Bureau International des Poids et Mesures

Consultative Committee for Length (CCL)

Report of the 17th meeting
(14 – 15 June 2018)
to the International Committee for Weights and Measures

Comité international des poids et mesures

LIST OF MEMBERS OF THE CONSULTATIVE COMMITTEE FOR LENGTH

as of 14 June 2018

President

Dr I.A. Castelazo, Member of the International Committee for Weights and Measures, Centro Nacional de Metrología, Querétaro, Mexico.

Executive Secretary

Dr G. Panfilo, International Bureau of Weights and Measures [BIPM], Sèvres.

Members

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

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

Centro Español de Metrología [CEM], Madrid.

Centro Nacional de Metrología [CENAM], Querétaro.

Conservatoire national des arts et métiers/Institut National de Métrologie [LNE-Cnam], La Plaine-Saint-Denis.

Czech Metrology Institute/Český Metrologický Institut [CMI], Brno.

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

Federal Office of Metrology/Office Fédéral de Métrologie [METAS], Bern-Wabern.

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

Istituto Nazionale di Ricerca Metrologica [INRIM], Turin.

JILA [JILA], Boulder.

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

National Institute of Metrology [NIM], Beijing.

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

National Measurement Institute, Australia [NMIA], Lindfield.

National Metrology Institute of Japan, Advanced Institute of Science and Technology [NMIJ/AIST], Tsukuba.

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

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

National Physical Laboratory [NPL], Teddington.

National Research Council of Canada - Measurement Science and Standards Portfolio [NRC], Ottawa.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

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

VSL [VSL], Delft.

VTT Technical Research Centre of Finland Ltd, Centre for Metrology/Mittatekniikan keskus [MIKES], Espoo.

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

Observers

Industrial Technology Research Institute/Center for Measurement Standards [CMS/ITRI], Hsinchu.

Instituto Português da Qualidade [IPQ], Caparica.

1 WELCOME BY THE DIRECTOR OF THE BIPM, DR MILTON

The Consultative Committee for Length (CCL) held its 17th meeting at the International Bureau of Weights and Measures (BIPM), Sèvres, on Thursday 14 and Friday 15 June 2018.

The following delegates were present:

M. Abe (NMIJ/AIST), M. Aşar (UME), P. Balling (CMI), A. Balsamo (INRIM), Y. Bitou (NMIJ/AIST), S. Bize (LNE-SYRTE), H. Bosse (PTB), I. Castelazo (CCL President), V. Coleman (NMIA), R. Dixson (NIST), B. Eves (NRC), R. Fira (SMU), W.-E. Fu (CMS/ITRI), P. Gill (NPL), A. Hirai (NMIJ/AIST), F. Hungwe (NMISA), J. Jin (KRISS), N. Kononova (VNIIM), R. Koops (VSL), P. Křen (CMI), O. Kruger (NMISA), A. Lassila (MIKES), Y. LeCoq (LNE-SYRTE), A. Lewis (NPL), M. Matus (BEV), M.Milton (BIPM Director), A. Moskalev (VNIIM), J. C. V. de Oliviera (INMETRO), J.-J. Park (KRISS), E. Prieto (CEM), J.-A. Salgado (LNE-LCM), F. Saraiva (IPQ), D. Sawyer (NIST), H. Schnatz (PTB), J. Stone (NIST), J. Stoup (NIST), T. Takatsuji (NMIJ/AIST), R. Thalmann (METAS), M. Viliesid (CENAM), J.P. Wallerand (LNE-Cnam), Y. Wang (NIM), and S. Yu (NMC, A*STAR)

Representatives from Member States invited to attend as Observers: N. Alqahtani (SASO-NMCC), D. Czulek (GUM), V.H. Gil (INM Colombia), K. Madanipour (ISIRI), O. Terra (NIS).

Guests: M. AlSenaidi (EMI), K. Bastida (INTI), S. Bize (LNE-SYRTE), J. Buajarern (NIMT), O. Kostrikov (NSC IM), J. Stone (NIST).

CIPM members: L. Erard (CCTF President) and B. Inglis (CIPM President).

Also present: E. de Mirandés (BIPM), G. Panfilo (Executive Secretary of the CCL, BIPM), S. Picard (KCDB Executive Secretary, BIPM), P. Tavella (BIPM), N. Zviagin (JCRB Executive Secretary).

Excused: S. Gao (NIM), D. Sendogdu (UME), M. Zucco (INRIM).

2 INTRODUCTION BY THE PRESIDENT OF THE CCL

Dr Castelazo, President of the CCL, welcomed the participants to the 17th meeting of the CCL and thanked Dr Milton, Director of the BIPM. Dr Milton welcomed Dr Castelazo as the new CCL President and Dr Panfilo, new Executive Secretary of the CCL.

Dr Panfilo gave some housekeeping information. Dr Castelazo requested the participants to introduce themselves.

3 APPOINTMENT OF THE RAPPORTEUR

Dr Lewis was appointed as Rapporteur after being proposed by Dr Castelazo.

4 APPROVAL OF THE AGENDA

Dr Castelazo tabled the agenda. No other business was tabled. The agenda was approved by the attendees with no changes or additions.

5 REPORT ON ACTIONS ARISING FROM THE SEPTEMBER 2015 CCL MEETING

Dr Castelazo presented the action list from the previous meeting of the CCL together with the updated status, as reported in the following table.

No	Action	Status
A.1	Dr Stone would write a document describing the realization of the metre to be included in the SI brochure.	Completed
A.2	The WGFS will undertake necessary actions to include the ^{87}Rb d/f crossover saturated absorption at 780 nm D_2 line in the LoR at its next update.	Completed
A.3	The WGFS will undertake necessary actions to include, with 50 kHz (10^{-10}) uncertainty, the $^{127}I_2$ saturated absorption at 531 nm in the LoR at its next update.	Completed
A.4	Dr Herrmann will ask Dr Baker to clarify the point regarding simplification of the CMCs in the KCDB for the topic of surface metrology.	Completed
A.5	Dr Lan will forward information on CMS-ITRI's involvement in APMP and the level of performance in comparisons to the CCL Executive Secretary (Dr Robertsson).	Completed
A.6	Dr Inguscio to report on the situation of both candidates for CCL membership to the CIPM.	Completed
A.7	Dr Lan and Dr Alqahtani to complete the documentation required for their applications for membership of the CCL	Completed

The actions were approved. There were no outstanding actions.

6 OUTCOMES OF MEETINGS:

106th meeting of the CIPM

Dr Castelazo informed the delegates that he had attended two of the three days of the last CIPM meeting before travelling to be able to present the key items from that meeting at the WG-MRA meeting in Finland. He described the key decisions from the 106th CIPM meeting.

The CIPM will submit a proposal to the General Conference on Weights and Measures (CGPM) to allow the CIPM to exclude Members of the Metre Convention after they are six years in arrears with their contributions. Currently, the CIPM is required to try to arrange a rescheduling agreement with defaulting Member States and wait until the next CGPM, which may eventually decide on exclusion. This can result in an unnecessary increase of the Member State's debt.

The CIPM's Pension Advisory Board reached an agreement with the BIPM's employees to bring the pension fund to a sustainable level. It is contingent on a new actuarial study that will be carried out in 2019.

The BIPM will propose a flat budget to the 26th CGPM meeting for the period 2020-2023, except for extra contributions and subscriptions from new Member States and Associates acceding to the BIPM. This will complete seven years without an increase. It is expected that an increase due to inflation and for new investment will be necessary at the next CGPM.

In order to further emphasize the consultative nature of the Consultative Committees and the importance of the consensus-based decision-making processes, Document CIPM-D-01 should be updated so as not to make any reference to voting taking place in Consultative Committees.

Associate States whose 'UN scale' is less than 0.02 will no longer be encouraged to become Member States after 5 years, however they can still become Member States voluntarily at any time if they wish. Associates meeting the criterion and which are paying increased contributions will have their contributions reduced to the minimum in 2018. Reductions will not be retroactive.

Each RMO will be invited to send one or two reports to the next meeting of the CC Presidents to be held on 19-20 June 2018.

The CIPM requested the CCM to provide a note on the dissemination process for the kilogram after its redefinition, addressing in particular the consensus value and an updated *Mise en Pratique*. The CIPM noted that the agreed conditions for the redefinition have now been met and decided to submit Draft Resolution A to the 26th meeting of the CGPM and to undertake all other necessary steps to proceed with the planned redefinition of the kilogram, ampere, kelvin and mole.

The CIPM approved the edited version of the 9th edition of the SI Brochure, as approved by the CCU. It had been changed by adding the preface on "The BIPM and the Metre Convention" used in the 8th edition of the SI Brochure, correcting the number of Member States and Associate States/Economies, and deleting the former Appendix 1 on "The Metre Convention and its Organs".

The CIPM had welcomed the excellent progress on the promotion of the revised SI by the CIPM Task Group for Promotion of the SI and encouraged all NMIs to take advantage of the material they develop.

The CIPM decided that the *Mises en Pratique* prepared by the Consultative Committees for each of the base units should be presented in a common format, to be developed by the BIPM editing team. The CCL was following this approach.

In order to be informed of technical developments and evolving stakeholder needs in different areas of metrology, the CIPM has Consultative Committees with agreed scopes and the following three objectives:

- 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,
- 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
- to demonstrate and improve the global comparability of measurements. Particularly by working with the RMOs in the context of the CIPM MRA.

The CIPM will decide the status of whether an international organization is a “liaison” within the context of the Consultative Committees on the extent to which they meet criteria that includes: being international in structure and scope of activity; concerned in matters of the field of activity of the BIPM; allowing voting rights; and having been established at least three years before they apply for liaison status. Organizations that are not offered liaison status within the context of the Consultative Committees will be known as “organizations in cooperation”.

7 CURRENT STATUS OF THE REDEFINITION OF THE SI

Dr de Mirandés presented the current situation and recent steps towards the revision of the SI. The CCM/CCU roadmap was shown. All of the necessary steps had been concluded and it was now up to the relevant committees to make final approvals.

The special 2017 CODATA adjustment was triggered initially by Resolution 1 of 24th CGPM in 2011 which requested the initial work of CODATA and then by Decision CIPM/104-9 (2015) which requested a special adjustment of the data. The Planck constant data had required an expansion factor of 1.7 on the submitted uncertainties in order for the data to be consistent. It will be the consensus value that is disseminated by the NMIs, not their own individual value(s). For the Boltzmann constant, the data was already in good agreement. The four universal constants h, e, k, and N_A now had final values and relative standard uncertainties and after the new SI is in place, the uncertainties will be removed. The current fixed values *e.g.* mass of the IPK, will continue with their current values but taking on the necessary uncertainties to ensure consistency of the present system with that of the revised SI.

