Bureau International des Poids et Mesures

Consultative Committee for Mass and Related Quantities (CCM)

Report of the 17th meeting
(16-17 May 2019)
to the International Committee for Weights and Measures

Comité international des poids et mesures

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

as of 16-17 May 2019

President

Dr P. Richard, Federal Institute of Metrology [METAS], Bern-Wabern.

Executive Secretary

Dr H. Fang, International Bureau of Weights and Measures [BIPM], Sèvres.

Members

Bundesamt für Eich- und Vermessungswesen [BEV], Vienna.
Central Office of Measures [GUM], Warsaw.
Centro Español de Metrología [CEM], Madrid.
Centro Nacional de Metrología [CENAM], Querétaro.
CSIR National Physical Laboratory of India [NPLI], New Delhi.
D.I. Mendeleyev Institute for Metrology [VNIIM], St Petersburg.
Danish Fundamental Metrology Ltd [DFM], Hørsholm
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 Research Council of Canada [NRC], Ottawa, Ontario.
Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.
RISE Research Institutes of Sweden AB [RISE], Borås.
Slovak Institute of Metrology/Slovenský Metrologický Ústav [SMU], Bratislava.
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 Nacional de Metrologia, Qualidade e Tecnologia [INMETRO], Rio de Janeiro.

Instituto Português da Qualidade [IPQ], Caparica.

Laboratorio Tecnológico del Uruguay [LATU], Montevideo.

National Institute of Standards [NIS], Giza

National Metrology Institute of Turkey [UME], Gebze-Kocaeli.

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

The seventeenth 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 16 and 17 May 2019.

The following were present: H. Ahmadov (UME), F. Arrhén (RISE), M. Ballico (NMIA), H. Baumann (METAS), F. Beaudoux (LNE), M. Borys (PTB), J.H. Choi (KRISS), S. Davidson (NPL), D. El Haddad (NIST), A. Eltawil (NIS), K. Fujii (NMIJ/AIST), Y. H. Fung (MSL), A. Germak (INRIM), R. Green (NRC), F. Härtig (PTB), I. Hernandez (CENAM), T. Kobata (NMIJ/AIST), Z. Kubarych (NIST), N. Kuramoto (NMIJ/AIST), K.-C. Lee (KRISS), E. Lenard (GUM), V. M. Loayza (INMETRO), E. Massa (INRIM), A. Malengo (INRIM), T. Mautjana (NMISA), M.N. Medina (CEM), L. Nielsen (DFM), K. Ogushi (NMIJ/AIST), P. Otal (LNE), A. Peruzzi (VSL), S. Preste (LATU), P. Richard (METAS, CIPM, President of the CCM), I.A. Robinson (NPL), I. Spohr (IPQ), C. Stambaugh (NIST), A. Steele (NRC / CIPM), M. Thomas (LNE), D. Trochta (SMU), B. Ünsal (UME), B. van der Merwe (NMISA), L. Vitushkin (VNIIM), J. Wang (NIM), Z. Zelenka (BEV), Y. Zhang (NIM).

Representatives of Institutes from Member States invited to attend as Observers: D. Ondoro (KEBS).

Invited: H. Bettin (PTB), S.-J. Chen (CMS/ITRI), K. Jousten (PTB), I. Kolozinskaya (NSC IM), R. Kumme (PTB), S.R. Low III (NIST), B. Mickan (PTB), C. Mitsas (EMI), V. Pálinkáš (VUGTK), A.M. Quiroga Rojas (INACAL), S. Schlamminger (NIST).

Also present: S. Bergstrand (JCRB Executive Secretary), F. Bielsa (BIPM), H. Fang (BIPM, Executive Secretary of the CCM), E. de Mirandés (BIPM), M.J.T. Milton (Director of the BIPM), S. Picard (BIPM, KCDB Coordinator), M. Stock (BIPM).

Excused: D. Newell (NIST).

The President of the CCM, Dr Richard opened the meeting and welcomed the participants to this 17th meeting of the CCM. Dr Milton, BIPM Director, also welcomed the participants.

The President emphasized that schedule of the meeting was tight and reminded presenters to stick to schedule. He encouraged the participants to be active in the discussions. The President thanked Dr Nielsen for accepting to act as Rapporteur for the meeting. He also thanked NIST for having sponsored a *Metrologia* Focus issue on Realization, Maintenance and Dissemination of the Kilogram (copies were distributed to CCM members).

The President presented the agenda. He mentioned that a workshop with technical presentations was on the agenda of the CCM for the first time. He thanked Dr Steele for having accepted to chair this workshop. The agenda was approved.

All attendants introduced themselves to the CCM.

2. CIPM, CGPM AND BIPM

The President said that the 18 members of the CIPM had been elected (including six new members) at the CGPM meeting in November 2018 for the next four years. The CIPM elected a new CIPM President and other CIPM bureau members, at its meeting in March 2019. In addition, it elected CC Presidents for a period of four years.

He also recalled that the CGPM had approved Resolution 1 on the revision of the International System of Units (SI) with an implementation date of 20 May 2019.

Dr Milton updated the CCM on the membership of the Meter convention. As of November 2018 there were 59 Member States and 42 Associates of the CGPM. Ukraine, an Associate since 2002, had become Member State in 2018. Uzbekistan and Kuwait had become Associates in 2018. Venezuela had been excluded as Member State due to non-payment of contributions.

He gave an update on participation in the CIPM MRA. A total of 261 institutes take part in the MRA: 101 National Metrology Institutes; four International Organizations and 156 Designated Institutes.

Dr Milton recalled that World Metrology Day is celebrated annually on 20 May, and every year a poster is prepared by a regional metrology organization (RMO). He thanked APMP for preparing the poster for 2019. He hoped that the NMIs were well prepared for celebrating the upcoming World Metrology Day and encouraged them to inform the BIPM about their planned activities on the day. The poster for 2020 will be produced by AFRIMETS.

Dr Milton summarized the five resolutions of the 26th meeting of the CGPM (2018), which are available on the BIPM website. The historic resolution on the revision of the International System of Units was highlighted and a YouTube reference was given to a recording of the open session on the topic.

Dr Milton referred to the first meeting of the CIPM after the CGPM. At this meeting Dr S.R. Park was appointed as President of the CCQM and Dr N. Dimarcq was appointed as President of the CCTF. The presidents of the remaining eight consultative committees were re-elected. The CIPM decided to set out three objectives common to all consultative committees at its 2018 meeting: 1) to progress the state-of-the-art by providing a global forum for NMIs to exchange information about the state-of-the-art and best practices, 2) to define new possibilities for metrology to have impact on global measurement challenges by facilitating dialogue between the NMIs and new and established stakeholders, and 3) to demonstrate and improve the global comparability of measurements; particularly by working with the RMOs in the context of the CIPM MRA to plan, execute and monitor KCs, and to support the process of CMC review.

3. ACTIONS ARISING FROM THE MINUTES OF THE 16TH CCM MEETING IN 2017

The President summarized the actions arising from the 16th meeting of the CCM (2017), where the preparation and adoption of the CCM Recommendation for a new definition of the kilogram in 2018 (G1, 2017) was the main issue. At its meeting in October 2017, the CIPM approved this recommendation (decision CIPM 106-10). At the same meeting, the CIPM accepted DFM (Denmark) as a new member of the CCM. In April 2018 the CCM approved by correspondence 1) the final version of the *mise en pratique* for the definition of the kilogram in the SI, 2) a short note on the dissemination process after the proposed redefinition of the kilogram, and 3) the terms of reference and membership of the Task Group on the phases for the dissemination of the kilogram following redefinition (CCM TGPfD-kg). In accordance with its terms of reference, the CCM TGPfD-kg had prepared a detailed note (document CCM/19-06B) to be presented under item 6 on the agenda of this meeting.

4. CCM WORKING GROUP ON STRATEGY AND MRA COORDINATION

4.1 CCM Strategy

Dr Fang reported on the CCM strategy for the period 2017-2027, which is laid down in a CCM document entitled 'Strategy 2017-2027'. The first CCM strategy document was approved on 14 January 2013 but in October 2017, the document underwent a major revision to become a version 3.0 covering the period 2017-2027. This version was last revised on 28 June 2018. Two elements of the strategy were highlighted: 1) the establishment of long-term tables of KCs; 2) and decisions on how many KCs are needed in order to cover a particular field of measurement ('how far the light shines'). Following the revision of the SI on 20 May 2019, the CCM strategy will need to be revised in the following way: 1) two CCM working groups, WGD-kg and WGR-kg, will be merged; 2) the activities of the BIPM have to be updated; and 3) the plan for ongoing and future KCs will have to be updated. The next major revision of the CCM strategy is scheduled for 2021.

A major topic of the CCM strategy is to address the recommendations of the CIPM MRA review carried out by the Working Group on the Implementation and Operation of the CIPM MRA. Dr Fang highlighted three actions that are under way: 1) reduction of the number of CMC entries in the KCDB (without reducing the percentage coverage of NMI services in the KCDB); 2) development of specific guidance documents to ensure an efficient and effective approach to the CMC review carried out in the CCM Working Groups; and 3) the use of the NIST consensus builder to analyse the results of KCs.

Dr Fang reported that the CCM Strategy Group has reviewed the status of all CIPM and RMO key and supplementary comparisons in the field of mass and related quantities. As a result of this review, the BIPM KCDB will be updated. She thanked the RMO TC-M chairs, the CCM WG chairs and colleagues at the BIPM that work with the KCDB for their assistance in completing the review. A number of issues were identified during the review: 1) The comparison protocols often lack a stage in which the relevant CCM WG could review important aspects of the comparison, such as the linking procedure applied, use of transfer standards etc. 2) Comparisons are often registered in the KCDB using inconsistent nomenclature, and the relevant CCM WG is not always notified or asked for approval. 3) It is not clear how it is ensured that all potential participants in a comparison have been given the opportunity to take part. 4) Comparisons are occasionally registered as a SC, although registration as a KC would be more appropriate. 5) In some cases several bilateral comparisons could be replaced by a coordinated KC/SC. 6) Review of published CMCs after completion of a KC should be part of the comparison process.

