

Bureau International des Poids et Mesures

# Consultative Committee for Length (CCL)

Report of the 16th meeting  
(23 – 24 September 2015)  
to the International Committee for Weights and Measures



Comité international des poids et mesures

Note:

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

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

M. Milton,  
Director BIPM

## LIST OF MEMBERS OF THE CONSULTATIVE COMMITTEE FOR LENGTH

as of 23 September 2015

### President

Dr M. Inguscio, Member of the International Committee for Weights and Measures, Istituto Nazionale di Ricerca Metrologica, Turin.

### Executive Secretary

Dr L. Robertsson, International Bureau of Weights and Measures [BIPM], Sèvres.

### Members

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

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

Centre for Metrology and Accreditation/Mittatekniikan Keskus [MIKES], Espoo.

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. Mendeleev Institute for Metrology, Rosstandart, [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, 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.

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

### **Observers**

Instituto Português da Qualidade [IPQ], Caparica.

**1. OPENING OF THE MEETING;  
APPOINTMENT OF THE RAPPORTEUR;  
APPROVAL OF THE AGENDA**

The Consultative Committee for Length (CCL) held its 16th meeting at the International Bureau of Weights and Measures (BIPM) headquarters, Sèvres, on Wednesday 23 and Thursday 24 September 2015.

The following delegates were present:

A. Balsamo (INRIM), R.H. Bergmans (VSL), H. Bosse (PTB), R. Dixson (NIST), B. Eves (NRC), R. Fira (SMU), O. Ganioglu (UME), S. Gao (NIM), P. Gill (NPL), J. Herrmann (NMIA), A. Hirai (NMIJ/AIST), K. Hosaka (NMIJ/AIST), F. Hungwe (NMISA), M. Inguscio (INRIM), J. Jin (KRISS), C.S. Kang (KRISS), P. Křen (CMI), O. Kruger (NMISA), A. Lassila (MIKES), Y. Lecoq (LNE-SYRTE), A. Lewis (NPL), M. Matus (BEV), H. Noura (LNE-LCM), F. Riehle (PTB), J. Saldago (LNE-LCM), D. Sendogdu (UME), Y. Shi (NIM), J. Stone (NIST), T. Takatsuji (NMIJ/AIST), R. Thalmann (METAS), J.P. Wallerand (LNE-Cnam), S. Wang (A\*STAR) and M. Zucco (INRIM).

Guests: N. Alqahtani (SASO), Y.-P. Lan (CMS/ITRI).

Also present: E.F. Arias (BIPM), M. Milton (Director of the BIPM), S. Picard (KCDB Executive Secretary, BIPM), L. Robertsson (Executive Secretary of the CCL, BIPM).

Apologies: J.C. Oliveira (INMETRO).

Dr Inguscio, President of the CCL, welcomed the participants to the 16th meeting of the CCL and thanked Dr Thalmann and Dr Lewis for the help they gave him in the preparation of the meeting and thanked Dr Milton, Director of the BIPM, and Dr Robertsson, Executive Secretary of the CCL for the support from the BIPM.

Dr M. Milton welcomed the delegates.

Dr Zucco was appointed as Rapporteur after being proposed by Dr Inguscio.

The agenda was approved by attendees with no changes or additions.

Dr Robertsson mentioned a few items of housekeeping.

## 2 REPORT ON ACTIONS ARISING FROM THE SEPTEMBER 2012 CCL MEETING

Dr Thalman 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	Who
A.1	The WG-MRA will send additions, if any, to the FSWG single frequency list.	in progress, ongoing	Lewis
A.2	The WG-N will prepare a document proposing new standards for nanometrology.	abandoned for the moment, priority on A.5	Dixson Bosse
A.3	Dr J.C. Oliveira to inform officially (in writing) to Dr C. Thomas on the COOMET problems. Dr M. Kühne, BIPM Director, will raise this issue in the next JCRB meeting	completed	Oliveira
A.4	CCL shall propose to CCPR to group all service categories related to refractive index in their classification scheme, thus to transfer DimVIM service 6.7.1 to CCPR, and to introduce new entries for spectral properties of material.  Alternatively CCL would be ready to keep entry 6.7.1, but does not intend to include material properties.  Dr M. Matus to introduce a new input in DimVIM (1D artefact) and to decide on the possible measurands.	completed (AL on 30.10.13)  in progress by DG6	Lewis  <del>Matus</del> DG6
A.5	WG-N/CCL, with possible input and cooperation of the CCQM, to prepare a document stating a position on the use of TEM in dimensional nanometrology and realizing SI traceability through the Si lattice	almost completed	Dixson Bosse
A.6	CCL-CCTF invited to confirm the approval of the full list of new recommended frequencies, before full approval by CCL	completed	Robertsson
A.7	Dr T. Takatsuji to contact CCT for a possible action with respect to possible common services.	completed (cf. minutes WG-MRA-14)	Takatsuji
A.8	Dr M. Matus to contact CCM in order to clarify in DimVIM a possible overlapping with respect to hardness indenter's geometry.	abandoned	Matus