CIPM 106-10 decision in October 2017 laid the final path to the resolutions to be set before the 26th CGPM meeting in 2018 in order to have the new SI ready for implementation on 20 May 2019. Dr de Mirandés presented the text of Draft Resolution A for the 26th CGPM meeting.

The draft of the 9th edition of the SI Brochure is in its final stage. It will include the *var* and *gal*, but requests for the inclusion of more non-SI units are being rejected. The CCQM and IUPAC have agreed a new definition of the mole. All the draft documents (brochure, resolution and concise summary) can be found on the BIPM website.

The CIPM Task Group for the promotion of the SI, chaired by president of the CCU, Prof. Ullrich, started a campaign for promotion of the new SI on 20 May 2018, which will end on 20 May 2019. The webpage www.bipm.org/en/si-download-area contains many freely downloadable resources for promotion of the new SI.

The 26th meeting of the CGPM will be held on 13-16 November 2018, at Versailles, where the final decision on the new SI will be made.

8 REPORT FROM THE CCL WORKING GROUP ON DIMENSIONAL NANOMETROLOGY (CCL-WG-N)

Dr Dixson, one of the co-chairs of WG-N gave the presentation. He recalled the six meetings of WG-N held so far, which had experimented with using tele-conferencing: the majority were however conventional meetings. The WG-N Terms of Reference had been prepared in 2009 and were edited and approved at the 2012 CCL meeting.

Discussion Group 7 (DG7) for Nanometrology of the CCL/WGDM decided to perform a comparison for five different types of artefacts among interested NMIs, which had then become the pilot studies within WG-N.

- Photomask Linewidth (NANO1) Pilot: PTB/NIST, Planned 2019
- Step Heights (NANO2) Pilot: PTB, Completed 2003
- Linescales (NANO3) Pilot: PTB, Completed 2003
- 1D Gratings (NANO4) Pilot: OFMET, Completed 2001
- 2D Gratings (NANO5) Pilot: DFM, Completed 2008

Subsequent Proposals for comparisons had included AFM silicon Linewidth (NANO6) piloted by NIST for which the artefact circulation was now complete.

The following pilot studies and RMO supplementary comparisons had been discussed:

- Photomasks: Nano1 planned2019
- Silicon wafer: Nano6 circulation complete
- Nanoparticles: APMP.L-S5 almost complete

A recent NIST-PTB bilateral comparison had shown good results, published as *Meas. Sci. Technol*. **28** 065010 (2017), though there may be some issues with drifting of standards.

Regarding the NANO6 comparison, (Silicon Linewidth using AFM), the overall status is that the circulation loop was completed in 2017 and the sample is back at NIST. Follow up check measurements are due to be performed by the pilot. The draft report is expected in late 2018. Dr Dixson commented that this comparison is a pilot study – not intended for the KCDB. There had been sample damage and changes of target during circulation. Due to logistics, the total time

of the study had become very extended (~ 6 years). Some participants had undergone significant capability changes during this timeframe.

There had been a discussion within the two recent WG-N meetings about the *Mise en Pratique* for the metre and realization of the SI metre in a manner applicable for dimensional nanometrology. This has been a topic of interest within WG-N since 2012. Three specific examples for traceability and length scale realization for dimensional nanometrology have been considered, for which detailed guidance documents are under development:

(1) Calibration of lattice-resolving TEM on crystalline silicon nanostructures by reference to the Si lattice parameter. (NIST and PTB project; WG-N guidance document).
(2) Step height standards based on lattice constant. (PTB project).
(3) X-ray interferometry for micro/nano displacement metrology. (NPL/PTB COXI).

The needs of dimensional metrology to demonstrate traceability to the SI at the nanometre scale are already approaching the limits of resolution available from the existing methods defined in the *Mise en Pratique* of the definition of the metre. (Traditional metrology techniques involving displacement interferometry are viewed as top-down at the nanoscale).

Nano-scale manufacturing is following predictions made in the 1980s in terms of the accuracy levels demanded in future decades and that these now require manufacturing capability at the nanometre or sub-nanometre scale for which the traceability infrastructure is not fully available.

There is a risk that industry and science, working at the nanometre scale, may look to non-SI traceability routes if there is no suitable traceability infrastructure in place to fulfil their needs: it was cautioned that this is already happening. For example, if metrology had followed the well-known Moore's Law, we would routinely be able to calibrate small structures to better than 0.2 nm by now – this is not the case.

Dr Dixson then described the recent WG-N discussions on each of the three above techniques.

Regarding traceability to the SI through Si Lattice: NIST and PTB both have interest in establishing the SI traceability of lattice-resolving TEM measurements of crystalline silicon nanostructures. Such structures are used in dimensional nanometrology, for example the calibration of CD-AFM tip width. The two NMIs worked together to develop a guidance document within WG-N. This was completed and has been available on the BIPM/WG-N website since 2016. In summary:

(1) WG-N believes that TEM (full field and scanning) is an important measurement technology for dimensional nanometrology.

(2) If appropriate practices are followed, TEM may be made traceable to the SI metre through reference to the silicon lattice.

(3) Prior studies illustrate important limitations of TEM. However, these issues are more limiting for film thickness than for structural metrology.

(4) WG-N regards the localized metrology of nano-structures as residing within the CCL and a proper subject for the *Mise en Pratique*.

For Traceability to the SI through the Si lattice using TEM, the PTB is interested in promoting the acceptance of silicon atomic lattice step height standards as sources of traceability at the nanometre scale. NIST also supports this direction. In summary:

(1) WG-N believes that lattice-based step height standards are a potentially valuable resource for dimensional nanometrology.

(2) If appropriate sample preparation practices are followed, silicon step height standards may be traceable to the SI metre through reference to the silicon lattice.

(3) WG-N regards the development of such standards as within the CCL space, and supports the explicit inclusion of a traceability pathway based on the silicon lattice within the *Mise en Pratique.*

Underpinning the above two traceability discussions is traceability to the SI through Si Lattice using X-ray Interferometry (XRI). The NPL, PTB and INRIM have developed X-ray interferometry for displacement metrology at the micro/nano scale and could now achieve significantly sub-nm resolution and accuracy. The NMIs worked together to develop a guidance document within WG-N. A draft is available on the BIPM/WG-N website. In summary:

(1) WG-N believes that XRI, is an important measurement technology with applications in dimensional nanometrology.

(2) If appropriate practices are followed, dimensional measurements with XRI may be made traceable to the SI metre through reference to the silicon lattice.

(3) WG-N has a responsibility to promote good measurement practice and SI traceability in dimensional nanometrology and thus proposes, after further development of this document, to issue a (CCL) recommendation.

Dr Dixson gave information on the conference and standards activities within WG-N.

WG-N received a report about ongoing activities in ISO/TC229 and IEC/TC113, which were concerned with “Nanotechnology”.

Recent Conferences included: SPIE Advanced Lithography; Frontiers of Characterization and Metrology for Nanoelectronics; BAM-PTB Workshop 2018 on reference nanomaterials and Nanoscale 2019.

The CCL strategy document developed by WG-S in 2012 is due for revision/updating and has been reviewed by the WG-N co-chairs and circulated among the WG-N membership.

The terms of both co-chairs of WG-N were ending and WG-N officially nominated Dr Andrew Yacoot (NPL) for consideration by the CCL as the next chair of WG-N.

Dr Dixson presented the current text of a Recommendation for the CCL from WG-N and invited discussion. The text of the Recommendation was discussed under agenda item 18.

The **CCL Working Group on Dimensional Nanometrology** (CCL/WG-N).

Under its Terms of Reference, given by CCL and

considering:

- that the needs of dimensional metrology to demonstrate traceability to the SI at the nanometre scale are already approaching the limits of resolution available from the existing methods defined in the *Mise en Pratique* of the definition of the metre;
- that nano-scale manufacturing is following predictions made in the 1980s in terms of the accuracy levels demanded in future decades and that these are now requiring manufacturing capability at the nanometre or sub-nanometre scale for which the traceability infrastructure is not fully available;
- that there is an increased risk that industry and science, working at the nanometre scale, may look to non-SI traceability routes if there is no suitable traceability infrastructure in place to fulfil their needs;

and **taking into account**

- recent work, preparing for the forthcoming revision of the SI, has resulted in an agreed CODATA value for the Si {220} lattice spacing, d_{220} = 192.015 571 4 10^{-12} m, which is available with a standard uncertainty of 0.000 003 2 10^{-12} m,

recommends that:

- member laboratories of the CCL increase their efforts towards making the Si {220} lattice spacing an available standard for use in providing traceability to the SI metre for dimensional nanometrology applications in the broader sense;
- the CCL prepares the necessary documentation and evidence for the future consideration of the Si {220} lattice spacing as a candidate for entry into the *Mise en Pratique* of the definition of the metre, for applications in dimensional nanometrology.

Dr Milton asked if WG-N wanted to state a definite range of lengths over which this possible metre realization, based on the Si lattice, may be applicable. He asked if the isotopic purity of the Si was a concern. Dr Dixson, Dr Lewis and Dr Prieto responded that the details would be part of the documentation that the resolution was asking the CCL to prepare. Three documents (one relating to each of the mentioned methods of using the Si lattice) were already in preparation and would include the necessary details, cautions and practicalities to achieve the best accuracy. The documents would also state the range over which the techniques could be used and the uncertainty that is achievable.

Dr Balsamo asked who had the final authority to issue the revised *Mise en Pratique* that was being worked on at the moment. Dr Castelazo commented that it was up to the WG-N to decide if it was technically ready to recommend this, then the CCL would give its approval; if WG-N thought the technology and data were ready, it should ask for approval directly.

Dr Dixson added that the WG-N was already satisfied with these aspects and therefore wished to request approval from CCL at the present meeting. He would add the necessary text to the final Recommendation to be tabled under agenda item 18. Dr Milton welcomed the new version of the *Mise en Pratique* that was being prepared because, for some time, no official *Mise en Pratique*

for the metre had been available on the BIPM website. He commended the CCL in preparing such a document that was following the same format of the documents being prepared in other Consultative Committees.

The meeting broke for coffee and the official photograph.

9 REPORT FROM THE CCL WORKING GROUP ON THE CIPM MRA (CCL-WG-MRA)

Dr Balsamo, chairman of the WG-MRA presented the report.