Dr Fang listed a number of recommendations regarding the organization of KCs and SCs: 1) the working groups should publish timetables for the comparisons, 2) the RMOs should inform the relevant WG Chair on proposed KCs and SCs as early as possible, so that the comparisons can be coordinated with those of the CCM and other RMOs, 3) the WG Chair should review comparison protocols and ensure that, among other things, appropriate procedures are applied and proper transfer standards are used, 4) the RMO should report progress on all KCs and SCs annually as required, 5) the RMOs should be given guidance on the choice between KCs and SCs, 6) the WG chair should be informed of relevant KC and SC registrations in order to ensure that a consistent nomenclature is used, and 7) the RMO and WG Chair should ensure that relevant CMCs are reviewed at the end of a KC.

Finally, Dr Fang referred to three CCM Guidance documents that are available on the BIPM website (https://www.bipm.org/en/committees/cc/ccm/): 1) CCM Guidelines for Submission and Review of CMCs, 2) CCM Key Comparison Report Template, and 3) CCM Guidelines for approval and publication of the final reports of key and supplementary comparisons.

The President summarized the decisions taken and conclusions made at the meeting of the CCM-WGS on 14 May 2019: The CCM-WGS 1) took note of the information from the CIPM, CCM Strategy and CCM guidance documents, 2) took note of the presentations made by the WG Chairs using the harmonized template for such presentations, 3) confirmed the importance of adding a statement in the final report of KCs regarding ‘how far the light shines’, 4) reviewed the action plans for the last two years, 5) approved the action plans for the next two years, 6) reviewed the list of planned KCs, 7) approved the recommendations on registration of RMO KCs, 8) took note of information on hybrid comparisons, which was discussed at the meeting, 9) took note of the presentations on the KCDB version 2.0 and on the JCRB (see item 10), and 10) approved the list of WG chairs and vice-chairs (see item 11).

The President thanked the CCM members for having prepared the requested technical report on current activities in their NMI. The members of CCM were encouraged to read these reports that contain useful information on the trends in research in the field of mass and related quantities. The reports are available on the BIPM website.

5. REPORTS OF THE WORKING GROUPS

Before starting the WG Chair presentations, the President paid a memorial tribute to Dr Chris Sutton, who passed away in December 2018 at the age of 70. Chris was chairman of CCM-WGD-kg for six years and former chairman of the CCM working group on CMCs. His warmth, gentleness and helpfulness towards other people will be remembered. Chris was extremely appreciated within the CCM community. He made great contributions to the CCM and will be missed. The President thanked members of the CCM, who had sent condolences to the family of Chris.

5.1 Density and viscosity

Dr Fujii presented the report of the CCM Working Group on Density and Viscosity (CCM-WGDV). The working group was established July 2014 following a merger of the former working groups WG Density and WG Viscosity.

Since the last CCM meeting, there has been no change in the membership of CCM-WGDV. A single meeting has been held (13 May 2019) with 55 participants from the 27 member institutes. The next meeting is planned to take place at BIPM during the week of the next CCM meeting. A list of the main actions taken and the main achievements for the period 2001 to 2016 was presented. The latest achievement (from 2016) was a revision of CCM Service Categories for density.

Dr Fujii mentioned that with regard to progressing the state of the art in the field, the volumes of Si spheres can now be measured with a relative standard uncertainty of the order of 1×10^{-8} using optical interferometry. This has been demonstrated by a comparison carried out between PTB and NMIJ. At the same time, density comparators based on hydrostatic weighing have been developed, which uses two silicon spheres as a density standard. It compares the density of another Si sphere under test against the density of the two silicon spheres used as a reference, with a relative standard uncertainty of 3.6×10^{-8}. As a result, solid density standards are now available that enable volume and density measurement with an uncertainty much lower than in the past, where most such measurements were performed using the density of water as a reference.

Seven points were listed under the heading ‘Liaison and stakeholders’: 1) Si density standards, the calibration of which is covered by CCM.D-K1, are now used by most NMIs as reference standards for measuring density of solids, liquids and even gases, 2) due to legal metrology and taxation requirements, the oil, liquor and alcohol industries still have a high demand for calibration of hydrometers, which is covered by CCM.D-K4, 3) due to automation, the same industries have an increasing demand for calibration of oscillating-type density meters, which is covered by CCM.D-K2 and CCM.D-K5, 4) due to a high demand for measuring the density and volume of stainless steel weights, there is a need for the planned CCM.D-K3, 5) in the food industry and in agriculture, there is a need for traceable standards for the refractive index of liquids in order to measure sugar content of liquids, 6) in order to supply the refractive index of liquids, liaison with CCPR is being established, and 7) traceable gas density measurements are needed for saving and transportation of energy, such a measurement service will be covered by a new key comparison for p-ρ-T properties of fluids.

A list of all completed KCs in the field of density was presented: 1) CCM.D-K1: Density measurement of a silicon sphere by hydrostatic weighing (2001-2003), 2) CCM.D-K2: Comparison of liquid density standards (2004-2005), and 3) CCM.D-K4: Hydrometers (2011-2012). Two KCs in the field of density are under way: 1) CCM.D-K3: Density measurements of stainless steel weights (2019-) and 2) CCM.D-K5: Density measurements by oscillation-type density meters (2019-). Two regional KCs on hydrometer calibration, EUROMET.M.D-K4 (piloted by INRIM) and SIM.M.D-K4 (piloted by CENAM) have been linked to CCM.D-K4, and a third one APMP.M.D-K4 (piloted by KRISS) is in the process. These linked KCs cover hydrometer calibrations performed in 36 NMIs.

A joint CCM/CCPR KC on refractive index of liquids, CCM.D-K6, has been planned, with a start date in 2021. The liquids in question are similar to those used as liquid density standards.

A list of all completed KCs in the field of viscosity was presented: 1) CCM.V-K1: Five samples of Newtonian liquids - wide viscosity range (2002), 2) CCM.V-K2: Six samples of Newtonian liquids.- wide temperature range (2006), and 3) CCM.V-K3: Three samples of Newtonian liquids - wide viscosity range (2012-2013). One KC is under way: CCM.V-K4: Two samples of Newtonian liquids - wide temperature range (2018-).

The programme of work for the next five years included: 1) completion of the KCs under way and planned, 2) consideration on the influence of surface tension for hydrometer calibration, 3) linking of RMO KCs to CIPM KCs, 4) liaison with CCPR for refractive index evaluation, 5) consideration regarding the measurement of density under high pressure and temperature, and 6) calibration of viscosity standards for non-Newtonian liquids.

Since the CCM-WGDV Deputy Chair, Henning Wolf, retired from PTB in 2018, Dr Fujii proposed that he should become Vice-Chair, representing the subfield of density, and that Yoshitaka Fujita (NMIJ) should replace him as Chair, representing the subfield viscosity. The proposal had been subject to voting among the 27 members of CCM-WGDV, with the result that 19 were for and none were against the proposal. The proposal was adopted by CCM under item 11 of the agenda.

5.2 Force and Torque

Dr Kumme presented the report from the CCM Working Group on Force and Torque (CCM-WGFT).

Due to changes in the staff of four NMIs, four new delegates to CCM-WGTF representing these NMIs had been appointed: 1) Simon Dignan, NMIA, Australia, 2) Vavrecka Lukàs, CMI, Czech Republic, 3) Sipho Dlamini, NMISA, South Africa, and 4) Bulent Aydemir, UME, Turkey.

Two WGTF meetings have been held since the last CCM meeting: A three day meeting was held at PTB on 6-8 June 2017, and a short meeting was held in Belfast on 4 September 2018 during the XXII IMEKO World Congress.

A list of all completed KCs in the field of force was presented: 1) CCM.F-K1.a (5 kN, 10 kN) and CCM.F-K1.b (5 kN); 2) CCM.F-K2.a (50 kN, 100 kN) and CCM.F-K2.b (50 kN); 3) CCM.F-K3.a (0.5 MN, 1 MN) and CCM.F-K3.b (0.5 MN); and 4) CCM.F-K4.a (2 MN, 4 MN) and CCM.F-K4.b (2 MN). Each of these four KCs were divided into two groups A and B. In group A, two transducers were circulated and calibrated at two force steps F_1 and F_2. In group B, two other transducers were circulated but calibrated only in the lower force step F_1. The circulation was of star type, so that the transfer standards came back to the pilot laboratory between measurements by other participants. The measurement principle applied in groups A and B, respectively, was presented. According to Dr Kumme, the KC scheme described had provided excellent results but took a long time and had imposed a large workload on the pilot laboratory. Graphs showing the degrees of equivalence for each of the two force steps in the four KCs were presented. According to these graphs, the RMO comparisons EUROMET.M.F-K2, APMP.M.F-K2.a, APMP.M.F-K2.b, and APMP.M.F-K4.b had been linked to the proper CCM KCs.

Two KCs in the field of force are under way: 1) CCM.F-K2.a.2 (5 kN, 10 kN, 50 kN, 100 kN, 200 kN) and 2) CCM.F-K3.1 (0.5 MN, 1 MN).

A list of RMO KCs and SCs in the field of force registered in the KCDB was presented with an indication of their current status. The list included four KCs and one SC from APMP, two SCs from AFRIMET, two SCs from COOMET, three KCs and two SCs from EURAMET, two SCs from GULFMET, and eight SCs from SIM.

In the field of torque, a total of five KCs have been completed: 1) CCM.T-K1 (500 N m, 1000 N m), 2) CCM.T-K1.1 (500 N m, 1000 N m), 3) CCM.T-K1.2 (500 N m, 1000 N m), 4) CCM.T-K1.3 (500 N m, 1000 N m) and 5) CCM.T-K2 (10 kN m, 20 kN m). In each KC, two transducers were circulated and calibrated in two torque steps, clockwise as well as anticlockwise. Excellent results were obtained, but similarly to the KCs in the field of force, the comparison scheme had required a lot of work by the pilot laboratory. Graphs showing the degrees of equivalence obtained in the KCs (and in any linked RMO KC) were presented.

A list of RMO KCs and SCs in the field of torque registered in the KCDB was presented with an indication of their current status: One KC and one SC from APMP, one SC from COOMET, five SCs from EURAMET and one SC from SIM.

