas Flow, Liquid Flow and Volume. The last TC-F meeting was held in Vienna, Austria, on 13-15 March 2012. There are 67 EURAMET projects registered, 50 % of which have been completed. Projects proposed for 2011/2012 were: 1201 - Evaluation of a comparison between the PTB and the NEL in water flow rates from 30 m^3/h to 220 m^3/h; 1225 - Comparison of very low air speed standard facilities (0.05 m/s to 1 m/s); and 1224 - Comparison between the VSL and the PTB of Volume flow for Natural Gas under High Pressure. The number of CMCs has been reduced by almost 50 % through rationalization.

SIM WG10 has 34 members. Eleven are signatories of the CIPM MRA and 5 NMIs have submitted CMCs. The last WG meeting was held on 8 October 2012 in Mexico. Current CMCs were summarized. Recent comparisons are SIM.M.FF-K4, Volume of liquids at 20 L and 100 mL (final report published); SIM.M.FF-S4, Volume of Liquids at 50 mL (final report submitted for publication in the KCDB); and SIM.M.FF-S6, Volume of Liquids at 20 L and 100 mL (measurements completed and Draft A report is in progress). Additionally, Pilot Studies in gas flow at low pressure and water flow were planned or already under way. Overall, over 200 CMCs have been added or updated over the last two years and a draft procedure on CMC review is being developed.

Dr Baumann asked if other NMIs were active in the area of water speed. Dr Wright said that while no NMIs were active in this area, other types of laboratories do this work and this should not preclude the METAS from submitting CMCs (with the support of results from a comparison with another (non-NMI) laboratory).

8 CONFIRMATION OF CCM AND RMO KCS IN PROGRESS, WITH THE PARTICIPATION OF THE COORDINATOR OF THE KCDB

Dr Thomas asked the President for his advice regarding the publication of the results of KCs with respect to pair-wise degrees of equivalence (where large amounts of data were contained) which generates a lot of work for the Pilot Laboratories and the KCDB Office. Dr Richard replied that the CCM recommends that pair-wise degrees of equivalence no longer be published in the KCDB and that information on pair-wise degrees of equivalence published in KC reports is limited to the equations needed to calculate them, with the addition of any information on correlations that may be necessary to estimate them more accurately. He added that the CCM stresses the importance of continuing to report the values and the graphs representing the degrees of equivalence relative to the key comparison reference value. Concerning CCM

documents on the approval of results, Dr Richard commented that a general CCM guidance document was under development and he was taking advice from other CCs.

9 OTHER TECHNICAL ADVANCES IN THE FIELD OF MASS AND RELATED QUANTITIES NOT YET PRESENTED ABOVE (INCLUDING NEWS FROM THE NMIS)

As there were no additional presentations, the meeting returned to the preparation of Recommendation G1 (2013) on the new definition of the kilogram.

4.3 (Continued) Possible recommendations of the CCM to the CIPM

Dr Schwartz thanked Dr Borys, Dr Baumann and Dr Thomas for assistance in preparation of the latest draft of CCM Recommendation G1 (2013). He went through v3.0 and comments were collected. A number of minor improvements were agreed.

10 MEASUREMENTS INVOLVING THE INTERNATIONAL PROTOTYPE OF THE KILOGRAM (IPK) AND OTHER TECHNICAL WORK AT THE BIPM NOT YET PRESENTED ABOVE (DOCUMENTS CCM/13-29 AND CCM/13-30)

Dr Stock gave a report on the BIPM Mass Department Programme of Work 2009-2012 and the outlook for 2013-2019 on behalf of Mr Picard. Ongoing activities are: M-A1, Mass calibrations for NMIs and the BIPM (including volume and magnetic susceptibility determination); M-A2, Improvement of mass metrology at 1 kg (weighing of Si spheres (IAC) and mass transfer between air-vacuum); M-A3, Provision of 1 kg Pt-Ir prototypes to Member States; and M-A4, Coordination activities (CCM, CCT, RMOs, OIML, …). New projects are: M-P1A, Maintenance of a reference facility for 1 kg comparisons under vacuum or inert atmospheres; M-P1B, Creation of an ensemble of 1 kg mass standards stored in inert atmospheres to facilitate dissemination.