He started with the Terms of Reference where the previous CCL had agreed a minor change to the Terms. The WG is no longer 'coordinating' but instead 'monitoring' the review of existing CMCs in the context of new results of key and supplementary comparisons'. He showed the current structure diagram for the CCL and its Working Groups, Discussion Groups and Task Group. A change of officials had taken place with Dr Balsamo replacing Dr Lewis as WG-MRA chair and Dr Panfilo replacing Dr Robertsson, who had retired, as CCL Executive Secretary. The majority of the WG-MRA membership was *ex officio*. A systematic review of membership will be undertaken at the next meeting. The meetings are usually held annually due to the workload and typically followed a three-year cycle based around the CCL year. In non-CCL years the WG-MRA tends to meet at major conferences, usually MacroScale and NanoScale. Since the last CCL meeting, the WG-MRA had met three times, WG-MRA-7 in October 2016 at the VSL, Delft (the Netherlands); WG-MRA-8 in October 2017 at VTT/MIKES, Espoo (Finland); and WG-MRA-9 in in June 2018 at the BIPM.

The next meetings are already being planned: WG-MRA-10, 17-18 October 2019 at the PTB, Braunschweig (Germany); WG-MRA-11 likely to be in South Africa in September 2020; and WG-MRA-12 in 2021, at the BIPM.

Meeting topics include: KC/SC reports and agreeing the reporting timescales; KC/SC planning (GD4) and monitoring; CMC foresight – anticipating workload; Corrective actions after comparison reports; collating a list of 'bad' results; asking RMO TC-L to review annually; escalating any non-action to RMO TC-Q; asking for an annual statement from each RMO TC-L; Updates to CMC categories ('DimVIM') and translations; Introduction of a new "flexible" 1D CMC; Linking of KCs – TG-Linking recommendations; Updates from the JCRB and CIPM. One highlighted achievement was that the CMC category list, the DimVIM was now available in 14 languages.

Between meetings, the work focuses on: KC and SC progress (technical protocols, evaluation and discussion of Final Reports, approval of reports, equivalence tables, Executive Reports); Detailed 'peer review' of comparison reports by at least two reviewers, including (sometimes) significant editing before submission to *Metrologia Technical Supplement* or approval by the WG-MRA; Discussion on linking issues and techniques (TG-L); CMC review (RMOs, monitored by sWG-CMCs); CMC corrective actions (RMO TC-L chairs); Technical discussions in DGs; Updates to Guidance Documents.

The Key Comparison Scheme (GD-02) that had been agreed some years ago was shown. The choice of comparison format is based on the number of participants world-wide that would need to take part. The particularities of the dimensional comparisons had caused some problems in working out linking schemes but TG-Linking had now prepared some guidance, resulting in the proposal of three linking schemes as follows.

(1) Numerical: this is mostly not suitable for dimensional KCs and has not been applied so far.

(2) Visual (common graph): different KCRVs in different KCs. Linkage is achieved when the (2-3) linking NMIs achieve consistent results in either KC.

(3) Distributed: the KCRVs of different loops are influenced by each other through the linking NMIs; possible only for parallel loops (*e.g.* in a same KC), as modifying the results of an already finalized KC would create confusion.

Dr Balsamo reported that 46 comparisons had been 'active' in the last 3 years and was pleased to see that the new RMO GULFMET was now running comparisons. Responding to the formal request to review the need for new comparisons at CCL meetings, the CCL WG-MRA confirmed that the current portfolio of KCs 1 to 11 is complete to fulfil the CIPM MRA requirements for length. The CCL WG-MRA does not recommend that the CCL add new KCs to the portfolio in the coming years.

The change of WG-MRA chair had triggered updates to the allocation of duties. To reflect this, the Task descriptions of the sWGs have been reviewed and the new ones are submitted for the CCL's approval. The proposed new Task description of the sWG-KC and of sWG-CMC will be the subjects of WG-MRA recommendations 1 and 2, to the CCL.

The WG had prepared an extensive range of guidance documents to help comparison pilots.

- GD01 Running of length comparisons and monitoring CMC impact
- GD02 CCL comparison scheme
- GD03 Preparation of KC reports
- GD03.1 Technical protocol template
- GD03.2 Comparison report template
- GD03.2a Bilateral Comparison report template
- GD03.3 Executive report template
- GD04 KC planning tool (frequently updated)
- GD05 Formatting CMC entries and their inter-RMO review
- GD06 CMCs of category Standards of 1D point-to-point dimensions(*)

*(GD06 was prepared in cooperation with the DG6)

These will be made available on the open access CCL website. The current version of GD04 was examined. It helps organize and plan the key comparisons to ensure a maximum 10 year periodicity between participations for member laboratories which need to support CMCs in the relevant categories.

A systematic review of the full body of GD documents every 5 years has been agreed: this will start soon.

The CMCs of category '1. Radiation of the *Mise en Pratique*' were renamed to eliminate the unnecessary highlight given to the stabilized laser of the *Mise en Pratique*. The change is being handled by a significant update, which is under way. This will affect 80 current CMC entries of 46 countries, for which the main transition is under way. Minor edits will then follow.

Coordinate Measuring Machines are capable of measuring standards of virtually any geometry; a "flexible" CMC would be beneficial to the NMIs, and reduce their burden. Unfortunately, the uncertainty would vary considerably with the measurement task, and capturing them all in a single CMC is impossible. The most pronounced flexibility, still with the due rigour, is for 1D measurands, lying on a single straight line in space. The CMCs according to the DimVIM are categorized by standards, while this is instead a measurand. A new "placeholder standard" has been introduced. Confusion and misuse might arise for the coexistence of conventional and flexible CMCs, possibly at the same NMI. To help this out, a Guidance document (GD-06) has been prepared by the CCL Discussion Group 6 and approved by the CCL WG-MRA. The document was tabled for this CCL meeting. This document (GD-06) has been submitted to the CCL for final approval.

As described earlier, TG-Linking had proposed and detailed three linking schemes for comparisons. A full visual linkage of recent K8 (surface texture) comparisons has been accomplished. This will also serve as a template for linking other Key Comparisons. A full linkage of the very extensive K1 (gauge blocks) comparison topic has been decided upon, due by the next meeting. This will help identify possible issues not considered so far.

Length CMCs are currently registered in the KCDB as numerical equations, such as:

$$u = \mathrm{Q}[49,\ 0.083L] \text{ nm, with } L \text{ in millimetres,}$$

which is a shorthand format which means

$$u = \sqrt{49^2 + (0.083L)^2} \text{ nm, with } L \text{ in millimetres.}$$

Unfortunately, this format is usually not used in publications nor in accreditation bodies, so the CMCs are not compliant with the approach used by accreditors. There is now a proposal, based around the possibility offered by KCDB 2.0, to move to quantity equations, such as:

$$u = \mathrm{Q}[49 \text{ nm},\ 83 \times 10^{-9}\ L]$$

or

$$u = \sqrt{(49 \text{ nm})^2 + (83 \times 10^{-9} L)^2}$$

This had formerly been proposed, even though it had not been technically feasible. The forthcoming KCDB 2.0 opens the opportunity to use this format. The workload of making the change falls almost totally to the NMIs with equation-based CMCs; these are mostly in length (~850), mass (~400) and some in chemistry. Lobbying is under way with the CCM. Even for PTB and METAS, which have the most numerical equations, modifying it would only take a few hours.

Dr Thalmann iterated that ILAC requires this format to be used by all accredited laboratories and CCL laboratories should set an example. Dr Prieto added that this new formatting is fully in line with the formatting that is to be used within the new SI.

Dr Milton said that this should be on the agenda for the CC Presidents' meeting. Dr Inglis recommended preparing a few examples before that meeting.

The proposal is reiterated as WG-MRA Recommendation 4.

Recommendations from the Working Group on the Implementation and Operation of the CIPM MRA/CCL Implication

Dr Balsamo tabled the four Recommendations to the CCL from WG-MRA.

Recommendation WG-MRA 1 (2018)

The CCL WG-MRA,

having carefully revised the Task description of its sWG KC,

recommends

that the CCL amends it as follows:

- to coordinate, supervise and support the administrative process of the pilot laboratories in conducting key comparisons;
- to prepare and maintain guidance documents and templates ready to use for the pilot laboratories;
- to examine all relevant documents for each key comparison, starting with the protocol and ending with the Draft B report;
- to advise the pilot laboratory in preparing the text of the entry to Appendix B of the CIPM MRA as required, including the calculation of degrees of equivalence and linking, and to prepare a recommendation on these subjects for approval by the CCL, and
- to prepare guidance documents on identifying significant deviations for use by the pilot laboratories.

Recommendation WG-MRA 2 (2018)

The CCL WG-MRA,

having carefully revised the Task Description of its sWG-CMC,

recommends

that the CCL amends it as follows:

- to establish and maintain lists of service categories (DimVIM) and, where necessary, rules for the preparation of CMC entries (DimVIM Guide);
- to agree on detailed technical review criteria;
- to coordinate and, where possible, conduct inter-regional reviews of CMCs submitted by RMOs for posting in Appendix C of the CIPM MRA;
- to provide guidance on the range of CMCs supported by particular key comparisons;
- to identify areas where additional key and supplementary comparisons are needed;
- to monitor the review of existing CMCs in the context of new results of key and supplementary comparisons, and

- to monitor and enforce the corrective actions resulting from key and supplementary comparisons, in cooperation with the RMO's concerned.

Recommendation WGMRA 3 (2018)

The CCL WG-MRA,

taking account that

- the same equipment may be used for calibrating different standards with similar uncertainty, a typical example being a CMM used to calibrate standards whose measurands lay on a single straight line;
- the CCL Length Service Classification (DimVIM) is organized by standards, and the use of the abovementioned equipment would require duplicated CMCs;

and **considering** that

- the NMIs should be encouraged to keep the number of their CMCs to the minimum necessary, and duplication should be avoided;
- a flexible CMC "Standards of 1D point-to-point dimensions" would be beneficial to this end;
- the coexistence of conventional and flexible CMC's might create confusion,

recommends

- that the CCL approves the guidance document CCL-GD-06, which clarifies the extent of the flexibility and resolves the overlapping between conventional and flexible CMCs.