Dr Kumme presented a plan for KCs under the heading 'Main actions taken and main achievements' in the field of force and torque defining the period of repetition, the time for the next execution and the range of CMCs covered by the KC. The plan included five KCs in the field of force and two KCs in the field of torque. The first KC in the plan, CCM.F-K23 (500 N, 1000 N), will be carried out by following a new scheme: each participating laboratory will bring its own set of transducers and resistance bridge (BN 100) to the pilot laboratory, which will calibrate the measurement system using the same deadweight force standard machine. It is then up to the participating laboratory to evaluate the stability of its own measurement system.

Dr Kumme presented the following list under the heading 'Liaison and stakeholders of CCM-WGFT': 1) all regional metrology organizations, 2) ISO TC 164/SC 1 and ISO TC 164/SC 4, 3) Industry in force and torque measurement, and 4) IMEKO TC3.

Under 'Progressing state of the art' it was reported that: 1) members of CCM-WGFT are involved in research, 2) development in the area of large force measurements has taken place in the project EMRP SIB63, 3) development in the area of large torque measurements has taken place in the project EMPIR 14IND14, 4) developments in small force and torque have been published by IMEKO, 5) consequences of SI redefinition on force and torque, in particular in the field of small forces and torques, have been considered and published by IMEKO, 6) multicomponent force and torque measurements have been progressed, 7) traceability of dynamic force measurement, which is considered an important topic, will be investigated in a new project, EMPIR 18SIB08, and 8) torque measurement in support of the wind power energy sector is planned to be developed in a proposed EMPIR project 'WindEfficiency'.

The programme of work for the next five years in CCM-WGFT is as follows: 1) completion of measurements in CCM.F-K23 (500 N, 1000 N) by mid-2020 and evaluation of results in 2020-2021, 2) development of harmonized review criteria for CMCs in force and torque in 2020/2021, 3) start of the new CCM.F-K1 (5 kN, 10 kN) force comparison in 2021, 4) start of new CCM.T-K1 (500 N m, 1000 N m) comparison in 2022, 5) definition of other KCs needed in the fields of force and torque.

The next planned meetings in CCM-WGFT will take place at 1) NIST, Gaithersburg (Autumn 2020), 2) XXIII IMEKO World Congress, Yokohama (2021), and 3) KRISS, Daejon (2023).

The President asked if the measurement scheme proposed for CCM.F-K23, according to which participants bring their own measuring systems to the pilot laboratory, would decrease the time it would take to complete the measurements in the KC. Dr Kumme confirmed that this would probably be the case.

5.3 Pressure and vacuum

Dr Jousten presented the report of the CCM Working Group on Pressure and Vacuum (CCM-WGPV).

There has been no change in membership of CCM-WGPV since the last meeting of the CCM. The working group has 20 members and one observer represented by 40 individuals in total. In 2017, the working group decided that inactive members/observers should have their membership/observer status revoked. Based on this decision, the membership of INMS-NRC (Canada), INRIM (Italy), NMIA (Australia), NPL-I (India) and the observer status of SMU (Slovakia) were under review.

No meetings of CCM-WGPV have taken place since the last CCM meeting. The next meeting is planned in May 2020 at PTB, Berlin, combined with workshops held within two EU projects 16NRM05 ‘Ion gauge’ and 18SIB04 ‘Quantum pascal’.

Under the heading ‘Main actions taken and main achievements’, Dr Jousten reported that CCM-WGPV has established a Task Group that should 1) define the most accurate device as unit under calibration (UUC) for a specified part of the pressure range covered by the WG (10^{-9} Pa to 10^{9} Pa), 2) identify whether overlapping pressure ranges are necessary in the light of UUCs chosen, 3) agree on the uncertainty contribution to the CMC from each of the selected UUCs, 4) give an opinion, if a change of the ‘Statement 2 of the CCM-WGPV on the content of CMC entries’ (May 2017) is deemed necessary, 5) identify problems, if any, which cannot be solved by the task group due to unclear guidelines of the CIPM/BIPM, JCRB, or CCM.

Under ‘Progressing state of the art’ it was reported that 1) optical methods for total pressure (possibly a new realization of the Pascal) and partial pressure measurement are being investigated, 2) traceable partial pressure measurement traceable outgassing rate measurement are being developed, 3) research on measurement of dynamic pressures (vacuum and pressures higher than 100 kPa) is continued, 4) a research activity within EURAMET towards a standardized ionization gauge have been established, and that 5) an oil micromanometer with integrated density measurement has been developed.

The following list was presented under the heading of ‘Liaison and stakeholders: 1) Support work of ISO TC 112 ‘Vacuum technology’ by doing research in standardized ionization gauges. 2) Act as advisory group for project EMPIR 18SIB04 ‘Towards quantum-based realizations of the pascal’. 3) Collaboration with the project EMPIR 16NRM05 ‘Ion gauge’.

No KCs have been completed or started since the last meeting of the CCM. The following KCs are planned: 1) CCM.P-K4.2012.1, where two CDG and two RG manometers will be calibrated by NIST using optical techniques and an Ultrasonic Interferometer Manometer (UIM) and by PTB using series expansion systems, 2) a first KC on measurement of leak rates against atmosphere, 3) a new CCM.P-K3, 4) a new CCM.P-K1.b, and 5) a new CCM.P-K2.

Following a request from Dr Jousten and the President, the CCM approved the protocol of CCM.P-K4.2012.1.

The following programme of work for the next five years for CCM-WGPV was presented: 1) completion of the work of the Task Group set up to define the smallest uncertainty contributions from calibrated devices to be included in CMCs, 2) promotion and execution of the planned KCs, 3) Supporting work of ISO TC 112 ‘Vacuum technology’, 4) further investigation in the use of optical methods for measuring partial or total pressure, and 5) act as advisory group for the project EMPIR 18SIB04.

Dr Milton asked if the increased interest in the measurement of dynamic pressure had led to a need for comparisons in the field. Dr Jousten replied that for the time being there was no need for such a comparison. Mr Arrhén agreed and added that the measurement technology used for measurement of dynamic pressure was not yet mature.

5.4 Hardness

The report of the CCM Working Group on Hardness (CCM-WGH) was presented by Dr Low. The working group has 20 NMI members. Each member is represented by a delegate and, optionally, a technical expert. There have been no changes in membership since 2017, but the delegates of NMISA and VNIIFTRI have changed due to changes in staff.

The working group has held a single meeting since the last meeting of the CCM. The 18th CCM-WGH meeting, with the participation of eight NMI members, was held on 19 September 2018 in Stockholm at the Swedish Standards Institute in conjunction with meetings of ISO TC 164 'Mechanical testing of metals' held at the same location in the same week. At that meeting, decisions on finalizing reports of three Pilot Studies (CCM.H-P1, CCM.H-P2, CCM.H.P3) were taken. In addition, the hardness definitions for Rockwell 15N, 30N and 45N were discussed: Whereas ASTM and ISO set up tolerances for various test parameters influencing the hardness value measured, the CCM-WGH find it necessary to define specific values for test parameters, including the parameters characterizing the indenter balls. To this end, a proposal for maintaining stocks of well characterized indenter balls for Rockwell and Brinell scales were discussed. In addition, the protocol for the Rockwell C key comparison CCM.H-K3 was redesigned: the number of participants was reduced in order to ensure that the transfer standards were not used up before the end of the comparison. This problem could be alleviated by using the star-type comparison scheme suggested in the report from the CCM-WGFT. This might allow Rockwell 15N, 30N and 45N to be carried out on the same hardness block (going back and forth between a single participant and the pilot laboratory). A KC on Brinell hardness had revealed problems in measuring the indentation, so it had been converted into a pilot study. Comparisons on Rockwell B hardness are made difficult by the absence of stable transfer standards (made of brass and aluminium). A comparison on Vickers hardness is due in the near future. The meeting had also discussed if Instrumented Indentation Testing should be under the umbrella of the CCM-WGH or not; no conclusive decision was taken.

The 19th meeting of the CCM-WGH will be held in Ulm, Germany, at Zwick GmbH & Co. KG on 27 September 2019. The topics of the meeting will be: 1) analyses of CMCs by NMIs and possible sub-Group, 2) discussion of 'How far the light shines' in key comparisons in the field of hardness, 3) creation of Guidance Documents, 4) firm plans for new KCs.

The 20th meeting of the CCM-WGH will be held in Conshohocken, Pennsylvania, USA, at the ASTM International Headquarters in 2020, at a date to be determined.

Dr Low presented three bullets under the heading 'Main actions taken and main achievements'. The first bullet was that three Pilot Studies had been completed: 1) CCM.H-P1 'Pilot study on Rockwell diamond indenters', 2) CCM.H-P2 'Pilot study of Leeb hardness reference blocks scale D and G', 3) CCM.H-P3 'Pilot Study of Brinell Hardness scale'. The final reports of these studies had been reviewed and accepted by participants, and they would soon be approved and submitted for publishing on the BIPM website. The second bullet was that definitions for the following hardness scales had been (partially) developed (currently only the Rockwell HRC scale is officially defined by CCM-WGH): 1) Rockwell HR15N, HR30N and HR45N scales (definitions had been developed and would soon to be circulated to the CCM-WGH for approval), 2) Rockwell HRBW scale (definitions had been developed, but decisions for how to define the indenter ball had to be taken), 3) Leeb hardness scales (PTB would continue to develop draft definitions for the Leeb hardness scales) 4) Knoop and Vickers hardness (NPL would continue to investigate the development of draft definitions for the Knoop and Vickers hardness). The third and final bullet was that CCM-WGH had decided to revise the technical protocol plan for CCM.H-K3 (Rockwell HRC) so that only five NMIs will participate (INRIM, PTB, VNIIFTRI, KRISS, NMIJ); other NMIs will have to obtain their equivalence through RMO KCs, which will include one or more of the NMIs participating in CCM.H-K3.

Dr Low presented the following list of the WG's contribution towards progressing the state of the art: 1) defining hardness tests for an optimum balance between lowest measurement uncertainty obtainable and industrial need for fast measurements, 2) improving hardness test methods through influence parameter investigations and transferring the knowledge to standards development organizations, and 3) possible improved stability in Rockwell ball scale reference block transfer standards.