Staff of the Mass Department were presented. Mass calibrations for NMIs since 2009 for 1 kg standards in both stainless steel and platinum-iridium were listed along with calibrations performed for other departments within the BIPM. Fabrication of Pt-Ir masses included a 1 kg prototype for Mexico, four 1 kg prototypes and a 1 kg stack of discs for the BIPM pool of artefacts and two 1 kg prototypes for the BIPM (to replace two degraded prototypes). Services provided by the Mass Department to Member States were detailed by NMI in terms of provision of Pt-Ir standards, mass calibrations and susceptometers, and associated standards. During the period 2002-2012, 146 mass calibrations had been provided to Member States.

Recent improvements in the Mass Department included laboratory refurbishment, a new Mettler-Toledo M-one comparator and air-vacuum transfer facilities. The trilateral collaboration between the BIPM, the NPL and the METAS was outlined. Dr Stock noted that a lot of experience had been accumulated which will be useful for the future *mise en pratique* of the new kilogram.

The history of the BIPM standards was described, along with the establishment of the BIPM ensemble of mass standards and the associated storage system. The current state of progress on the BIPM watt balance was outlined. Uncertainties of the order of 1 in 10^6 (type A) and 1 in 10^5 (type B) had been achieved. The watt balance has recently been moved to the new purpose-built laboratory. CCM, CCT and KC coordination activities were described.

An overview of the approved Programme of Work for the period 2013 to 2015 was presented. This includes: the provision of prototypes to Member States, work on the ensemble of mass standards, the watt balance experiment, work on the Avogadro project, participation in EURAMET EMRP projects SIB-03 (kNOW) and SIB-05 (NewKILO), and coordination activities.

New activities are projected to be extraordinary calibrations against the IPK and BIPM key comparisons of primary realizations of the new definition of the kilogram. There was also likely to be a significant increase in requests for mass calibrations related to the planned use of the IPK. Activities that have been discontinued are magnetic susceptibility calibrations and the provision of susceptometers.

A long-term view of the Programme of Work beyond 2015 identified the key activities as: provision of prototypes, mass calibrations in air (using the ensemble of reference mass standards after redefinition), a new calibration service for weight pieces under vacuum, completion of the watt balance achieving a target uncertainty of less than 5×10^{-8}, calibration of masses of the ensemble, continuation of the ongoing KC of primary realizations and repeat KCs of all existing primary realizations if necessary.

Dr de Mirandés described the proposed functioning of the BIPM ensemble of mass standards and improvements to the storage apparatus. Surface-study artefacts (discs with diameters of about 10 mm and 40 mm) would be included in the storage containers with the mass standards. Dr de Mirandés asked for cooperation of laboratories who were interested in surface studies on these artefacts.

Prof. Faller asked about bulk effects in mass standards. There was a general feeling that bulk effects were very slow. Dr Davis said that early standards probably outgassed hydrogen due to the way platinum was purified. Dr Steele said that hydrogen could penetrate the bulk but masses are not kept in hydrogen.

Dr Davis presented the flowchart for the extraordinary calibration prior to the redefinition of the kilogram. The conclusions and recommendations of the planning exercise were that:

- The BIPM recommends creation of a support group to assist in making major decisions in a timely way.
- The BIPM recommends not proceeding with cleaning of national standards, whether they be in platinum-iridium or in stainless steel. Silicon spheres involved in the Avogadro Project will be cleaned according to the WGAC protocol.

- The BIPM recommends a direct calibration in air for all artefacts involved in this extraordinary calibration.
- The BIPM recommends an indirect calibration in vacuum limited to silicon spheres involved in the Avogadro Project and the standards belonging to the ERMS stored in vacuum.
- No "normal" calibration service will be offered to NMIs of Member States (except for participating NMIs) during the extraordinary Calibration Campaign.
- Based on the BIPM recommendations, the BIPM Calibration Campaign in anticipation of the kilogram redefinition, using the IPK, will last 13 months (including one month for unforeseen delays).