Recommendation WGMRA 4 (2018)

The CCL WG-MRA,

considering that

- the CMCs for length currently registered in the KCDB are in the form of numerical equations;
- the preferred way for expressing equations in science and accreditation is by quantity equations instead;
- the CCL made a proposal to update the CMCs in length to make them expressed in quantity equations (Decision CCL 5 2012);
- the KCDB is currently under structural revision, to become the so called KCDB 2.0,

recommends

- that the CCL asks the KCDB manager to do whatever possible to format the CMCs in length as quantity equations.

Dr Castelazo invited comments or questions. Dr Takatsuji asked regarding the difference between KC and SC as he saw that GULFMET.L-S2 was in fact a Key Comparison topic. Dr Lewis said that the situation had changed since the comparison had started and in fact this was a key comparison topic which was now incorrectly labelled as a supplementary comparison. Dr Milton confirmed that the type of comparison is based on the measurand and not the participation.

Dr Picard recalled that the 'Flexible CMC' is called 'Broad Scope' in other committees – she recommended harmonizing terminology if this is the case.

10 KCDB 2.0

Dr Picard reminded the meeting of the 20-year-old process that had resulted in the KCDB and its evolution. The background to the need for the revision to the KCDB was given. The opportunity was taken to improve the functionality of the KCDB and the CMC review process. Four key requirements were agreed: web-based CMC submission and review; better search facilities; tracking of comparisons; and user-friendly web support. The renewal triggered a complete overhaul of the database and environment. Legacy data will be uploaded to the new system. The use of Excel sheets for managing CMCs will be abrogated in favour of a web platform process supporting submission, intra- and inter-RMO reviews. There will be a possibility for a risk-based evaluation, *e.g.* sort on uncertainties and review the smallest uncertainties; a user may also choose to split a batch of CMCs into smaller subsets, with each reviewed by one or more RMOs, each performing a partial review. CMCs will be submitted one by one (no batches) – CMCs with no comments will be approved automatically.

There will be links to DoEs or to comparison reports in the KCDB. Supporting evidence for the CMC should be mandated before review. Intra-RMO comments will be visible for JCRB review, and then deleted.

A 'free word sort' will be available, sorting and filter refinement; search by year of approval or status; there will also be the possibility to make a numerical search or filter on measurands.

Statistical tools with pre-programmed graphs will be available as well as access to statistics on review performance. Data can be presented in block text format and also in tabular format.

At present, the mock up and user interface are being prepared. The target date for implementation is 2019.

Regarding the CCL's entries in the KCDB, there are some specific questions. These were being handled through discussion within WG-MRA.

11 REPORT FROM THE CCL WORKING GROUP ON STRATEGIC PLANNING (CCL-WG-S)

There was no specific report from WG-S but its chairman, Dr Castelazo, indicated that the majority of the work under way recently within the WG-S was concerned with two key documents; the CCL Strategy Document and the new *Mise en Pratique* for the realization of the definition of the metre.

a. CCL Strategy document

Dr Castelazo presented the current draft version of the CCL Strategy Document, which was being edited within WG-S. Updates to the document included: revisions to administrative data, *e.g.* on numbers of comparisons; CMCs; and the new Terms of Reference (after approval later in this CCL meeting). There were some revisions to the document layout with duplicated information being removed and sections re-ordered.

b. Mise en pratique

Dr Lewis presented a short review of the current situation on the preparation of the new *Mise en Pratique* document for the metre. The template supplied by the CCL Executive Secretary had been filled out using the information shown on the BIPM website for the three existing methods of realizing the metre, together with two documents prepared previously within WG-MRA by Dr Stone (NIST) and Dr Schödel (PTB). These two documents had been prepared in response to the lack of a visible *Mise en Pratique* link on the BIPM website but the documents had been under discussion when the need to use the new template had arisen.

Dr Castelazo asked if the Si lattice should be included in the document. Dr Balsamo cautioned that this should only take place when the supporting documentation was ready. Dr Lewis responded that the Recommendation to the CCL would include the necessity to prepare the relevant document. Dr Dixson added that the documentation would be prepared in time.

12 REPORT FROM THE CCL-CCTF FREQUENCY STANDARDS WORKING GROUP (WGFS)

The CCL chairman of the FSWG, Dr Gill presented the report. He described the Terms of Reference of the WGFS. The WGFS had been formed in early 2000s by amalgamating the respective CCL and CCTF groups. Dr Riehle (PTB) and Dr Gill became the chairs. Dr Bize took over recently from Dr Riehle and Dr Gill was stepping down today. The CCL nominated Dr Matus (BEV) to take over from the CCL side of the joint working group. Dr Gill presented the new procedure for entry of values into the 'List of Frequencies', where formal discussion and approving of values in turn by both CCL and CCTF had been replaced by a process where the new data is discussed in detail at the sponsoring CC, with the other CC kept informed. Dr Gill showed a *précis* of the two CCTF recent Recommendations to CIPM.

Recommendation CCTF 1 (2017)

The Consultative Committee for Time and Frequency, **considering that**

- a list of Secondary Representations of the Second (SRS) has been maintained following the recommendations of the CIPM,
- different optical SRS have estimated fractional frequency uncertainties nearly two orders of magnitude lower than those of the best Cs primary standards,
- improvement in uncertainty associated with optical frequency standards is ongoing,
- a roadmap for a future redefinition of the second using optical frequency standards has been agreed upon by the CCTF;

recommends that

- the institutes put effort into operating their frequency standards to realize SRS in such a way that they routinely contribute to TAI via reporting to the BIPM,
- the optical standards be compared with uncertainties that are comparable to the estimated uncertainties of the standards themselves,
- the institutes measure the frequencies of the realizations of their SRS with the best primary caesium standards as a necessary requirement for a possible future redefinition of the second in terms of optical transitions,
- the relevant CCTF working groups finalize the milestones for a redefinition and the CIPM be regularly informed about progress towards meeting these milestones,
- the institutes measure the frequencies of the realizations of their SRS with respect to the best primary caesium standards as a necessary requirement for a possible future redefinition of the second in terms of optical transitions,
- the relevant CCTF working groups finalize the milestones for a redefinition and regularly inform the CIPM about the progress towards meeting these milestones.

Recommendation CCTF 2 (2017)

The CCTF, considering that

- a common list of "Recommended values of standard frequencies for realization of the metre and secondary representations of the second" has been established,
- the CCL-CCTF Frequency Standards Working Group (WGFS) has reviewed several candidates for updating the list,

recommends

that the following transition frequencies shall be updated in the list of recommended values of standard frequencies:

- $^{115}In^{+}$ ion $^{1}S_0 - {}^{3}P_0$: f = 1 267 402 452 901 050 Hz, $u_{rel\ std\ unc} = 1.6 \times 10^{-14}$
- ^{199}Hg atom $^{1}S_0 - {}^{3}P_0$: f = 1 128 575 290 808 154.4 Hz, $u_{rel\ std\ unc} = 5 \times 10^{-16}$ *
- $^{88}Sr^{+}$ ion $^{2}S_{1/2} - {}^{2}D_{5/2}$: f = 444 779 044 095 486.5 Hz, $u_{rel\ std\ unc} = 1.5 \times 10^{-15}$ *
- ^{88}Sr atom $^{1}S_0 - {}^{3}P_0$: f = 429 228 066 418 007.0 Hz, $u_{rel\ std\ unc} = 6 \times 10^{-16}$
- ^{87}Sr atom $^{1}S_0 - {}^{3}P_0$: f = 429 228 004 229 873.0 Hz, $u_{rel\ std\ unc} = 4 \times 10^{-16}$ *
- $^{40}Ca^{+}$ ion $^{2}S_{1/2} - {}^{2}D_{5/2}$: f = 411 042 129 776 399.8 Hz $u_{rel\ std\ unc} = 2.4 \times 10^{-15}$

- ^{171}Yb atom $^1S_0 - {}^3P_0$: f = 518 295 836 590 863.6 Hz, $u_{rel\ std\ unc} = 5 \times 10^{-16}$ *
- ^{87}Rb atom hyperfine: f = 6 834 682 610.904 312 6 Hz $u_{rel\ std\ unc} = 6 \times 10^{-16}$ *

and informs the CIPM accordingly.

Dr Gill presented detailed information on the strontium transition frequency values and how the precision of these measurements had improved over time.

At the 2018 FSWG meeting the main topic of discussion had been the CCL-K11 comparison, which is designed to provide a technical basis for the review of CMCs in the field of optical frequency/wavelength. After discussion, it was decided that the longer more detailed document would become a guidance document CCL-GD-08 and the newer protocol would become the official protocol for the K11 comparison. This was brought to the CCL in the form of a recommendation.

Recommendation CCL-CCTF-WGFS 1 (2018)

On the revision of the 2009 CCL-K11 protocol

Considering that

- in 2009, the CCL requested WGFS to take responsibility of key comparisons of standard frequencies such as CCL-K11
- a new draft protocol for CCL-K11 has been developed
- CCL-K11 is insufficient to validate all CMC claims of laser frequencies and vacuum wavelengths

The WGFS recommends that

- the CCL-K11 is developed further by the WGFS
- CCL delegates authority to WGFS to approve this protocol
- the guidance document CCL-GD-08 concerning alternative arrangements for reviewing CMCs in the laser frequency field is further developed and finalized by WGFS for CCL approval.

Dr Gill then mentioned the list of possible milestones identified by CCTF for a future optical redefinition of the second. Dr Castelazo asked for any comments or questions and there were none. Dr Castelazo asked the CCL to join him in thanking Dr Gill for his 25 years of service on the WGFS and its former structure.

13 REPORTS FROM THE DISCUSSION GROUPS

The Discussion Group (DG) moderators presented short reports from their respective DGs.

DG1 - Gauge blocks. The report presented by Dr Lewis was a brief summary of the tabled formal DG1 report to the CCL. A possible requirement to re-start the K2 comparison had been

mentioned – this will be discussed in DG 1 throughout year with a possible recommendation to WG 2019. Issues of ancillary influence quantities were highlighted, since for dimensional metrology, the influence of temperature is more critical than the laser length scale traceability, in terms of uncertainty. The possibility of example uncertainty budgets for comparisons had been discussed. A lack of laser tubes for the popular 543 nm He-Ne radiation had been highlighted – several DG1 member laboratories would try to work together to persuade a manufacturer to produce further laser tubes.

Dr Lewis recommended an Open Access paper from his temperature colleague, Dr de Podesta, which highlighted some issues in measuring air temperature:

'Air temperature sensors: dependence of radiative errors on sensor diameter in precision metrology and meteorology', de Podesta *et al. Metrologia* **55** 229-244 (2018)
DOI: 10.1088/1681-7575/aaaa52

DG2 - Thermal expansion coefficient. The report was presented by Dr Abe.