Dr Low mentioned that under the heading of ‘Liaison and stakeholders’ the CCM-WGH deals with hardness standards and promotes international cooperation among NMIs, DIs, RMO members and international organization such as ISO, ASTM, VAMAS and others, in order to improve traceability and standardization in the field. The following stakeholders were listed: 1) producers of hardness equipment and reference standards, and 2) industries and customers that rely on hardness measurement data for assuring the desired and required properties of their products.

Dr Low reported that one KC had been completed since the establishment of the CIPM MRA: CCM.H-K1 ‘Vickers hardness scales (HV 0.2, HV 1, HV 30)’. One KC was reported as being under way: CCM.H-K3 ‘Rockwell C hardness scale (HRC)’.

Under ‘KCs planned’, it was reported that it had been proposed that: 1) VNIIFTRI should pilot KCs on the Rockwell hardness scales HR15N, HR30N and HR45N, 2) PTB pilot KCs on the four Brinell hardness scales HBW 1/30, HBW 2.5/187.5, HBW5/750 and HBW10/3000 with measurements at 2 or 3 hardness levels (250 HBW, 350 HBW and 450 HBW), and 3) a Pilot Study or KC for the Rockwell HRBW scale is being delayed until additional research in a block design has been investigated at NIST.

The following programme of work for the next five years was presented: 1) Develop additional hardness measurement definitions. 2) Complete the Rockwell C Key Comparison (CCM.H-K3). 3) Initiate the five new Key Comparisons CCM.H-P4 ‘Rockwell B scale’ (2020), CCM.H-K5 ‘Rockwell HR15N scale (2021), CCM.H-K6 ‘Rockwell HR30N’ (2022), and CCM.H-K7 ‘Rockwell HR45N scale’ (2023).

5.5 Fluid Flow

The report of the CCM Working Group on Fluid Flow (CCM-WGFF) was presented by Dr Mickan.

No changes in the membership of CCM-WGFF were proposed. In 2018, Dr Mickan (PTB) was elected as the new Chair, and Dr Li (NIM) was elected as Deputy Chair.

The last meeting of the working group was held on 19-20 March 2018 in Queretaro, Mexico, in conjunction with the 10th International Symposium on Fluid Flow Measurement (ISFFM). Three meetings had been planned: 1) a meeting on 24-25 June 2019 in Lisbon in conjunction with the FLOMEKO 2019 conference, 2) a meeting in 2020 (date and location to be determined), and 3) a meeting in 2021 in conjunction with the 11th ISFFM.

Under the heading ‘Main actions taken and main achievement’, Dr Mickan gave an update on the status of activities in the RMOs (AFRIMETS, APMP, COOMET, EURAMET, and SIM). Seven countries are active in AFRIMETS sub-WG Flow, and a key comparison AFRIMETS.M.FF-K4.2.2015 ‘Micro-pipettes 100 μL’ is in progress. Twenty-five organizations are active in APMP TCFF, which had organized a workshop (in 2018) on how to 1) make CMC entries, 2) carry out on-site peer review, 3) set up uncertainty budgets, and 3) carry out measurement comparisons. APMP NMIs also carried out research on methods for the calibration of flue gas S type pitot tubes and 3D pitot tubes and on inter-comparison under different flow conditions. COOMET TC-F were reported to have improved its relationship with CCM-WGFF and EURAMET TC-F, and a list of comparisons on bell provers, gas flow rates and water flow rates were presented. EURAMET TC-F were reported to face increasing measurement challenges in the fields of 1) liquefied natural gas (LNG), 2) micro flow/volume of various liquids, 3) conversion of electrical power to hydrogen, 4) multiphase flow, 5) waste water and large pipe lines, and 6) flow meter diagnostics and sensor networks. With regard to flow, activities within SIM, NIST and CENAM were reported to be the most active NMIs, taking part in almost all CCM key comparisons on fluid flow.

Two additional ‘Main actions taken and main achievement’ were reported: 1) The number of CMCs published within all RMOs have increased. The increase is mainly due to CMCs published by developing NMIs for measurement of liquid volume. There has been an ongoing process to reduce the number of CMCs by combining entries with a high degree of redundancy. 2) In order to enable a reduction of CMCs in a consistent and logical way, a new set of service categories under fluid flow was proposed: 9.10.1 ‘Liquid flow’, 9.10.2 ‘Gas flow’, 9.10.3 ‘Quantity of fluid’, 9.10.4 ‘Flow speed’, 9.10.5 ‘Multiphase flow’, and 9.10.6 ‘Heat flow’.

Following a request from Dr Mickan and the CCM President, the CCM approved the proposed new service categories under fluid flow.

Under the heading of ‘Progressing the state of the art’, it was reported that improvements in the process of organizing and conducting measurement comparisons had been improved by using similar protocols and not “reinventing the wheel”.

Under the heading of ‘Liaison and stakeholders’, Dr Mickan reported that his communication with EURAMET, APMP, and SIM TC-Flow chairs was regular and smooth, and that the relationship between CCM-WGFF and COOMET had improved. As stakeholders he listed: 1) IMEKO TC9 ‘Flow measurement’, 2) ISO/TC 48 ‘Laboratory equipment’ (pipettes), 3) legal metrology organizations such as OIML and notified bodies, and 4) accreditation bodies.

A list of ‘KCs completed and under way’ was presented. The list contained nine key comparisons; five of them had been completed in 2017 or before. A comparison CCM.FF-K3.2011.1 ‘Air speed’ had been completed in 2018, and for CCM.FF-K2.2011 ‘Hydrocarbon liquid flow’ a Draft A report had been issued. Two comparisons were under way: CCM.FF-K1.2015 ‘Water flow’ and CCM.FF-K6.2017 ‘Low pressure gas flow’.

Two KCs had been planned: CCM.FF-K5.2016 ‘High pressure gas flow’ and CCM.FF-K1.2019 ‘Microflow of water’. The former comparison will be very costly (more than 70 000 €), and the cost should be shared in a fair way among the participants. This is an administrative challenge that needs to be solved. The pressure certificate for the high pressure equipment to be circulated had expired, so either a new (expensive) test should be spend, or all participants should agree to take the risk.

The ‘Programme of work for the next five years’ was presented. It contained the following elements: 1) Continue effort to apply KC results to CMC reviews in an objective way. 2) Plan the next round of WGFF and RMO comparisons for the next 10 year cycle starting in 2020. 3) Increase participation by developing economies, strengthen coordination and linkage with RMOs, encourage different labs to serve as Pilots in key comparisons. 4) Solve key comparison transport and cost sharing problems. 5) Share more validated uncertainty spreadsheet templates. 6) Develop comparison calculation template, guidelines on linkage and how to handle multiple artefacts.

5.6 Gravimetry

The report of the CCM Working Group on Gravimetry (CCM-WGG) was presented by Dr Germak.

The CCM-WGG has 22 members (14 NMIs, three DIs, four personal and one international). No changes in membership were proposed. However, Dr Germak proposed a change to the chairmanship, so that Dr Shuqing (NIM) became CCM-WGG Chair, and Dr Pálinkáš (VUGTK) became Vice-chair.

Since the last meeting of the CCM, one CCM-WGG meeting had been held. This meeting took place on 13 May 2019 at the BIPM and had 21 participants (16 members and five invited guests or observers).

The next CCM-WGG meeting was planned to be held in conjunction with the IAG General Assembly 2021 in Vienna.

Dr Germak reported that under the heading of 'Main actions taken and main achievements', the working group had organized and promoted CCM and RMO key comparisons as well as submissions of CMCs in the field of gravimetry. New CMCs for NSC IM were published in June 2017, whereas CMCs for VUGTK, CENAM, NIM and NIMT were under review. The CCM-WGG had also dealt with metrological issues in the field. In cooperation with the geodetic and geophysicist community, the WG had issued (in 2014) a document 'CCM-IAG Strategy for Metrology in Absolute Gravimetry' that describes different ways of obtaining traceability in gravimetry. Dr Germak pointed out that CMCs for absolute gravity measurement on a site are different from CMCs for calibration of absolute gravimeters (by comparison with another absolute gravimeter or with a gravity reference station).

Under 'Progressing the state of the art' it was reported that a better understanding of uncertainty in gravity measurement had been obtained. A long list of influence parameters had been identified. There is probably a systematic error in all measurements performed with the dominant absolute gravimeter FG5. Therefore, a lower limit of 4.5×10^{-8} m/s^2 for the expanded uncertainty ($k = 2$) associated with the FG5 had been agreed. It was also reported that by implementing all possible traceability paths described in the document 'CCM – IAG Strategy for Metrology in Absolute Gravimetry', better possibilities for obtaining traceability in gravity measurements had been given. Finally, Dr Germak mentioned the progress in developing new types of absolute gravimeters, such as quantum-based atomic gravimeters, which is a welcome alternative to the traditional corner cube gravimeters.

The following list of 'Liaison and stakeholders' information was presented: 1) NMIs that need support for their CMCs in the field of gravity and for the realization of the kilogram using Kibble balances, and 2) the geodetic and geophysicist community via IAG SC2.1 'Gravimetry and Gravity Networks'.

Dr Germak presented the following list of KCs completed and under way: 1) CCM.G-K2.2017, Pilot Lab: NIM, Period: October to November 2017, Status: Draft B issued, 2) EURAMET.M.G-K3, Pilot Lab: VÚGTK, Period: April to June 2018, Status: Draft A issued, 3) SIM.M.G-K1, Pilot lab: NIST, Period: October 2016, Status: Approved, and 4) COOMET.M.G-S1, Pilot lab: NSC IM, Period: January 2016, Status: Approved.

The next CCM key comparison in gravimetry was planned to take place in 2023. Immediately thereafter, the next RMO key comparisons in the field should be carried out.

The following 'Programme of work for the next five years' was presented: 1) Definition of the features of gravity reference sites, and improvement of the quality and the number of reference sites in the regions. 2) Organization of technical seminars/workshops (to coincide with WGG meetings). 3) Improvement of CMCs. 4) Organization of Key Comparisons with periodicity of six years. 4) Support for the realization of the International Gravity Reference System - IGRS (Resolution No. 2 of the IAG at the XXVI General Assembly of the IUGG in 2015). The achieved uncertainty for gravity measurement at reference stations should be better than 10 µGal, including systematic effects.