Questions arose concerning whether these comparisons could be combined with the first KC envisaged in the *mise en pratique*. Opinions varied and it was decided that, although the issue is important, it is not yet possible to reach a common agreement.

Dr Robinson asked about the provision of vacuum calibrations in order to check this step in the various watt balance experiments. Dr Davis replied that a procedure involving specially-constructed surface artefacts had been developed for calibration of the mass of silicon spheres in vacuum, and the same procedure is generally applicable to watt balances. In addition, he reminded the meeting that the NIST is developing a complementary procedure based on comparing the mass of an artefact in vacuum with one in air using a special double-pan balance with magnetic suspension.

Dr Davis said there was a possibility of starting the 13 months of extraordinary calibrations in January 2014, but that this was exactly the type of issue for which the BIPM would welcome the advice of the support group which had been proposed. Dr Steele noted that he appreciated the flowchart and felt that it was possible to achieve the plan with the goodwill of the participants. Dr Milton asked if he could assume that the CCM had given its assent to the process.

The President suggested the formation of a small support group chaired by the BIPM Director to be concerned with the measurements involving the IPK. The group would consist of the CCM President, the Chairs of WGD-kg and WGR-kg, a representative of the watt balance community and a specialist in estimating uncertainty. The concept of a support group was accepted by the CCM.

11 FOLLOW-UP DISCUSSIONS ON THE CCM RECOMMENDATION

Dr Schwartz chaired a final discussion on CCM Recommendation G1 (2013). Version 3.1 had been prepared following the earlier discussion and was distributed to attendees. After further discussion, a few minor changes were agreed. Condition 4 at the end of the recommendation was shortened and Footnote 1 was expanded to refer specifically to the CODATA adjustment of *h*.

Dr Ballico asked about the status of CODATA and how appropriate it was for the CODATA Task Group on Fundamental Constants (TGFC) to set the value of *h*. Dr Williams and Dr Steele both assured the meeting of the TGFC's unique suitability for this work. During further

discussion it was suggested that there may be considerations for mass metrology beyond those normally considered by the CODATA Task Group and that a more formal arrangement with the CODATA TGFC may be useful. Dr Milton agreed to investigate this.

The meeting considered version 3.2 of CCM Recommendation G1 (2013). This version was adopted. (see the Appendices of this report for the final version, in both English and French. These are also available as documents CCM/13-31a and CCM/13-31b).

12 REVIEW OF CONCLUSIONS, ACTION ITEMS AND DEADLINES

- The CCM Strategy was updated and approved [After the meeting – the final version will be sent to the CIPM President on 1 March 2013]
- A simplified WG structure was agreed:
  - WGAC and WGSI-kg merged into WGR-kg
  - WGR-kg chair: Dr Bettin
  - WGM with Task Groups 1 and 2 merged into WGD-kg
  - WGD-kg chair: Dr Sutton
  - WGCMC merged into WGS
  - WG KC merged into WGS
  - Chairpersons' meeting merged into WGS
- New memberships were approved
  - WGHP: the METAS (Dr Wüthrich)
  - WGR-kg: the MSL (Dr Sutton)
  - WGG: the KRISS (Dr In-Mook Choi)
  - WGAC: the NIST and the NRC (new members to be included in the merger of WGAC and WGSI-kg)
- The present membership of all WGs will be clarified in relation to the written WG reports to be updated by 30 April 2013.
- The WG Chairs will receive feedback from the CCM President and Dr Davis on their written reports.
- The WG Chairs will send the updated version of the written WG reports to the CCM President before 30 April 2013.
- The written WG reports will be approved and published on the CCM restricted website before 15 May 2013.
- The CCM took note of the oral reports from all WG chairs (oral report of WGH presented by proxy).