Dr Abe informed the meeting that despite the requirement from some industrial standards for a statement concerning CTE of reference artefacts, the majority of modern industry is quite happy with conventional values of CTE and the variation limit when gauge materials or similar are considered. There is less of a driving force toward dissemination of CTE calibration. Dilatometric length measurement is considered to be time consuming and time-periodical calibration of CTE is less meaningful. Three NMIs have published CMCs for short gauge block CTE measurement (BEV, JV, PTB), and three for long gauge block CTE (CMI, NPL, PTB).

Both the CTE value and the associated uncertainty have a significant impact on the economic balance in certain niche industries, *e.g.* Coordinate Measuring Systems. Currently, no urgent need has been recognized to initiate an international comparison but there will likely be future need, as smaller uncertainties are demanded. Dr Balsamo and Prof Lewis commented that it was surprising that the detailed CTE information was not widely desired. Several people commented that it should be kept in mind that this will likely be a future need and we should continue to make services available ready to meet this demand.

Dr Abe presented a possible problem coming from thermometry, where the new definition of the kelvin is expected to deviate from the ITS-90 by a few millikelvin at 20 °C, according to recent CCT documents. This would be significant for dimensional metrology.

Dr Balsamo commented that the CTE contribution to the uncertainty budget is one of the dominant issues; he was thus surprised at the lack of demand for calibration of CTE for dimensional artefacts. He recalled the 5 mK change in temperature at 20 °C when the ITS-90 was introduced.

Dr Lewis commented it would be necessary to check what temperature scale is specified in the relevant ISO documents (*e.g.* ISO 1) which refer to 20 °C – he thought that it was ITS-90, in which case there would not be a problem. However, on checking the standard, it was clear that the document did not specify the scale to be used. Dr Bosse added that recent information showed that the difference between ITS-90 and the kelvin is now regarded as being less than

1 mK. Dr Milton added that ITS-90 is still to be regarded as the main route to traceability. Only NMIs with the ability to utilize primary thermometers at the gallium point would notice the difference.

Dr Milton asked Dr Castelazo to raise the lack of clarity on communities coming from the CCT as a topic of interest from the CCL. Dr Castelazo would ask the CCT President to request the CCT to provide clear guidance on the issue. Dr Inglis mentioned that the CC Presidents' meeting would be the first opportunity to raise this. Dr Milton added that temperature measurement and the use of the correct scale should be included in the *Mise en Pratique* of the metre.

DG3 - Angle standards and equipment. The report was presented by Dr Kruger.

Over recent years the Key Comparisons focused on the use of optical polygons as artefacts, however there was a wider range of angle measurements in the DimVIM. Checking the KCDB revealed that 39 labs have taken part in polygon calibration comparisons, 19 have taken part in an autocollimator calibration and six are able to take part in a rotary encoder comparison to support CMC claims. However, there are technical issues with rotary encoders so the decision was that the next CCL-K3 will only use a polygon – the protocol for this comparison is based on the previous CCL-K3. The pilot has performed stability measurements on the artefact.

DG4 – Diameter standards. The report was presented by Dr Viliesid.

He informed the meeting that there were 18 members in the group but the membership was being revised. Dr Viliesid had taken over recently from Dr Stone who had retired. There had been four comparisons related to diameters. At the moment, the following comparisons are under way:

CCL-K4.2015 – Pilot Laboratory NIST. Circulation has finished, Draft A report expected from September 2018, Draft B report expected for mid-2019, Final report for late 2019.

EURAMET.L-K4.2005.1 – Pilot Laboratories VSL and SMD. Draft B report under way. Final report to be issued in late 2018.

EURAMET.L-K4.2015 – Pilot laboratory is INRIM. Two circulation loops, one of them completed, the other one to be finished shortly. Draft A expected before September 2018, Draft B expected for March 2019, Final report before the end of 2019.

No potential topics for discussion have been forwarded to the moderator at present. However, the moderator suggested the following topic to open the discussion: measurement of very small diameters, internal and external (under 0.2 mm by probing or other means); high accuracy dead-weight balance piston-cylinder diameter uncertainty requirements; non-contact high accuracy diameter measurement.

DG5 – Step gauges. The report was presented by Dr Prieto.

There are 19 members in the group. No new discussions have taken place since the last CCL/WG MRA meeting in 2017. He reported on recent and ongoing comparison activities.

Comparison APMP.L-K5.2006.1 had been registered at the KCDB on 22 August 2012, as a follow-up comparison of the previous APMP.L-K5.2006. Participants were NPLI (India) and

NMIJ (Japan). A commercial company supplied the circulated step gauge and participated in the comparison but their results were not included in the reports. The comparison ran from August 2012 to May 2013. The Draft A Report was submitted to the participants in September 2014 followed by Draft B1 circulated in October 2014. The Final approved version, Draft B3, was accepted in January 2017 and the Executive Report was prepared on 29 March 2018 and has recently been approved.

Comparison APMP.L-K5.2014 was registered in the KCDB on 24 February 2015. Participants are KRISS (Republic of Korea), the Pilot, NIM (China), NIMT (Thailand), NMIA (Australia) and Puslit KIM-LIPI (Indonesia). The comparison is finished and Draft B is under preparation.

A large comparison, EURAMET.L-K5.2016 is under way with 23 participants, piloted by Mr Coveney of NPL. The technical protocol had been prepared and presented at the 2015 CCL meeting. There are three participants from the SIM region (an additional participant from this region withdrew without making measurements) and one from the AFRIMET region, all with step gauge CMCs under the CIPM MRA. A single participant from GULFMET was added after the comparison began with the agreement of the other participants. This institute does not have a current CMC for step gauges. Four participants from APMP are acting as linking labs between EURAMET.L-K5.2016 and APMP-K5.2014. Additionally, a non-NMI participant was included at the request of the chair of EURAMET TC-L with the agreement of the other participants. Two artefacts (a 620 mm step gauge and a “new design” 1020 mm monolithic step gauge) are under circulation following two independent loops.

For the first time, a new type of step gauge with similar metrological dimensions to well-known existing step gauges is being circulated, but is machined from a single piece of ceramic to avoid the ‘slugs’ moving during shipping and a relatively low CTE (2.3×10^{-6} K^{-1}), much lower than common step gauges. It may thus be a better artefact for proving the lowest uncertainty CMCs. The circulation is under way and measurements are estimated to conclude in October 2018.

No potential topics for discussion had been communicated to the DG Moderator.

The meeting broke for coffee and resumed 30 minutes later.

DG6 – Coordinate metrology. The report was presented by Dr Balsamo.

This Discussion Group has 29 members. A significant recent topic of discussion was the 1D flexible (or generic) standard and measurand. Discussions had been completed; the new flexible CMC is included in the DimVIM, the related guidance document CCL-GD-06 was tabled for approval. The document was discussed.

A second topic of discussion was the opportunity to resume K6 on “true” coordinate standards. It would include how to support current CMCs, specifically for ball plates. The metre is defined in 1D, coordinate metrology is about 3D. Currently, no Key Comparisons are about 3D artefacts, following discontinuation of the previous K6 (2D) ball plate comparisons. The group is discussing if there is a need for a dedicated Key Comparison. The thinking was that ball plates

should no longer be used as they are expensive and not the best representative of real coordinate measurements. Discussions on the possible comparison considered topics such as discrete parameter (prismatic) versus free form standards; conventional (laboratory) range versus large volumes. Over the last few years, DG6 activity has been dedicated to preparation of the CCL-GD-06 document. Future discussions will focus on resuming a K6 comparison on 3D standards.

DG7 – Line Scales. The report was presented by Dr Bosse. The member list had changed and there were some new members in the discussion group, which now numbered 25 members.

The technical discussions undertaken in the period since the last CCL meeting in 2015, concentrated on the planning of a 2D grid plate comparison and the issue of optical size metrology of structures (bidirectional optical measurements). In addition, international comparisons for CIPM MRA purposes were prepared and organized.

There is no special conference that deals with the DG 7 issues only: at conferences such as 'Macroscale' in 2011, 2014 and 2017, some contributions on line scale related research work were presented and published. A scan of research papers showed a larger research effort being performed in metrology for lithography applications, including dimensional metrology. These lithography related topics are partly dealt with in the WG-N and not fully covered here.

Potential future discussion topics included the following.

1. Setting up an infrastructure for improved traceability chain for high precision optical size reference measurements on well-defined structures (for example photomasks) to optical CMM measurements on different types of measurement objects;
2. Extending the analysis of line scale comparisons with respect to condensed measurement results to be used for linking, where possible. An example of a condensed measurement result is the deviation from nominal length, determined over all measured line positions of a line scale;
3. Extending the measurement capabilities of high precision line scale comparators, for example determination of straightness or roundness deviations of features; standards with graduations calibrated for position and straightness may be valuable references for industrial 2D comparators as well as the recently developed 1.5D length encoder systems;
4. Calibration of length encoders in addition to classical line scales, maybe also using a length encoder system as a transfer standard for DG 7 comparison measurements;
5. Take into account the application of interferometers as well as graduated standards and scale-based measurement systems for calibration and position feedback purposes in measurement instrumentation as well as manufacturing equipment, for example lithography wafer scanners and machine tools, and analyse the requirements from these applications on calibration aspects of graduated scales at the NMI and accredited laboratory level;
6. Customers are asking frequently for line width and from edge-to-edge distances with line scale calibration. These would be useful for calibration of vision CMMs.

Results of measuring straightness using the PTB nano-comparator were shown.

DG8 – Surface Texture. The report, prepared by Dr Baker, was presented on his behalf by Dr Coleman.

Dr Coleman presented the list of 22 members. No technical discussions have been undertaken in the period since the last CCL meeting. Completed international comparisons included:

- APMP.L-K8 Final Report, *Metrologia Tech. Suppl*., 2013, **50**, 04003.
- SIM-EURAMET.L-K8.2009, *Metrologia* Tech. *Suppl.* 2016, 54**,** 04001.
- EURAMET.L-K8.2013, *Metrologia Tech. Suppl.*, 2015, **53**, 04001.
- COOMET.L-S13 (bilateral), 2015, *Metrologia Tech. Suppl*., 2015, **52**, 04012.

In terms of planning comparisons, there is likely to be a need for a comparison in at least APMP in 2019 and EURAMET would also start planning for 2020. Consideration can be made over which measurement techniques are allowed in any particular comparison where instrument ranges overlap. There is a suggestion for a pilot study to examine different methods (for example profilometry, AFM, optical microscopy, XCT, *etc.)* that have range overlap. There is a need for volunteer pilot and artefacts.