After the presentation, Dr Milton asked if the systematic error of FG5 measurements leading to an expanded uncertainty of 4.5×10^{-8} m/s^2 was larger than expected. Dr Germak replied, that some participants in key comparisons had claimed a lower uncertainty.

5.7 Realization and dissemination of the kilogram

The report of the CCM Working Group on the Realization of the Kilogram (CCM-WGR-kg) was presented by Dr Bettin.

Dr Bettin reported that on 20 May 2019, the working group CCM-WGR-kg would be merged with the CCM Working Group on the Dissemination of the Kilogram (CCM-WGD-kg) to create the CCM Working Group on Mass (CCM-WGM). Members of CCM-WGR-kg would all be transferred to CCM-WGM. Dr Bettin proposed CMS/ITRI of Chinese Taipei as an additional member. This NMI had given presentations about the X-Ray Crystal Density (XRCD) method for future realization of the kilogram. The NMI possessed a Si-28 sphere produced by PTB and was setting up a XRF/XPS apparatus for measuring the mass of the surface layer on the sphere. Dr Sheng-Jui Chen was proposed as a delegate.

Since the last CCM meeting, two meetings of CCM-WGR-kg had been held: 1) a meeting on 6 July 2018 had been held jointly with the CCEM Working Group on Electrical Methods to Monitor the Stability of the Kilogram (CCEM-WGKG) as a satellite meeting of CPEM 2018 in Paris, and 2) a meeting held on 14 May 2019 at the BIPM.

Dr Bettin reported that in terms of ‘Main actions taken and main achievements’, the Planck constant had been measured with relative standard uncertainties 1) $u_r = 0.9 \cdot 10^{-8}$ by NRC using a Kibble balance, 2) $u_r = 1.3 \cdot 10^{-8}$ by NIST using a Kibble balance, 3) $u_r = 5.7 \cdot 10^{-8}$ by LNE using a Kibble balance, 4) $u_r = 1.2 \cdot 10^{-8}$ by the International Avogadro Coordination (mainly INRIM, NMIJ, and PTB) using the XRCD method, and that based on these measurements, 5) a final value of the Planck constant had been determined, and 6) a new definition of the kilogram based on a fixed value of the Planck constant had been approved by the CGPM. In addition, 7) development of commercial Kibble balances had been initiated by NIST, NPL and PTB, 8) four additional Si-28 spheres had been produced by PTB, 9) development of apparatus for measuring small masses and forces directly, in terms of the fundamental constants defining SI, as of 20 May 2019, had been initiated by KRISS, NIST, NMIJ, INRIM, and possibly other NMIs, and 10) support of the Task Group on the Phases for the Dissemination of the Kilogram following redefinition (CCM-TGPfD-kg) was ongoing.

In terms of ‘Progressing the state of the art’, Dr Bettin reported that 1) additional Kibble balances had been planned by various NMIs, 2) additional Si-28 spheres would be produced and measured by PTB and would be available for purchase by other NMIs, and 3) spheres of natural Si would be used by PTB to realize the kilogram.

Liaison and stakeholder activities of the working group were listed: 1) CCM, CIPM, CGPM, BIPM, and NMIs. 2) OIML, WELMEC, and offices for legal verification of weights and weighing instruments. 3) Calibration laboratories calibrating mass standards and weighing instruments. 4) Industries manufacturing balances and mass standards.

Under the heading ‘KCs completed and under way’, Dr Bettin reported that a Pilot Study CCM.R-kg-P1 ‘Comparison of future realizations of the kilogram’ had been completed and published, and that the organization of the first KC on realization of the kilogram had started. This KC would probably start at the end of 2019 and would be repeated after (probably) two years. These are the only KCs planned by CCM-WGR-kg.

The ‘Programme of work for the next five years’ (to be carried out by CCM-WGM) was presented: 1) Organization of the two KCs on the realization of the kilogram. 2) Support for the task group TGPfD-kg in determining the consensus value of the realizations of the kilogram. 3) Establish review criteria and service categories for CMCs. 4) Update the *Mise en pratique* for the kilogram, if necessary. 5) Meetings on projects for the realization of the kilogram, including reporting of progress to the CCM.

Dr Bettin concluded his report by thanking the CCM for some exciting years and announced that he would retire from PTB by the end of 2019.

The President thanked Dr Bettin for his contribution to the CCM.

The report of the CCM Working Group on the Dissemination of the Kilogram (CCM-WGD-kg) was presented by Dr Davidson.

Under ‘Proposed changes to the membership’, Dr Davidson paid a tribute to the late Dr Chris Sutton, MSL, New Zealand, and reported that Dr Yin Hsien Fung will be the new contact person within the working group at the MSL. No other changes in the membership of the working group were proposed.

Dr Fung thanked, on behalf of MSL, the President and Dr Davidson for their memorial tributes to the late Dr Chris Sutton.

The last meetings of the CCM-WGD-kg were held in May 2017 and May 2019 in conjunction with the CCM meetings. The next meeting (in the merged CCM-WGM) was planned to take place in conjunction with the next meeting of the CCM in 2021.

In terms of ‘Main actions taken and main achievements’, Dr Davidson reported that 1) the Task Group on the Phases for the Dissemination of the Kilogram following Redefinition (CCM-TGPfD-kg) had met twice to decide on the contents of the extended note on the dissemination process after the proposed redefinition of the kilogram, 2) mass CMCs have been reviewed to assess the impact of the increase in uncertainty due to the use of a consensus value for the kilogram following 20 May 2019, and 3) a number of RMO KCs and SCs reports have been reviewed and approved for publication in the KCDB.

Regarding the review of CMC values, Dr Davidson explained that following the redefinition of the kilogram on 20 May 2019, CMCs would need to be increased in order to reflect the extra 10 µg uncertainty in the mass of the International Prototype of the Kilogram. The approaches for doing this had been discussed: 1) NMIs review and if necessary update CMCs based on the additional 10 µg uncertainty; such updates should be reviewed by the RMO and CCM-WGD-kg. 2) A WG steering group updates the necessary CMCs and asks the affected NMIs to review. 3) A note is added to the KCDB to detail the need for an additional uncertainty contribution to be added to mass CMCs. The third approach was preferred by the working group but it would require a lot of work in updating the KCDB, and CMC entries would be less easy to interpret. Instead, the following approach was proposed to the CCM: The WGD-kg chair, with help from Mr Zelenka, reviews and recalculates CMCs of those NMIs affected. NMIs confirm that they agree with the revised CMCs, which are then submitted to the RMO TC Chairs for approval. Finally, the revised CMCs are submitted to KCDB for publication. Ideally, the whole process might be completed in one month. The CCM had no objections or comments to the proposal.

Under ‘Progressing the state of the art’, Dr Davidson reported that both the work in TGPfD-kg and the organization of KCs on realization of the kilogram had promoted the development of existing realization experiments and also encouraged additional NMIs to explore the option of developing realization experiments at various points on the mass scale. Dr Davidson recommended that NMIs should also consider how realization experiments could be developed by NMIs with the aim of providing what he called ‘shop-floor’ level SI traceability.

Liaison and stakeholders were listed: 1) Regional Metrology Organizations. 2) NMIs who are not members of the working group. 3) Other metrology organizations such as OIML, WELMEC, EA, ISO etc. 4) Manufacturers of balances and weights. 5) Academia, which cooperates with NMIs in developing experiments for the realization of the kilogram.

Dr Davidson reported that KCs completed and under way were: 1) the Pilot Study CCM.R-kg-P1 ‘Comparison of future realizations of the kilogram’ and 2) the comparison CCM.M-K7 (5 kg, 100 g, 10 g, 5 g and 500 mg) had both been completed, and that 3) the comparison CCM.M-K8.2019 on realizations of the kilogram was planned to start at the end of 2019.

A table of planned KCs was presented, with four comparisons and the years for their execution: 1) a 1 kg comparison scheduled for 2022-2024 (depending on changes in traceability due to the redefinition of the kilogram), 2) a comparison on (sub-)multiples of the kilogram (2024-2026), 3) a 50 kg comparison (2023-2025), and 4) a biannual KC on the realization of the kilogram. Comparisons on (sub-)multiples of the kilogram would be run every ten years. Dr Davidson asked the CCM to approve the proposed comparison CCM.M-K8.2019 on the realizations of the kilogram, which was scheduled to start at the end of 2019 but would probably be extended until March 2020 in order to maximize the number of participants.

Dr Davidson summarized the ‘Programme of work for the next five years’ in the following list: 1) Prepare a draft ‘CCM detailed note on the dissemination process after the proposed redefinition of the kilogram’ (May 2019). 2) Agree details around the calculation of the kilogram consensus value and get approval from the CCM (May 2019). 3) Agree a method for updating published CMCs with respect to the uncertainty change after the kilogram redefinition. 4) Complete first comparison of realization experiments (2020). 5) Review the need for CCM 1 kg KC with respect to the ongoing implementation of the redefined kilogram. 6) Ensure the 10-yearly repeat of (sub-)multiple and 50 kg KCs (2024). 7) Coordinate with RMOs to ensure the effective use of KCs and minimization of (non-linked) SCs. 8) Support NMIs in continuation with, or initiation of, realization experiments and to look for additional areas, where the redefinition of the kilogram can have wider impact for end users (2024).

Following the two presentations, the President explained that the former working group on mass standards was split a few years ago into the two groups CCM-WGR-kg and CCM-WGD-kg in order to share the workload during the preparations for the new definition of the kilogram. Now that this work had been completed, it would be natural to merge the two working groups again into a new working group on mass, CCM-WGM. He also reported that the CCEM in March 2019 had closed two working groups related to the redefinition of the SI, namely the CCEM Working Group on Electrical Methods to Monitor the Stability of the Kilogram (CCEM-WGKG) and the CCEM Working Group on Proposed Modification to the SI (CCEM-WGSI). It had been agreed with the President of the CCEM to welcome all interested members of the CCEM to join the new CCM-WGM.