- The CCM agrees to NIM (China) as the site for the 2017 KC of absolute gravimeters. This KC is not yet approved. A decision on this point will be made by the CCM at its next meeting in 2015.
- The President of CCM will prepare a document on approval of CCM KC final reports before the end of April 2013 with the help of the WG chairs, Dr Thomas and the CCM Executive Secretary.
- The *mise en pratique* v7.0 was discussed.
  - The participants are requested to send their comments using the template to Dr Bettin and Dr Davis before the end of April 2013.
  - Dr Davis will distribute v7.1 (slightly updated) to the participants of the November 2012 Workshop and Dr Richard will forward them to the President of the CCEM and the Chair of the CCEM Working Group on Electrical Methods to Monitor the Stability of the Kilogram.
- The CCM President will consult the WG chairs about the application of the INMETRO for CCM membership and make a recommendation to the CIPM.
- A special edition of *Metrologia* on the *mise en pratique* is planned for the second half of 2015. The *Metrologia* editor, Dr Miles, will coordinate this with the chair of the WGR-kg.
- The CCM took note of the reports from the RMOs and the combined report from TC-Flow.
- The CCM took note of a presentation on the Programme of Work 2009-2012 and outlook 2013-2015 and 2016-2019 of the BIPM and the first plans concerning the comparison with the IPK.
- The CCM decided to create a support group for the comparison with the IPK. The members of the support group are: Dr Bettin, Dr Sutton, Dr Bich, Dr Pratt (NIST) and Dr Richard. The support group is chaired by the BIPM Director.
- All participants are invited to send their feedback on this meeting by email to the CCM President (what was good and what can be improved?).
- For the next CCM, each member NMI will be asked to provide a report on scientific activities, to be submitted prior to the meeting.

(Most of these points are summarized in document CCM/13-32)

13 NEXT MEETING AND ANY OTHER BUSINESS

After consultation with the Executive Secretary and the BIPM Director, the 15th CCM meeting is planned for the first half of 2015 [the tentative dates for the next meeting are 23-27 February 2015].

Before concluding, the CCM President invited participants to send him feedback by email on this meeting, in particular, what was good and what can be improved. He said that he was looking forward to receiving the feedback and thanked the participants in advance.

RECOMMANDATION DU COMITÉ CONSULTATIF POUR LA MASSE ET LES GRANDEURS APPARENTÉES PRÉSENTÉE AU COMITÉ INTERNATIONAL DES POIDS ET MESURES

RECOMMANDATION G 1 (2013) : Sur une nouvelle définition du kilogramme

Le Comité consultatif pour la masse et les grandeurs apparentées (CCM),

rappelant ses précédentes Recommandations au Comité international des poids et mesures (CIPM) sur les « Conditions pour une nouvelle définition du kilogramme », CCM G 1 (2005), et sur les « Considérations sur une nouvelle définition du kilogramme », CCM G 1 (2010),

accueillant la Résolution 1 (2011) « Sur l'éventuelle révision à venir du Système international d'unités, le SI » adoptée par la Conférence générale des poids et mesures (CGPM) qui, lorsqu'elle sera mise en œuvre, permettra de relier l'unité de masse à la constante de Planck,

reconnaissant la nécessité de confirmer et de clarifier la Recommandation CCM G 1 (2010) à la lumière de cette Résolution,

considérant

- les déclarations récentes de parties prenantes et de communautés d'utilisateurs, telles que l'Organisation internationale de métrologie légale (OIML) et le Comité européen des constructeurs d'instruments de pesage (CECIP), sur la révision à venir du Système international d'unités, le SI, ainsi que les activités spécifiques mises en place par le CCM et ses groupes de travail afin de répondre aux demandes exprimées dans la Résolution 1 (2011) de la CGPM,
- les progrès continus des expériences fondées sur la balance du watt et sur la méthode XRCD de mesures de masse volumique de cristaux par rayons x, mises en œuvre par plusieurs laboratoires nationaux de métrologie et par le Bureau international des poids et mesures (BIPM) et représentant deux voies distinctes pour déterminer la valeur de la constante de Planck au plus haut niveau d'exactitude, ces progrès ayant permis d'obtenir des résultats nouveaux et améliorés de façon significative et permettant d'envisager de disposer de résultats supplémentaires avant la fin de 2015,
- les progrès effectués concernant la mise en pratique pour la réalisation de la nouvelle définition du kilogramme et sa future dissémination,
- les progrès significatifs réalisés par le BIPM afin de mettre en place un ensemble d'étalons de masse de référence,