DG8 suggested discussion topics may include:

1. Upcoming comparisons for maintaining confidence in 2D parameter CMCs.
2. Linking APMP.L-K8 (2008), SIM-EURAMET.L-K8 (2009) and EURAMET.L-K8 (2013).
3. Application of Areal instruments (optical and stylus) and parameters.
4. Industry needs such as NMI level support for additive manufacturing.
5. Simplification of CMC listings for too many parameters.
6. Comparisons for supporting addition of 3D Areal parameters to KCDB (pilot study?).
7. XCT for surface texture measurements.

DG11 – Lasers. The report was presented by Dr Matus.

Current membership is 24; most are members of CCL but with a few CCTF members. The DG discusses recent research of relevance to the CCL relevant, informs the membership of events, and ideas for comparisons. Only a single key comparison is currently active: CCL-K11. All the results from 2009 to 2017 have now been published in *Metrologia Technical Supplement*, showing data from 39 participants. The workload is distributed over five node laboratories and one host laboratory (NIMT). The expected workload is four to five participations per year at each node laboratory. The technical protocol originated in 2008 and had required updating. It contains some carryovers from the former BIPM comparisons (conducted prior to the CIPM MRA): there was an ongoing ambiguity on the measurand / KCRV definition; organization of the document was not well adopted for the pilot's reporting needs; demand of some NMIs to include non-artefact-based methods (publications, assessment of working procedures; fibre link, …).

Clarification on actual the DimVIM service led to its modification. The Technical Protocol had been drafted strictly according to CCL guidance documents on running a KC, with the benefit that one obtains JCRB compatibility at the same time and the new document prevents ambiguities.

Preparation of the guidance document on CMC review in this field serves top-level NMIs where CCL-K11 is inappropriate – the document CCL GD-08 is being edited for approval by the CCL.

No discussion topics came up during the period reported, and the list of recommended frequencies serves the requirements of the CCL very well. More technical issues (for example multiwavelength interferometry) are handled in other DGs (namely DG1), but there is still a need for information on equipment sources and availability for anyone wanting to build a stabilized laser.

14 REGIONAL METROLOGY ORGANIZATIONS

Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB)

Dr Zviagin presented his report. He noted that several JCRB meetings had taken place since the last CCL meeting.

March 2016:	35th JCRB at the BIPM
September 2016:	36th JCRB held in Nairobi (Kenya)
March 2017:	37th JCRB at the BIPM
September 2017:	38th JCRB held in Bern (Switzerland)
March 2018:	39th JCRB at the BIPM – 3 day Meeting

Planned meetings were:

No meeting in September 2018 because of the 26th CGPM meeting.

March 2019:	40th JCRB at the BIPM
September 2019:	41st JCRB - offer to host from ESMA (Dubai)

Details of the Capacity Building and Knowledge Transfer Programme and its goals were presented. JCRB outcomes are available from the website:

http://www.bipm.org/jsp/en/JCRBOutcomes.jsp

A recent outcome from the JCRB with possible impact on the CCL was presented:

Resolution 38/1

> (Risk-based CMC Review and Representative CMCs): RMOs and CCs are encouraged to further implement a risk-based **approach** to review of CMCs and to develop statements for the levels of CMCs for which an intra-RMO review may be sufficient for the purposes of international acceptance.
>
> Taking note of the needs of NMIs and DIs at all levels, as a means towards implementation of recommendation 3b of the CIPM MRA review, the JCRB encourages Consultative Committees and the BIPM to continue to explore means to allow NMIs and DIs to publish CMCs in the KCDB for only their **smallest uncertainty capabilities** that are then used to support related services covered by their approved Quality System. Proposals are requested as to how to show the link between these capabilities and the “representative” CMCs.

RMOs are encouraged to propose additions to the Quality System review process to effect a fit-for-purpose review of these capabilities.

Extensive documentation on the CIPM MRA is available from the JCRB website: http://www.bipm.org/en/cipm-mra/documents/. There had been some changes to CIPM MRA-D-04 "Calibration and Measurement Capabilities in the context of the CIPM MRA" (approved at 37th JCRB Meeting). There were also changes to CIPM MRA-D-01 "Rules of procedure for the JCRB" (approved at 38th JCRB Meeting). Viewing of CMC reviews is possible using the website: http://www.bipm.org/JCRBCMCs/**.**

Some statistics on the Length CMCs were presented: there are 711 CMC sets of which 78 are related to length, totalling some 25 123 CMCs of which 1641 were from length. In terms of CMC review, it is usually the inter-regional review where the greatest delay occurs. CMC set COOMET.L12.2016 had been in review for more than 2 years. Silent comparisons in length were shown; one KC in COOMET (L-K3) and two SCs in AFRIMETS (L-S4, L-S5). Dr Zviagin commented that there is a new online JCRB directory and that the vacancy for the JCRB Executive Secretary has been posted on the BIPM website.

Report from the regional organizations

SIM

The report from SIM was presented by Dr Bastida, the SIM TC-L chair since 2016. She had attended the CBKT workshop at the BIPM. SIM had secured some research funding to start research activities.

The first new research topic was on Improvement and updating of interferometric systems for traceable dimensional nanometrology at SIM (Centro Nacional de Metrología, México-Instituto Nacional de Tecnología Industrial, Argentina - Instituto Nacional de Metrologia, Qualidade e Tecnologia, Brasil-Laboratorio Costarricense de Metrología, Costa Rica - Laboratorio Tecnológico del Uruguay). The first meeting was held in Brazil in December 2017, the second was held in Argentina in April 2018.

The second activity was on Large-scale dimensional metrology. (Centro Nacional de Metrología, México-Instituto Nacional de Tecnología Industrial, Argentina - Instituto Nacional de Metrologia, Qualidade e Tecnologia, Brasil - INACAL Instituto Nacional de Calidad, Perú - Laboratorio Custodio de Patrones Nacionales de Longitud de Chile). The first meeting was held in Argentina in April 2018,.

Third topic was on Calibration of standard reference material for use in calibrating the magnification or scale of optical microscopy and scanning electron microscopy (Centro Nacional de Metrología, México-Instituto Nacional de Tecnología Industrial, Argentina - Instituto Nacional de Metrologia, Qualidade e Tecnologia, Brasil - INACAL Instituto Nacional de Calidad, Perú). The first meeting was held in Argentina in April 2018.

The latest SIM TC-L meeting was held on 23 -27 April 2018 at INTI (Argentina). On 23-24 the workshop meeting discussed the projects: Large-scale dimensional metrology; Calibration of standard reference material for use in calibrating the magnification or scale of optical microscopy, scanning electron microscopy and photogrammetry; and improvement and updating of interferometric systems for traceable dimensional nanometrology at SIM.

AFRIMETS

The report from AFRIMETS was presented by Dr Kruger.

A characteristic of AFRIMETS was that only a few organizations had CMCs in the KCDB. Current comparisons in length are AFRIMETS.L-K1: Gauge blocks by interferometry; AFRIMETS.L-S1: end standards (gauge blocks) mechanical comparison. Planning has started for AFRIMETS.L-S7 on gauge blocks by mechanical comparison. The TC-L is supporting NMIs through comparisons but are also trying to support through additional training. The research support activities are currently centred on assistance on EDM calibration.

- TCL meeting 31 July 2017 – seven countries attended
- TCL meeting for 2018 is planned together with the Line scale comparison workshop planned, closing meeting.

APMP

The report from APMP was presented by Dr Buajerern.

APMP includes a total of 33 member economies. These comprised: 24 Members (22 with contact persons), nine Associate Members (six with contact persons). The TC-L chair is now Dr Buajarern NIMT (Thailand) with the vice-chair Dr Abe, NMIJ (Japan). APMP had completed 18 length comparisons, with four ongoing (all at Draft A) and there is one comparison being planned.

A total of 35 sets of CMCs had been created, but some had been abandoned and others were either undergoing the review process or waiting a designation.

The TC had five focus groups: energy efficiency, medical imaging, climate change, food safety, clean water.

The TC had an Initiative based on a proposal accepted in 2017, on a Pilot study on foil/film thickness comparison.

Dr Inglis recommended that the CCL WG-S take on board the initiative of the APMP focus groups and consider cross-disciplinary activities as part of the future strategy in terms of the future challenges.

COOMET

The report from COOMET was presented by Dr Kostrikov.

In terms of comparisons, there are five proposals, six in progress and seven completed, making 18 in total. The proposed comparisons are in: linescales, 2D standards for CMMs, long gauge blocks up to 1 m, two comparisons on short gauge blocks.

Projects in progress: rangefinder systems up to 2 or 3 km; GNSS/GLONASS; flatness standards up to 300 mm; sphericity; nanometric standards, length gauges.

Completed comparison projects were on: surface roughness parameters; length standards in the scale 0.01 mm to 1 mm; interferometric calibration of tapes up to 20 m; plane angle; flatness standards; gauge blocks by mechanical methods; involute gear measurements.

There are 21 members of COOMET with 300 published CMCs. Nine countries have no CMCs currently, but three countries are taking part in comparisons and will then be able to submit CMCs.

Dr Castelazo asked about the 'silent' K3 comparison. Dr Kostrikov believed that the delay was due to artefact issues. Dr Oliveira recommended ensuring that the internal COOMET project codes should also be joined with the external codes for example COOMET.L-SX for ease of recognition by non-COOMET members.

EURAMET

The report from **EURAMET** was presented by Dr Bosse. He talked about the length metrology areas of interest. Topics are dealt with in four roadmaps: advanced manufacturing; micro nano; large volume and long range; and enabling fundamental research. He reminded people of a CIRP keynote paper on the Contributions of Precision Engineering to the revision of the SI.

EURAMET was now in the middle of the EMPIR research programme. The schedule of calls for EMPIR research topics was shown. There had been a range of research projects of interest to TC-L:

Call 2014:

- Metrology for innovative nanoparticles (NPL)
- Metrology for highly-parallel manufacturing (NPL)
- Metrology for length-scale engineering of materials (NPL)
- Metrology for manufacturing 3D stacked integrated circuits (LNE)
- Metrology for the photonics industry (MIKES)

Call 2015:

- Metrology for additively manufactured medical implants (LNE)
- Traceable three-dimensional nanometrology (VTT)
- Reference algorithms and metrology on aspherical and freeform lenses (LNE)

Call 2017:

- Advanced Computed Tomography (PTB)
- Large Volume Metrology Applications (NPL)
- Multifunctional ultrafast microprobes for on-the-machine measurements (PTB)
- Improved traceability chain of nanoparticle size measurements (BAM)
- Standards for evaluation of the uncertainty of coordinate measurements in industry (INRIM)

Additional projects had started to prepare European Metrology Networks in the following topics:

Climate and Ocean Observation; Mathematics and Statistics; Quantum Technologies; Smart Electricity Grids; Traceability in Laboratory Medicine; and Energy gases. It is hoped that TC-L related networks will be prepared in follow-on calls.