Acknowledgments to resigning Chairs

Following the presentation of the working groups, the president took the opportunity to thank the resigning chairs: Dr Germak (CCM-WGG), Dr Wright (CCM-WGFF), and Dr Bettin (CCM-WGR-kg), who had all given significant contributions within their respective fields of work. The resigning chairs (John Wright in absentia) were each presented with a small gift from the CCM.

6. REPORT OF THE CCM TASK GROUP ON THE PHASES FOR THE DISSEMINATION OF THE KILOGRAM FOLLOWING REDEFINITION

The report from the CCM Task Group on the Phases for the Dissemination of the Kilogram following redefinition (CCM-TGPfD-kg) was presented by its chair Dr Davidson.

Dr Davidson explained that the dissemination of the kilogram after 20 May 2019 would take place in three consecutive phases: 1) Present traceability to the IPK (taking into account the additional 10 µg uncertainty in the IPK coming from the new definition). 2) Dissemination of the consensus value of mass. 3) Dissemination of individual realizations of the mass unit. This presentation would give a summary, but all details could be found in the 'CCM detailed note on the dissemination process after the redefinition of the kilogram' often referred to as the 'extended note',

The following Terms of Reference given to the Task Group was presented: Based on "the *mise en pratique* of the definition of the kilogram" and on "the CCM short note on the dissemination process after the proposed redefinition of the kilogram" the task group will: 1) Ensure the correct implementation of the present traceability across the period of the redefinition of the kilogram. 2) Propose a detailed calculation of the consensus value and its uncertainty and oversee the transition from the "present traceability" to the use of the consensus value and ultimately to individual realizations. 3) Propose methods to maintain the best possible stability of the consensus value over time (including comparison periodicity). 4) Propose clear criteria for moving from the consensus value dissemination phase to the individual realization dissemination phase. 5) Maintain a detailed document describing the three dissemination phases for the CCM and the mass community. This document shall include the calculation of the consensus value, its uncertainty and time scale as well as any other relevant information related to the dissemination of the kilogram. 6) Provide advice to the CCM-WGD-kg and CCM-WGR-kg in all questions regarding traceability of the kilogram during the first two phases above.

The members of the group were presented: Dr Davidson (NPL), Dr Bettin (PTB), Dr Medina (CEM), Dr Nielsen (DFM), Dr Steele (NRC), Dr de Mirandés (BIPM), Dr Stock (BIPM), Dr Fang (BIPM) and Dr Richard (METAS).

Two TG meetings had been held since the last meeting of the CCM: one in July 2018 and one in January 2019.

Dr Davidson presented a table defining the phases 0-3. Phase 0 ends on 20 May 2019. During this phase traceability goes to the International Prototype of the kilogram (IPK) having a mass of 1 kg with zero uncertainty. Phase 1 starts on 20 May 2019. In this phase, traceability still goes to the IPK having a mass of 1 kg but with a standard uncertainty of 10 µg inherited from the final determination of the Planck constant (which will then have zero uncertainty). Phase 2 starts when the first KC on the realizations of the kilogram has been completed and the first consensus value has been calculated. Phase three starts when consistency among realizations has been reached at a satisfactory level of uncertainty. In this phase, traceability to the SI will be established by individual NMIs realizing the kilogram from the fixed value of the Planck constant (and of other constants defining the SI) having zero uncertainty.

Dr Davison summarized the progress of the task group in the following way: 1) A method for calculation of the consensus value to be assigned to a BIPM working standard had been agreed. 2) The standard uncertainty to be assigned to the consensus value had also been agreed. 3) The conditions necessary for moving from phase 2 to phase 3 had been agreed. 4) A draft 'CCM detailed note on the phases for the dissemination of the dissemination of the kilogram following redefinition' had been produced. 5) The first KC on realizations of the kilogram had been agreed.

Dr Davidson explained how the consensus value approach would work: The consensus value was required to be consistent with the IPK, linked to all available realization experiments, stable in time and easy to access for dissemination. Ultimately, it will be based on the average of the Key Comparison Reference Values (KCRVs) of the last three biannual KCs on the realizations of the kilogram. Initially the IPK and the result of the Pilot Study on the Realizations of the Kilogram will be used as substitutes for KCRVs. The KCs will be piloted by the BIPM, and the consensus value will be maintained and disseminated by the BIPM using its Pt-Ir working standards. The BIPM will continue to provide calibration of mass standards for the NMIs, but traceability will switch from the IPK to the consensus value following the completion of the first KC on the realization of the kilogram. It was proposed that the standard uncertainty assigned to the consensus value should be 20 µg as agreed in the task group. Dr Davidson pointed out that the temporary use of a consensus value was driven by the need to address the observed inconsistencies in the realization experiments and not by a desire to reduce the uncertainty by averaging over realizations. The proposed value of 20 µg is 1) the typical uncertainty of "mature" realization experiments such as those at NIST, NMIJ, NRC and PTB, 2) the target uncertainty of newer realization experiments, which are predicted to be completed in the next ten years, 3) setting the expectations on future uncertainties from individual realization experiments (Phase 3) at the beginning of Phase 2, and 4) the target uncertainty that the CCM had established in the past to proceed with the redefinition of the kilogram.

As a criteria for the transition to the use of individual realization experiments (Phase 3), Dr Davidson proposed that a) there should be a minimum of five independent realization experiments with relative uncertainties of 40×10^{-9} or better that have demonstrated mutual consistency in at least two consecutive KCs on the realization of the kilogram, b) at least two of the realization experiments meeting the above criteria should have relative standard uncertainties less than 20×10^{-9}, c) the consistent set of experiments must include two independent methods of realizing the SI unit of mass (for example Kibble balance and X-ray crystal density experiments), and d) the relative difference between the consensus value for the kilogram (determined from three last Key Comparison results) and the KCRV for the final key comparison should be less than 5×10^{-9}.

The President thanked Dr Davidson for his presentation and asked if the members had any clarification questions.

Dr Härtig asked if the IPK would be used in Phase 1 and the beginning of Phase 2. Dr Stock replied that traceability to the IPK will be taken from the BIPM Pt-Ir standards and not directly from the IPK itself. The IPK will be kept in its safe, but it might be taken out in about ten years from now in order to determine its mass on the BIPM Kibble balance.

Dr Peruzzi asked what would happen if the criteria d) for the transition to individual realizations were not fulfilled. Dr Davidson replied that criteria d) was included in order to avoid discontinuities larger than 5 µg in the kilogram versus time, so Phase 2 would have to continue until the criteria had been met.

Mr Loayza pointed out that the public might be confused when we say that traceability in Phase 1 goes to the IPK and not to the Planck constant. Dr Davidson replied that we had to be careful to explain in the public domain that in Phase 1 traceability to the Planck constant goes via the IPK.

Dr Robinson asked for a mechanism for handling of outliers in the KCs on which the consensus value would be based. Dr Davidson replied that methods for identifying and handling of outliers were publicly available, but that no specific method had been selected yet by the task group.

Dr Malengo asked how changes in the consensus values should be handled by NMIs traceable to the consensus value. Should an NMI correct the value of its reference standard when the consensus value is changed after a realization KC, even if the standard of the NMI had not been recalibrated after the change? If not, should the uncertainty be enlarged? Dr Davidson replied that the change in the consensus value as a result of a realization KC was expected to be small compared to the uncertainty assigned to the consensus value but if not, the task group would consider how the situation should be handled.

Dr Malengo pointed out that the large uncertainty in the consensus value would lead to a high covariance between mass measurements at different NMIs, which would have no influence on the results of KCs on calibration of mass standards. He suggested that the covariance should not be included in the CMCs but be reported separately. Dr Davidson replied that the covariance had to be taken into account when analyzing the results of KCs on calibration of mass standards but the uncertainty of the consensus value should be included in CMCs and reported measurement uncertainties. Dr Steele added that the covariance was only relevant for the calculation of the uncertainty of a difference in mass between two mass standards. For the dissemination of mass from a single reference standard to another standard, the uncertainty of the consensus value needed to be included in the measurement uncertainty.

Dr Borys noted that the term ‘consistent’ was used in the criteria for moving from Phase 2 to Phase 3 and asked, if it would be meaningful to define what is meant by ‘consistent results’. Dr Davidson replied that the term should be understood in the same way as in the usual analysis of key comparisons and that a more specific definition was not advisable at this stage. This view was supported by Dr Nielsen, who said that the task group would deal with any problems in judging consistency as they occurred.

Dr Kubarych highlighted the necessity to inform clients about the increase in uncertainty in mass calibrations during the first two phases. Clients had already heard about the 10 µg increase in uncertainty due to the change in definition, but the 20 µg increase from the start of phase 2 was unknown before the release of the draft ‘extended note’ and had therefore not been communicated to clients. Dr Kubarych stressed the importance of NMIs telling the same story to clients. Dr Davidson agreed, but noted that it was as difficult to tell the same story in short as in full.

Regarding the criteria for the transition to Phase 3, Dr Fujii said that it was important to test the consistency among realizations made by Kibble balances on one side and the X-Ray Crystal Density method on the other side. Dr Davidson replied that consistency among all results would imply that.

Mr Massa found that the uncertainties specified in criteria a) for transition to Phase 3 were a little pessimistic compared to what has been achieved already. Dr Davidson said that the uncertainties of 40 µg were specified in order not to discourage NMIs to start realization experiments. He also noted that apparently no NMI had planned to realize the kilogram with the same low relative uncertainty as had been obtained for the measurement of the Planck constant.

Dr Robinson noted that since Kibble balance experiments were thought to be independent, a group of NMIs each realizing the kilogram could combine their realizations to an average realization with a reduced uncertainty. Dr Steele opposed this idea of averaging, and encouraged NMIs to disseminate the mass unit from their own, independent realization, just as it has been practiced for other SI units.

The President summarized the discussion by asking for two changes to the document 'CCM detailed note on the dissemination process after the redefinition of the kilogram':1) On page 1, a basic statement of the fact that traceability would change from the mass of IPK to the value of Planck constant as of 20 May 2019, and 2) In Table 1, the content of column 'Description' would be changed so that it would be clear that in the Phases 1 – 3 traceability is to the value of the Planck constant *via* the IPK, the consensus value, and individual realization experiments, respectively.