anticipant le besoin de mettre au point ou d'améliorer des méthodes et de maintenir des équipements de façon à ce qu'après la redéfinition de l'unité de masse, 1 kg soit réalisé et disséminé avec une incertitude-type n'excédant pas 20 µg,

recommande que les conditions suivantes soient remplies avant que le CIPM ne demande à la CODATA d'ajuster les valeurs des constantes fondamentales de la physique à partir desquelles une valeur numérique fixée de la constante de Planck sera adoptée :

1. qu'au moins trois expériences indépendantes, comprenant à la fois des expériences de la balance du watt et des expériences XRCD, donnent pour la constante de Planck des valeurs cohérentes présentant des incertitudes-types relatives[1] qui n'excèdent pas 5×10^{-8},
2. qu'au moins l'un de ces résultats présente une incertitude-type relative[1] qui n'excède pas 2×10^{-8},
3. que les prototypes du BIPM, l'ensemble d'étalons de masse de référence du BIPM, ainsi que les étalons de masse utilisés dans les expériences de la balance du watt et XCRD, aient été comparés le plus directement possible au prototype international du kilogramme,
4. que les procédures concernant la réalisation et la dissémination à venir du kilogramme, telles que décrites dans la mise en pratique, aient été validées en conformité avec les principes du CIPM MRA[2].

[1] Des arguments étayant ces exigences, qui visent à établir un fondement expérimental solide pour l'ajustement de *h* effectué par la CODATA avant la redéfinition du kilogramme, sont apportés dans Metrologia, 2010, 47, 419-428.
[2] Principes décrits dans le document CIPM MRA-D-05 « Measurement comparisons in the CIPM MRA ».

RECOMMENDATION OF THE CONSULTATIVE COMMITTEE FOR MASS AND RELATED QUANTITIES SUBMITTED TO THE INTERNATIONAL COMMITTEE FOR WEIGHTS AND MEASURES

RECOMMENDATION G 1 (2013)
On a new definition of the kilogram

The Consultative Committee for Mass and Related Quantities (CCM)

recalling its previous Recommendations to the CIPM on the "Conditions for a new definition of the kilogram", CCM G 1 (2005), and "Considerations on a new definition of the kilogram", CCM G 1 (2010),

welcoming Resolution 1 (2011) of the CGPM "On the possible future revision of the International System of Units, the SI" which, when accomplished, will link the unit of mass to the Planck constant,

recognizing the need to confirm and clarify Recommendation CCM G 1 (2010) in the light of that Resolution,

considering

- recent statements of stakeholders and user communities such as the OIML, the International Organization of Legal Metrology, and CECIP, the European weighing industry association, on the envisaged revision of the International System of Units, the SI, and specific activities of the CCM and its working groups in response to Resolution 1 (2011) of the CGPM,
- continued progress at several National Metrology Institutes and the BIPM with watt balance and X-ray Crystal Density (XRCD) experiments, two distinct and highly-accurate routes to determining the Planck constant, with new and significantly improved data available now, and additional results anticipated before the end of the year 2015,
- progress towards the *mise en pratique* for the realization of the new definition of the kilogram and its future dissemination,
- significant progress at the BIPM to establish an ensemble of reference mass standards,

foreseeing the necessity to develop or improve methods and operate facilities so that, after redefinition, 1 kg can be realized and disseminated with a standard uncertainty not larger than 20 µg,

recommends that the following conditions be met before the CIPM asks CODATA to adjust the values of the fundamental physical constants from which a fixed numerical value of the Planck constant will be adopted,

1. at least three independent experiments, including work from watt balance and XRCD experiments, yield consistent values of the Planck constant with relative standard uncertainties[1] not larger than 5 parts in 10^8,
2. at least one of these results should have a relative standard uncertainty[1] not larger than 2 parts in 10^8,
3. the BIPM prototypes, the BIPM ensemble of reference mass standards, and the mass standards used in the watt balance and XRCD experiments have been compared as directly as possible with the international prototype of the kilogram,
4. the procedures for the future realization and dissemination of the kilogram, as described in the *mise en pratique*, have been validated in accordance with the principles of the CIPM MRA[2].