TC-L currently has contact persons from 34 NMIs: four official observers with COOMET TC-L chair invited to attend. At the 2017 meeting held at VTT-MIKES there had been observers/guests from: South Africa, Saudi Arabia and Mexico. TC-L has no sub-committees, but three convenors for: EMPIR: preparation of TC-L for EMPIR Calls; coordination and information; Capacity building: training workshops, RPOT activities. CMC review is taken care of by the former TC-L chairperson.

Information was given on the recent and forthcoming TC-L meetings:

October 2017 at VTT-MIKES (Finland)

15-16 October 2018 at LNE (France)

14-15 October 2019 at PTB (Germany), in conjunction with the Nanoscale 2019 conference (15-16 October) and CCL WG-MRA and WG-N meetings (17-18 October).

GULFMET

The report from GULFMET was presented by Mr AlSenaidi. The RMO has seven members and had only been in existence for 4 years. There are two comparisons running (both supplementary), which are due to be completed by the end of 2018. Submission of the first sets of CMCs is foreseen for 2020. In addition to CIPM MRA work within the region, members participate in EURAMET TC-L and APMP TC-L.

15 CCL MEMBERSHIP AND MEMBERSHIP OF WORKING GROUPS

Dr Castelazo informed the meeting that there were two requests for Observer Status at the CCL, from GUM (Poland) and NIS (Egypt).

GUM (Poland)

Mr Czulek gave the presentation for GUM (Poland) and noted that GUM is celebrating its centenary in 2018. GUM (Central Office of Measures) operates under the ministry of entrepreneurship and technology. The metrology system in Poland is current undergoing a restructuring: GUM has ten laboratories and two administrative departments. The length department is organized into four sections: legal metrology, length, angle and geometry.

The Length laboratory has 35 measuring stations and 50 CMCs: its employees perform 3400 calibrations annually and it operates and maintains four national standards. The QS is maintained under ISO/IEC 17025:2005 and the standard PL EN 405011:2000. The length laboratory realizes the metre via an iodine stabilized laser and has an optical frequency synthesiser. It has taken part in eleven CIPM MRA comparisons including CCL-K11. The length laboratory has taken part in EMRP project IND53 on large volume metrology and in EURAMET project 1272 on phase correction of gauge blocks. Research results have been presented at nine conferences since 2009.

The Angle laboratory maintains the national angle standard based on a rotary encoder. It also operates a goniometer service and has a range of quartz plates for polarization rotation standardization. The laboratory took part in six comparisons and is running or has just concluded two EURAMET research projects. A list of publications from the angle section was presented.

The Geometry laboratory calibrates lines, dimeter, form, etc. and operates national standards for roundness and surface roughness. There is a line scale interferometric comparator and a 50 m interferometric tape bench facility built by GUM employees. A SIP CMM5 is used for coordinate metrology. The laboratory has or is taking part in eleven international comparisons under the CIPM MRA. The laboratory is taking part in two EMPIR projects and is planning to join an additional three in the 2018 call.

GUM is planning to set up a new campus in Kielce City, away from the centre of Warsaw where it is currently located.

Dr Castelazo asked for any comments or issues. There were none. A recommendation will be made later, after discussion with the Working Group chairs.

NIS (Egypt)

Dr Terra presented the report from NIS. The mission of NIS, which is part of the ministry of scientific research, includes the improvement of measurement procedures. Egypt signed the Metre Convention in 1962 and the CIPM MRA in 2000. NIS has 21 laboratories in six divisions and its head is Mohammed A Amer. NIS has submitted 39 CMCs in all TC areas.

Its Length division consist of three departments: primary length standards and lasers; end and line standards; engineering and surface metrology. It has ten researchers, ten assistant researchers and 14 technicians. NIS operates an iodine stabilized laser, has a frequency comb and performs laser calibrations of various measurands and optical fibre metrology. Additionally, laser doppler velocimeters are calibrated as are EDMs and GNSS receivers.

The work in end and line standards is mostly based around gauge blocks calibrated using a Koester interferometer. A double-sided Gauge Block Interferometer is under development.

Engineering and surface metrology is achieved using gauge blocks by comparison and diameter standards. Profile projects and CMM are also available as is a displacement measuring interferometer. Classical stylus instruments are available for roughness, as well as a phase stepping flatness icterometer and an AFM for nanoscale metrology.

NIS has produced over 60 publications in the last 8 years, in SCOPUS indexed journals.

Latest research includes a two-photon transition optical frequency standard, and a laser ranging system using a cavity locked laser, and absolute gauge block length calibration using a fibre laser locked to the comb.

NIS only has two CMCs in laser radiations at the moment, but has taken part in K11 and other Length comparisons (as well as CCPR comparisons) and these will provide evidence to facilitate the submission of new CMCs.

Dr Castelazo asked for any comments or questions. There were none. The recommendation would be given later after discussion with the Working Group chairs.

Subsequently, the Working Group chairs made the recommendation to admit NIS and GUM as Observers of the CCL, subject to approval from CIPM.

Membership and Chairs of Working Groups

Dr Castelazo showed the proposals for new members of Working Groups and Discussion Groups. There was a discussion on who approves the moderators and membership of Discussion groups. The consensus was that the DG moderators, WG chairs and sWG chairs are approved by the CCL. Membership of the Working Groups needs to be approved by CCL, but membership of Discussion Groups is open, subject to application by email to the Executive Secretary (copied to the DG moderator).

Working Group Chairs

M Matus (BEV) is proposed as chair of joint CCL/CCTF WGFS

Andrew Yacoot (NPL) is proposed as chair of WG-N

Moderators of Discussion Groups

Makoto Abe (NMIJ/AIST) is proposed as DG2 Moderator

Miguel Viliesid (CENAM) is proposed as DG4 Moderator

New proposed members of Discussion Groups

DG1: Joaquín Rodríguez (CEM) and Akiko Hirai (NMIJ-AIST)

DG2: Makoto Abe (NMIJ/AIST)

DG3: Mar Pérez (CEM)

DG4: Miguel Viliesid (CENAM), Rafael Muñoz (CEM) and Yoichi Bitou (NMIJ-AIST)

DG5: Joaquín Rodríguez (CEM)

DG6: Aelio A. Arce (CEM) and Takatsuji Toshiyuki (NMIJ-AIST)

DG7: Mar Pérez (CEM)

DG8: Laura Carcedo (CEM), Emilio Prieto Esteban (CEM) and Jiří Borovský (CMI)

DG11: José Antonio Salgado (LNE)

There were no objections so the changes were approved.

16 REPORTS FROM INTERNATIONAL OBERVERS/MEETINGS

Dr Balsamo reported on work within ISO/TC213 – The GPS. Committee ISO/TC213 – *Dimensional and geometrical product specification and verification* is responsible for the GPS system of standards (GPS – Geometrical Product Specification).

The committee has four advisory groups, one joint advisory group, and eleven working groups. In 2017, 22 years after its inception, the Secretariat and Chair of the ISO/TC213 moved from the

DS (Denmark) to the BSI (UK). The world-wide estimated expenditure for activities in mechanical engineering is of the order of 10^{13} US$ (= 10 T$). In an industrialized society, nothing would be produced without drawings and/or CAD models. Drawings not complemented with a tolerance layer would be insufficient for production and inspection. The GPS scheme covers the entire process from design, through manufacturing, to final inspection. A matrix model is used to describe the standards (ISO 14638). The duality principle (ISO 17450-1 and ISO 8015) relates the specification (design) and the verification (inspection).

The measurement is essential to the GPS. The GPS viewpoint is complementary to that of the CCL. No decisions are made when calibrating, and calibrations are carried forward along the traceability chain for others to decide. In the GPS, the traceability is assumed (there are provisions in the GPS); measurement results are used to make decisions, typically to accept or reject parts.

Metrologists may consider that mechanical drawings are for designers and production engineers only. In geometrical measurements, the definition of the measurands is all but trivial. As the real geometry deviates from the nominal geometry, the definition becomes more and more complex. It requires concepts, terms and definitions, and a graphical language: the GPS. The GPS is a common language for designers, production engineers and metrologists.

Particularly in America, a popular alternative exists – the GD&T – *Geometrical Dimensioning and Tolerancing*. Unlike the GPS, the GD&T is self-contained in a single comprehensive document, the ASME Y14.5. The GPS is based on first principles and a top-down approach. The GD&T is based on ideal gauges to fit, and is practical. The GD&T does not address any topic related to instruments, uncertainty and decision rules. The graphical alphabet is mostly the same with the same meaning, but some principles are opposite (for example the independence principle), which raises confusion in use.

Trends in complexity: the system is growing in magnitude and complexity with some 130+ documents, mostly connected to each other. Specifying geometries is intrinsically difficult. Subtleties in specification of very complex and expensive parts (for example in aerospace applications) may save large sums of money. The same GPS language is used by specialist engineers for top applications as well as by beginners for trivial applications. This puts an unnecessary burden of complexity (to deal with top applications) on every day applications. The WG17 (*Facilitation of the GPS implementation*) has recognized the increasing complexity as a major thread to the world-wide application of the GPS in industry and is tasked to investigate solutions for simplification.

Trends in micro-nano: Traditionally, the deviations from a nominal shape are categorized based on spatial wavelengths, to match the defects of the generating machine tool:

– Form → long wavelength → carriage geometry
– Waviness → medium wavelength → chatter
– Roughness → short wavelength → cutting process

This is reflected in the way micro- and macro-feature specifications are expressed; the “macro” tolerancing does not involve roughness; the roughness tolerancing is superimposed to a nominal geometry. This view is being challenged by micro- and nano- parts, for which this separation makes no sense. An *ad hoc* study group is in charge of investigating this issue.