7. TECHNICAL WORK AT THE BIPM AND PROGRAMME OF WORK OF THE BIPM

The first and general part of the presentation was given by Dr Stock.

Dr Stock presented an overview of the BIPM activities, which were divided into three groups. The first group, 'Ongoing activities' included mass calibrations (including measurement of volume/density and centre of gravity) of Pt-Ir and stainless steel mass standards as well as provision of 1 kg Pt-Ir prototypes to Member States. The second group, 'Preparations for the new SI', included the extraordinary calibrations with respect to the IPK completed in 2014, the CCM pilot comparison of kilogram realizations completed in 2016, the ongoing development of a Kibble balance for future realization of the kilogram, and finally the creation of an ensemble of 1 kg mass standards to facilitate the dissemination of the redefined kilogram and to be used in the ongoing key comparison. The final group of activities, 'Future tasks', included the organization of key comparisons on the realizations of the kilogram and the determination of the consensus value to ensure uniform dissemination of the kilogram following redefinition.

Dr Stock presented the key staff working in the mass area: Dr Fang, Dr Bielsa, Dr Li, and Mr Kiss are working on the Kibble balance experiment, Dr de Mirandés is working on the Ensemble of Reference Mass Standards (ERMS), and Mr Da Silva Conceição is performing the calibration of mass standards.

Since 2016, the BIPM had delivered three Pt-Ir prototypes: no. 110 to NIM, China (2016), no. 111 to KRISS, Republic of Korea (2017), and no. 107 for NPSL, Pakistan (2018). Fabrication of Pt-Ir prototype no. 112 had been completed and the fabrication of an additional three Pt-Ir prototypes (nos. 113-115) was under way. Since 1889, BIPM had delivered a total of 111 Pt-Ir prototypes to 44 NMIs and to the BIPM.

A graph showing the number of calibrations performed by the BIPM in the period 2001 – 2018 was presented. On average, five Pt-Ir prototypes and ten stainless steel standards had been calibrated annually, but in 2015, immediately after the Extraordinary Calibration of the BIPM Pt-Ir prototypes and NMI prototypes that contributed to the redefinition, the number of calibrations peaked with the calibration of 27 Pt-Ir prototypes and 14 stainless steel standards.

Dr Stock presented the hierarchy of BIPM Pt-Ir working standards, which were introduced in 2015 in order to ensure the dissemination of a stable mass unit traceable to the mass of the IPK. A graph showing the change in mass of the six Pt-Ir prototypes for current use (nos. 42', 63, 77, 88, 97, 103) relative to the three Pt-Ir prototypes for limited use (nos. 9, 31, 650) indicated that all prototypes for current use had lost mass; the mass losses were in the range from 4 µg to 10 µg since March 2015. Preliminary results for the current masses of the six Pt-Ir prototypes for current use relative to the masses of the three Pt-Ir prototypes for exceptional use (nos. 25, 73, 91), which had not yet been cleaned and washed, seemed to confirm the results.

Dr Stock discussed the use of the ERMS. Until the completion of the Extraordinary Calibrations in 2015, the BIPM believed that the observed instability of the BIPM Pt-Ir standards was due to contamination. The ERMS was therefore set up with standards of three different materials (Pt-Ir, silicon, and stainless steel), stored in four different environments (ambient air, vacuum, nitrogen gas, argon gas). Analysis of the outcome of the Extraordinary Calibration showed that the drift in mass of the BIPM Pt-Ir standards was principally due to wear and not to contamination. This wear had been brought under control by the introduced hierarchy of BIPM Pt-Ir working standards. Furthermore, recent measurements of BIPM standards and national prototypes had shown that contamination rates are typically less than 1 µg/year. Considering the high cost of storage under inert gas and the additional handling required for standards stored under vacuum, the BIPM had therefore decided that all standards in the ERMS would be brought into air during 2019. The standards of the ERMS, which were compared with the IPK in 2014 and with the realization experiments included in the pilot study in 2016, should be included into the weighing scheme of the planned key comparison on realizations of the kilogram in order to provide a solid link between these comparisons; the ERMS would not be used in-between the key comparisons.

Dr Stock presented the impact of the kilogram redefinition on past and future BIPM calibrations. NMIs using BIPM certificates issued before 20 May 2019 would have to add (in quadrature) an additional standard uncertainty of 10 µg to the standard uncertainty reported in the certificate. This additional uncertainty should be propagated to mass certificates issued by NMIs and if necessary, CMCs should be updated. After 20 May 2019 (in Phase 1), certificates issued by the BIPM would include the additional 10 µg, and as soon as the first KC on realization of the kilogram has been completed (i.e. in Phase 2), the standard uncertainty reported in BIPM certificates would be dominated by the 20 µg standard uncertainty assigned to the ‘consensus value’ determined from the KC results.

Dr Stock proposed a technical protocol for the first KC on the realization of the kilogram. As criteria for participation, it was proposed that a participant should be able realize the kilogram with a relative standard uncertainty not larger than 2×10^{-7}, corresponding to 200 µg. This uncertainty should be documented in a peer reviewed journal. As measurand for the KC, the mass of a 1 kg standard measured in vacuum was proposed. The standard should be provided by the participant. The participant should be able to document the stability during a vacuum-air-vacuum transfer of the provided standard. Dr Stock proposed that each participant should provide two 1 kg transfer standards. It is also possible to provide only one standard, at the risk that the comparison uncertainty for this NMI will be compromised in the (unlikely) case of a significant mass change of the standard during transportation. One of them should be a Pt-Ir standard (if available); the type of the second standard (for example Pt-Ir, stainless steel, Si-sphere) could be chosen by the participant. The following timetable for the KC was proposed: The technical protocol should be completed by July 2019, the measurement of transfer standards at NMIs using realization experiment should be completed by October 2019, measurements at the BIPM should be completed by January 2019, checking the stability of the transfer standards should be completed by the NMIs by Feb 2020, Draft A of the KC should be completed by April 2020, and Draft B by May 2020. Dr Stock proposed that a small steering support group should be set up for the comparison; Dr Davidson and Dr Nielsen had accepted to form such a group, should the proposal be agreed by the CCM.

A survey amongst NMIs with realization experiments had shown that five NMIs (NIST, PTB, NRC, NIM, KRISS) and the BIPM would be ready to start the KC in September-October 2019; two NMIs (LNE, NMIJ) would be ready in January-February 2020; two NMIs (METAS, UME) might be ready to start in September-October 2019 depending on their progress; and one NMI (NPL) would be ready to start by the end of 2020.

Dr Stock opened the discussion on the proposed technical protocol. Dr Kuramoto, NMIJ, wished to postpone the deadline for the NMIs to measure the masses of their selected transfer standards until February 2020. This wish was shared by representatives from LNE and METAS. Dr Steele said that he would prefer to retain the schedule as proposed by Dr Stock. Even if a delay of four months were accepted, the three NMIs in question might not be ready to take part after all, in which case the additional time given would have been wasted for nothing. He added that in any case, the Draft A should be ready in April 2020. He also claimed that the contributions to the key comparison reference value from the three NMIs would be rather small due to the relatively large target uncertainties for their realizations.

Dr Fang presented progress on the BIPM Kibble balance. The design of the BIPM Kibble balance was described. The weighing cell of the balance is kept static, and the vertical motion of the coil in the field from a permanent magnetic circuit is controlled by a motor inside a refined suspension carrying the coil. A new three axis interferometer had been installed to measure the motion of the coil. The following additional improvements of the Kibble balance were listed by Dr Fang: 1) A programmable Josephson junction voltage standard (PJVS) had been installed for the measurement of voltage. 2) A new current source containing two sets of batteries had been introduced enabling continuous measurements. 3) An additional interferometer that improved the servo control of the vertical displacement of the coil had been integrated. 4) Additional optical sensors for monitoring the six degrees of freedom of the coil assembly had been integrated. 5) The programs for controlling the operation of the Kibble balance and for data acquisition had been completely revised and successfully tested.

Dr Fang presented results for the measurement of the Planck constant using the BIPM Kibble balance in the period 2018-2019. The improvements in the design had reduced the type A measurement uncertainty by a factor of two giving a combined relative standard uncertainty of about 8×10^{-8}; however, this value still needs to be confirmed.

Dr Fang reported the outlook for the work with the BIPM Kibble balance: 1) Publication of a realization of the kilogram with a relative standard uncertainty of 8×10^{-8}. 2) Participation in the first KC on the realization of the kilogram. 3) Development of a new motor and guiding system for the vertical coil movement. 4) Achieving a relative target uncertainty of 2×10^{-8} by further improvements. 5) Participation in subsequent KCs on the realization of the kilogram.

8. REVISED SI (SI BROCHURE, IMPLEMENTATION DATE, COMMUNICATION)

Dr de Mirandés reported on the work of the CCU in relation to the revision of the SI.

A final draft of the 9th edition of the SI Brochure had been completed. The draft had been translated into French and was currently under external validation. A final draft Concise Summary of the SI Brochure had been completed and translated into French. Appendix 1 of the SI Brochure, ‘Decisions of the CGPM and the CIPM’ had been updated to incorporate 1) recent CIPM recommendations and decisions, 2) recent CGPM decisions including those taken in November 2018, 3) references to CIPM *Procès Verbaux* and *Metrologia* publications, and 4) side notes on abrogation of previous definitions. This appendix had also been translated into French. A final draft of Appendix 3 of the SI Brochure ‘Units for photochemical and photo-biological quantities’ had been agreed with the CCPR. This document’s translation into French had been completed. All the documents mentioned had been made available in the form of drafts on the BIPM open website on 6 February 2019. The final versions of the documents would come into force on World Metrology Day, 20 May 2019.

Dr de Mirandés reported that a CIPM Task Group for the promotion of the SI had been set up. This Task Group had developed promotional material on the new SI, including 1) a Brand Book, which was updated in April 2018 and sent to NMIs, 2) a press pack, which was updated in May 2018 and sent to NMIs to launch the campaign, and 3) speaking notes and key messages. A BIPM public webpage containing the material had been set up.