[1] supportive arguments for these requirements, which aim at a sound experimental basis for the CODATA adjustment of *h* before the redefinition, are given in Metrologia, 2010, 47, 419-428

[2] as stated in the document CIPM MRA-D-05 "Measurement comparisons in the CIPM MRA"

APPENDIX
WORKING DOCUMENTS SUBMITTED TO THE CCM AT ITS 14TH MEETING

Open working documents of the CCM 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=CCM).

Documents restricted to Committee members can be accessed on the restricted-access CCM website. (http://www.bipm.org/cc/CCM/Restricted/WorkingDocuments.jsp)

Document CCM/	
13-01	Draft Agenda (07 February 2013), P. Richard
13-02A-1	Strategy 2013-2023 v. 1.0, CCM WG Strategy
13-02B-1	Strategy 2013-2023 v. 1.0, Appendix 4, CCM WG Strategy
13-03	Draft Recommendation on a new definition of the kilogram, CCM Drafting Committee
13-03A	Comparison of DRAFT Recommendation G1(2013) with CCM Recommendation G1(2010), P. Richard
13-04	OIML statement on the proposed new SI, CIML
13-05A	CECIP Position on possible future revision of the International System of Units-SI, CECIP
13-05B	Response to CECIP position, B. Inglis (President of CIPM)
13-06A	*Mise en pratique* for the definition of the kilogram, version 6.3, CCM WGSI-kg
13-06B	Comments on v6.3 from Workshop participants; responses from editor of v7.0
13-06C	*Mise en pratique* for the definition of the kilogram, version 7.0, RD for the WGSI-kg
13-06CRevised	*Mise en pratique* for the definition of the kilogram, version 7.1, RD for the WGSI-kg
13-06DRevised	Template for comments on *Mise en pratique* v7.1
13-07	Protocol for the BIPM calibration campaign in anticipation of the kilogram definition (CIPM 2012-44), R. Davis
13-08	CCM Strategy, P. Richard
13-09	WG Mass, C. Sutton
13-10	WG Density, K. Fujii

13-11	WG Viscosity, H. Wolf
13-12	WG Force, R. Kumme
13-13	WG High Pressure, J. Torres
13-14	WG Low Pressure, K. Jousten
13-15	WG Hardness, A. Germak (presented by W. Bich)
13-16	WG Fluid Flow, J. Wright
13-17	WG Gravimetry, L. Vitushkin
13-18	WG Avogadro Constant / (WGSI-kg; WGR-kg), H. Bettin
13-19	Report on Workshop 21-22 November 2012, H. Bettin
13-20	Introduction to the *mise-en-pratique*, v7.0, R. Davis
13-21	WG CMCs, C. Sutton
13-22	News from the JCRB, C. Kuanbayev
13-23	News from AFRIMETS TC-M, A. Eltawil
13-24	News from APMP TC-M, T. Kobata
13-25	News from COOMET TC-M, I. Kolozinska
13-25a	Activity Report of COOMET TC 1.6, I. Kolozinska
13-26	News from EURAMET TC-M, N. Medina
13-26a	EURAMET TC-Mass Chair report, N. Medina
13-27	News from SIM TC-M, F. García-Leoro
13-28	Consolidated RMO reports on TC-Flow, presented by J. Wright
13-29	BIPM Mass Department programme of work, presented by M. Stock
13-30	Introduction to BIPM proposal on use of the IPK, presented by R. Davis
13-31a	CCM Recommendation G1, to be presented to CIPM in June 2013, R. Schwartz, facilitator
13-31b	French version of document CCM/13-31a
13-32	14th CCM Conclusions, P. Richard