Trends in surface texture: The ultimate reason for specifying and verifying surface roughness is to achieve desired tribological performances of the surface. The functional relationship

between standardized roughness parameters and surface performance is mostly unclear (design by experience). Many GPS parameters are defined by surface texture. The areal roughness (ISO 25178) – as opposed to the traditional profile roughness – was a major step forward, but has introduced even more parameters. The micro engineering of the surfaces challenges the set of standardized parameters, mostly intended for random surfaces instead. Surfaces produced by additive manufacturing exhibit unprecedented features, currently not captured by the GPS.

In summary, metrology is an essential part of the GPS. No manufacturing is possible without dimensional inspection. In the specification/verification duality, the measurements occur in the latter, the measurand definitions in the former. As soon as the technology evolves, the GPS catches up by adding provisions, making the GPS heavier. It is good for metrologists to monitor the evolution of GPS, as it reflects new needs and trends in manufacturing.

Dr Prieto commented that there was a related challenge coming from Industry 4.0/Future Factory - it was important early in the process to know whether or not a measurement with sufficient accuracy could be made to prove or disprove a tolerance that is specified in the manufacturing drawings. Dr Castelazo was interested to see if this ISO committee could be a liaison organization of the CCL. Dr Balsamo would take the invitation to them.

The meeting broke for lunch and resume one hour later.

17 PUBLICATIONS

Dr Panfilo gave a short presentation on the revised structure and content of the CCL website. There was greater visibility to the documents.

18 RECOMMENDATIONS TO THE CONSULTATIVE COMMITTEE FOR LENGTH (CCL)

RECOMMENDATION CCL-CCTF-WGFS 1 (2018): On the revision of the 2009 CCL-K11 protocol

Considering that

- in 2009, the CCL requested WGFS to take responsibility of key comparisons of standard frequencies such as CCL-K11;
- a new draft protocol for CCL-K11 has been developed;
- CCL-K11 is insufficient to validate all CMC claims of laser frequencies and vacuum wavelengths;

the CCL-CCTF-WGFS recommends that

- the CCL-K11 protocol document is developed further by the WGFS;
- CCL delegates authority to WGFS to approve this protocol;
- the guidance document CCL-GD-08 concerning alternative arrangements for reviewing CMCs in the laser frequency field is further developed and finalized by WGFS for CCL approval.

RECOMMENDATION CCL-WG-N 1 (2018):
On the entry of the Si {220} lattice parameter into the *mise en pratique*

Under its Terms of Reference, given by CCL and

considering:

- that the needs of dimensional metrology to demonstrate traceability to the SI at the nanometre scale are already approaching the limits of resolution available from the existing methods defined in the *Mise en Pratique* of the definition of the metre;
- that nano-scale manufacturing is following predictions made in the 1980s in terms of the accuracy levels demanded in future decades and that these are now requiring manufacturing capability at the nanometre or sub-nanometre scale for which the traceability infrastructure is not fully available;
- that there is an increased risk that industry and science, working at the nanometre scale, may look to non-SI traceability routes if there is no suitable traceability infrastructure in place to fulfil their needs;

and **taking into account**

- recent work, preparing for the forthcoming revision of the SI, has resulted in an agreed CODATA value for the Si {220} lattice spacing, d_{220} = 192.015 571 4 × 10^{-12} m, which is available with a standard uncertainty of 0.000 003 2 × 10^{-12} m,

the CCL Working Group on Dimensional Nanometrology (CCL/WG-N),

recommends that:

- member laboratories of the CCL increase their efforts towards making the Si {220} lattice spacing an available standard for use in providing traceability to the SI metre for dimensional nanometrology applications in the broader sense;
- the CCL prepares the necessary documentation and evidence for the future consideration of the Si {220} lattice spacing as a candidate for entry into the *Mise en Pratique* of the definition of the metre, for applications in dimensional nanometrology;
- the CCL approves the inclusion of the Si {220} lattice spacing in the *Mise en Pratique* of the definition of the metre.

The updated *Mise en Pratique* will be circulated to CCL members before approval is given by a decision of the CCL Working Group chairs and the CCL President.

RECOMMENDATION WG-MRA 1 (2018):
on the revision of the sWG-KC terms of reference

The CCL WG-MRA,

having carefully revised the Task description of its sWG-KC,

recommends

that the CCL amends the Task description of its sWG-KC as follows:

- to coordinate, supervise and support the administrative process of the pilot laboratories in conducting key comparisons;
- to prepare and maintain guidance documents and templates ready to use for the pilot laboratories;
- to examine all relevant documents for each key comparison, starting with the protocol and ending with the Draft B report;
- to advise the pilot laboratory in preparing the text of the entry to Appendix B of the CIPM MRA as required, including the calculation of degrees of equivalence and linking, and to prepare a recommendation on these subjects for approval by the CCL, and
- to prepare guidance documents on identifying significant deviations for use by the pilot laboratories.

RECOMMENDATION WG-MRA 2 (2018): on the revision of the sWG-CMC terms of reference

The CCL WG-MRA,

having carefully revised the Task Description of its sWG-CMC,

recommends

that the CCL amends the Task Description of its sWG-CMC as follows:

- to establish and maintain lists of service categories (DimVIM) and, where necessary, rules for the preparation of CMC entries (DimVIM Guide);
- to agree on detailed technical review criteria;
- to coordinate and, where possible, conduct inter-regional reviews of CMCs submitted by RMOs for posting in Appendix C of the CIPM MRA;
- to provide guidance on the range of CMCs supported by particular key comparisons;
- to identify areas where additional key and supplementary comparisons are needed;
- to monitor the review of existing CMCs in the context of new results of key and supplementary comparisons, and
- to monitor and enforce the corrective actions resulting from key and supplementary comparisons, in cooperation with the RMO's concerned.

RECOMMENDATION WG-MRA 3 (2018): on the guidance document CCL-GD-06 on flexible scope CMCs

The CCL WG-MRA,

taking account that

- the same equipment may be used for calibrating different standards with similar uncertainty, a typical example being a CMM used to calibrate standards whose measurands lay on a single straight line;

- the CCL Length Service Classification (DimVIM) is organized by standards, and the use of the abovementioned equipment would require duplicated CMCs;

and **considering** that

- the NMIs should be encouraged to keep the number of their CMCs to the minimum necessary, and duplication should be avoided;
- a flexible CMC "Standards of 1D point-to-point dimensions" would be beneficial to this end;
- the coexistence of conventional and flexible CMC's might create confusion,

recommends

- that the CCL approves the guidance document CCL-GD-06, which clarifies the extent of the flexibility and resolves the overlapping between conventional and flexible CMCs.

RECOMMENDATION WG-MRA 4 (2018):
on the use of quantity equations in the KCDB

The CCL WG-MRA,

considering that

- the CMCs for length currently registered in the KCDB are in the form of numerical equations;
- the preferred way for expressing equations in science and accreditation is by quantity equations instead;
- the CCL made a proposal to update the CMCs in length to make them expressed in quantity equations (Decision CCL 5 2012);
- the KCDB is currently under structural revision, to become the so called KCDB 2.0,

recommends

- that the CCL President presents this request to use quantity equations for length CMCs in the KCDB, with suitable worked examples, to the meeting of the Consultative Committee Presidents in June 2018.

The recommendations were approved with no objections.

19 ANY OTHER BUSINESS

None.

20 DATE OF NEXT MEETING

Dr Castelazo expects that the next CCL meeting will be in 2021 at the BIPM. The exact date will be confirmed in due course.

21 CLOSING THE MEETING

Dr Castelazo, Dr Panfilo and Dr Milton thanked everyone for their participation. Dr Inglis complimented Dr Castelazo on the meeting organization. The CCL President closed the meeting at 16:00.

Appendix L 1.

Working documents submitted to the CCL at its 17th meeting

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

https://www.bipm.org/cc/AllowedDocuments.jsp?cc=CCL

Documents restricted to Committee Members can be accessed at the restricted website.

Documents

CCL/18-01	Draft Agenda of CCL
CCL/18-05	Report from 16th CCL
CCL/18-05.1	List of actions from the 16th meeting
CCL/18-06	Outcomes from 106th meeting of CIPM
CCL/18-07	Progress towards the revision of the SI
CCL/18-08	Report from the WG-N
CCL/18-09	Report from the WG-MRA
CCL/18-09a	Reccomendations from the CCL WG-MRA
CCL/18-10	On the revision of the KCDB 2.0 CCL
CCL/18-11b	The Mise en Pratique
CCL/18-12	Report from the WG-FS
CCL/18-13.1	Report of DG1
CCL/18-13.11	Report of DG11
CCL/18-13.11a	Report of DG11 – Presentation
CCL/18-13.1a	Report of DG1 – presentation
CCL/18-13.2	Report of DG2
CCL/18-13.3	Report of DG3
CCL/18-13.3a	CCL DG K3- Angle standards - Presentation
CCL/18-13.4	Report of DG4
CCL/18-13.4a	Report of DG4 - presentation
CCL/18-13.5	Report of DG5
CCL/18-13.6	Report of DG6
CCL/18-13.6a	CCL-GD-06 (guideline - CMCs of category standards of 1D point to point dimensions)
CCL/18-13.7	Report of DG7
CCL/18-13.8	Report of DG8
CCL/18-14a	JCRB report to CCL

CCL/18-14b.1	EURAMET TC-L Report
CCL/18-14b.2	APMP TC-L Report
CCL/18-14b.3	AFRIMETS TC-L Report
CCL/18-14b.4	SIM TC-L Report
CCL/18-14b.5	COOMET TC-L Report
CCL/18-14b.6	GULFMET TC-L report
CCL/18-15.1	List of publications of NIS
CCL/18-15.2	CCL membership, chairs and moderators
CCL/18-15.3	Guidelines for membership in CCL working groups
CCL/18-15.4	Length Activities at NIS
CCL/18-15.5	Presentation of the laboratory of the length - GUM
CCL/18-16	Report from the ISO/TC213 - The GPS
CCL/18-17	CCL website

Appendix L 2.
List of actions resulting from the 17th CCL meeting

This is a list of the actions decided upon during the 17th meeting of the CCL.

No	Action	Status
A.1	Dr Castelazo to ask the CCT President to request that CCT provides clear guidance on the issue of temperature scale changes under the revised SI and any potential effect on length metrology, which uses a reference temperature of 20 °C for dimensional metrology.	
A.2	The updated *Mise en Pratique* will be circulated by Dr Castelazo to CCL members before approval is given by a decision of the CCL Working Group chairs and the CCL President.	
A.3	Dr Balsamo to approach the ISO/TC213 chair and secretariat informally to propose a possible liaison with the CCL	