Following a question from Dr Robinson, Dr de Mirandés confirmed that the SI Brochure would also be available in print.

9. POSSIBLE RECOMMENDATION OF THE CCM TO THE CIPM

The CCM had no recommendations to the CIPM at this meeting.

10. UPDATES FROM JCRB AND KCDB

10.1 Update from the JCRB

The update on the JCRB was presented by Dr Bergstrand, Executive Secretary of the JCRB.

Dr Sten Bergstrand reported that a total of 27 sets of CMCs had been published in the KCDB in the period March 2018 – February 2019 covering the time between the 39th and 40th meetings of the JCRB. In the same period, 19 sets of CMCs had been submitted in the field of mass; 13 of those sets had been published in the KCDB. Currently, 17 sets of CMCs were under review in the field of mass.

Since 2010, between 7 and 16 sets of CMCs had been submitted in the field of mass. The average processing time for a submission was 190 days.

Dr Bergstrand recalled that according to the rules laid down in document CIPM MRA-D-04, CMCs could be increased without intra-RMO review and inter-RMO review. CMCs that needed to be increased as a consequence of the redefinition of the kilogram could therefore be easily processed.

10.2 Update from the KCDB (KCDB 2.0)

This update was presented by Dr Picard, KCDB Coordinator.

Dr Picard presented the BIPM key comparison database (KCDB) version 2.0, which would replace the current version 1.0 implemented in 2000 following the establishment of the CIPM MRA in 1999. The new version would combine the two current databases holding CMCs and key comparison data, respectively. One of the important features of the new version was that no documents needed to be circulated during the review of CMCs.

Information on the use of KCDB 2.0 would be provided in the form of video clips, a user manual, demonstrations, and perhaps a web seminar.

11. REVIEW OF WORKING GROUP TERMS OF REFERENCE, MEMBERSHIP AND CHAIRS

The following CCM WG chairs and vice-chairs were confirmed by the CCM:

	CCM-WGDV	**CCM-WGFF**
Chair	Yoshitaka Fujita (NMIJ)	Bodo Mickan (PTB)
Vice-chair	Kenichi Fujii (NMIJ)	Chunhui Li (NIM)

	CCM-WGFT	**CCM-WGG**
Chair	Rolf Kumme (PTB)	WU Shuqing (NIM)
Vice-chair	Andy Knott (NPL)	Vojtech Pálinkáš (VUGTK)

	CCM-WGH	**CCM-WGPV**
Chair	Samuel R. Low (NIST)	Karl Jousten (PTB)
Vice-chair	Febo Menelao (PTB)	Jorge Torres (CENAM)

	CCM-WGM	**CCM-WGS**
Chair	Stuart Davidson (NPL)	Philippe Richard (METAS)
Vice-chair	Richard Green (NRC)	

12. TECHNICAL PRESENTATIONS OF INMETRO AND OF IPQ (POTENTIAL NEW CCM MEMBERS)

12.1 INMETRO

Mr Victor Loayza presented the activities at INMETRO (Brazil) in the field of mass and related quantities. He described the organizational structure of INMETRO and the activities in the four relevant laboratories: Mass Laboratory, Force Laboratory, Pressure Laboratory and Fluids Laboratory.

The activities in the mass laboratory included dissemination of mass from Pt-Ir prototype no. 66, measurement of volume of weights by hydrostatic weighing, surface characterization of stainless steel using X-ray diffraction, measurement of magnetic fields in mass comparators, manufacture and characterization of sub-milligram mass standards, development of a simple Kibble balance, and development of an acoustic volumeter.

The activities of the Pressure Laboratory included calibration pressure measurement equipment using pressure balances and a vacuum gauge calibration system, and calibration of mass flowmeters in the range 3 kg/h – 120 kg/h using a differential pressure measurement standard.

The activities in the Force Laboratory included measurement of force in the range 10 kN – 1.1 MN, measurement of torque in the range 20 N m – 3000 N m, certification of Brinell, Rockwell and Vickers hardness reference blocks, and verification of hardness diamond indenters. The research activities included measurement of dynamic force and torque, development of a micro force standard machine, development a low capacity static torque machine; development Vickers hardness reference blocks; and development of Charpy impact test reference materials.

The activities of the Fluids Laboratory included calibration of anemometers in wind tunnels, measurement of gas flow and liquid flow, calibration of volumetric glassware and the measurement of density, viscosity and surface tension of liquids.

Before inviting questions, the President noted that INMETRO and IPQ were both official observers already, but had applied for membership of the CCM.

Dr Steele asked for more information about the Kibble balance being developed at INMETRO. Mr Loayza explained that it was a demonstration of principle having a relative uncertainty of 1×10^{-3}.

Dr Fung asked about the nominal mass to be realized in the Kibble balance. Mr Loayza replied that the nominal mass was 100 g.

12.2 IPQ

Mrs Isabel Spohr presented the activities at IPQ (Portugal) in the field of mass and related quantities, which were carried out in five laboratories: Mass and Solid Density Laboratory, Force Laboratory, Pressure Laboratory, Volume and Flow Laboratory, and Laboratory of Liquid Properties.

The activities in the Mass and Solid Density Laboratory included dissemination of mass from Pt-Ir prototype no. 69 and measurement of solid density by hydrostatic weighing. IPQ had joined the NPL Kibble balance project and had participated in the 1 kg key comparison EURAMET.M.M-K4.2015 and the 500 kg supplementary comparison EURAMET.M.M-S7.

The activities in the Force Laboratory included calibration of force transducers using two dead weight force machines with capacity 50 N – 5 kN, respectively 1 kN – 100 kN and dead weight force machines with lever amplification covering the range 10 kN – 1 MN. With this equipment, IPQ had participated in the three key comparisons EUROMET.M.F-K1, EUROMET.M.F-K2, and EUROMET.M.F-K3.

The activities in the Pressure Laboratory included calibration of equipment for the measurement of gauge pressure in the range 40 kPa – 100 MPa using two pressure balances as reference and calibration equipment for the measurement of absolute or gauge pressure in the range 3.5 kPa – 170 kPa using a pressure balance in a vacuum enclosure. IPQ had participated in the key comparison EURAMET.M.P-K8 and the supplementary comparison EURAMET.M.P-S9.

The activities of the Volume and Flow Laboratory included calibration of volumetric standards in the range 1 µL – 10 000 L, the measurement of micro-flow in the range 0.12 ml/h – 600 ml/h, and the development of a photometric method for calibration of micropipettes. IPQ coordinated the EMPIR Project 18HLT08 ‘Metrology for Drug Delivery’ (MEDDII) and had coordinated the development and revision of EURAMET Calibration Guide No. 19 ‘Guidelines on the Determination of Uncertainty in Gravimetric Volume Calibration’. IPQ had also delivered training on the calibration of micropipettes to NIM, China, in 2013. IPQ had participated in eight comparisons in the fields of volume and flow; in six of them IPQ was the coordinator.

The activities in the Laboratory of Properties of Liquids included measurement of liquid density using hydrostatic weighing and oscillation-type density meters, as well as measurement of viscosity and surface tension. IPQ had participated in nine comparisons in the field and was a partner in the EMPIR project 17RPT-02 ‘Establishing traceability for liquid density measurements’ (rhoLiq).

Since 2011, IPQ had participated in two EMRP projects and five EMPIR projects. The President asked, if IPQ were involved in other research than that funded by EMPIR. Dr Spohr replied that the research of IPQ was limited to EMPIR projects or cooperation projects with academia.

13. TECHNICAL TALKS ON NEW ACTIVITIES IN THE FIELD OF MASS AND RELATED QUANTITIES

The technical workshop was chaired by Dr Steele. The following talks were given:

Dr Schlamminger: ‘The revised SI: Challenges and opportunities for mass and related quantities’.

Dr Robinson: ‘The Kibble balance: measuring mass and related quantities in the revised SI.’

Dr Pálinkáš: ‘Gravity measurements supporting Kibble balances’.

Dr Bettin: ‘Silicon spheres for the realization of the new kilogram definition.’

Dr Fujii: ‘Realization of small mass, force and torque measurements based on the new definition of the kilogram’.

Dr Stambaugh: ‘The NIST Magnetic Suspension Mass Comparator for Vacuum-to-Air Transfer of the Unit of Mass: Current Status’.

Dr Davidson: ‘Real-time contamination monitoring on mass standards stored in inert gas’.

Dr Jousten: ‘Traceable desorption and outgassing rate measurements’.

14. REVIEW OF ACTION ITEMS AND DEADLINES

On request of the working group chairs, the CCM approved 1) the protocol of the key comparison CCM.P-K4.2012.1, where two CDG and two RG manometers will be calibrated by NIST using optical techniques and an Ultrasonic Interferometer Manometer (UIM) and by PTB using series expansion systems, 2) the new simplified services categories proposed for fluid flow, and 3) the creation of a small task group consisting of Dr Davison (NPL) and Mr Zelenka (BEV), which was given the task to update CMCs in the field of mass standards after redefinition (Phase 1).

The CCM approved the ‘CCM detailed note on the dissemination process after the redefinition of the kilogram’ prepared by the CCM TGPfD-kg with the following editorial changes: 1) On page 1, a basic statement of the fact that traceability would change from the mass of IPK to the value of Planck constant as of 20 May 2019. 2) In Table 1, the content of the column with the heading ‘Description’ would be changed so that it would be clear that in the Phases 1 – 3 traceability is to the value of the Planck constant *via* IPK, the consensus value, and individual realization experiments, respectively.

The CCM approved the updated list of WG chairs and vice-chairs presented under item 11 on the agenda and appointed them for the next period.

The CCM took note of the BIPM ‘Note on the impact of the redefinition of the kilogram on BIPM mass calibration uncertainties’.

The CCM decided that the measurement period for the first key comparison on the realization of the kilogram should be September 2019 to April 2020, and that Draft A should be ready in April 2020.

15. NEXT MEETING AND ANY OTHER BUSINESS.

The 18th meeting of the CCM was scheduled for 17-21 May 2021.

ADJOURN

The President thanked the participants for their contributions and closed the meeting.