No	Action	Status	Who
A.9	WG-S to include in the strategic report the conclusion of Dr Kruger after the survey on angle standards and to consider which are the best standard(s) to satisfy angle needs.	completed	Kruger Stone
A.10	Dr M. Matus to prepare a proposal to modify CCL-K11 protocol, if needed, and DimVIM categories (merging 1.1.1 and 1.1.2 in a unique category 1.1.1?)	completed	Matus
A.11	Dr A. Lewis to take note of the last version of the WG-MRA ToR and as a consequence update the ToR	completed	Lewis
A.12	Dr L. Robertsson (BIPM) to upload the modified/approved ToR to the CCL website and verify if the acronym FSWG is the official acronym, making the corresponding correction if needed	completed (WGFS)	Robertsson
A.13	CCL to send a communication to Dr I. Mills (CCU) stating that the CCL does not fully agree with the wording of the new SI definitions, in particular the metre. The CCL recognizes the reasons for the new definitions and has taken note of these.	completed	Thalmann

The actions were approved and they were not carried forward to the action list for this meeting, which may be found in Appendix L3.

### 3 OUTCOMES OF MEETINGS: THE 25TH CGPM, THE 103RD CIPM (MARCH 2015)

Dr Milton informed the delegates about the meeting of the CGPM that was held on 18-20 November 2014 in Versailles. A total of 46 Member States and 20 Associate States and Economies participated. The meeting was chaired by Prof. Philippe Taquet, president of *French Académie des Sciences*.

Five resolutions were adopted by the CGPM:

Resolution 1 “On the future redefinition of the International System of Units, the SI”

Resolution 2 “On the election of the International Committee for Weights and Measures”

Resolution 3 “On the Pension and Provident Fund of the BIPM”

Resolution 4 “On the Dotation of the BIPM for the years 2016 to 2019”

Resolution 5 “On the importance of the CIPM Mutual Recognition Arrangement”.

There is a proposal for a visitor programme in order to increase the capability of NMIs of all Member States. The proposal was not supported with a budget but Resolution 4 urged Member States, as well as international organizations, private organizations and foundations, to maintain the provision of additional voluntary support of all kinds to support specific BIPM mission-related activities, particularly those that facilitate participation in the activities of the BIPM by those countries without a well-developed metrology infrastructure.

The BIPM offers training activities, especially for new Member States, and there is engagement with the Global QI capacity building community to carry out new types of comparisons of particular interest to Member States that are also developing countries.

Dr Milton commented that there is a new CCM road map to prepare for the proposed redefinition of the kilogram in 2018 and that an “Extraordinary Calibration” has been carried out with the International Prototype of the Kilogram and its official copies. The results have been published in *Metrologia*. The April 2015 edition of *Metrologia* included new data published for the Avogadro constant determination.

Dr Milton said that a review of the CIPM MRA has been initiated after 15 years of successful operation. The KCDB contains 887 key comparisons, 404 supplementary comparisons and 25 000 published CMC entries. The review should also address proposals from some Member States calling for a rationalization of the workload.

Dr Milton ended the presentation by reminding delegates that the NMI Director’s meetings would be held at the BIPM in October 2015 and that the World Metrology Day 2015 had been a success.



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

The chairman of the CCL Working Group on the CIPM MRA (WG-MRA) Dr Lewis presented the report of the 2015 meeting (WG-MRA-6) and of two other meetings which had taken place since the previous meeting of the CCL.

Dr Lewis recalled that the WG has a large workload associated with running the activities related to the CIPM MRA and for delivering its benefits. Dr Lewis presented the structure of the CCL, with the different Working Groups and Discussion Groups and reported the terms of reference which dictate the structure and the workload.

Since the previous meeting of the CCL, the WG-MRA has met three times. WG-MRA-4 was held in Taipei, (Chinese Taipei) before the ASPEN 2013 conference in November 2013, and was chaired by Dr Lewis with Dr Thalmann as rapporteur. The WG-MRA-5 was held at BEV, Vienna (Austria) following the MacroScale conference in October 2014, chaired by Dr Lewis, with Dr Thalmann and Dr Bergmans as rapporteurs. Finally the most recent meeting, WG-MRA-6, was held on 21-22 September 2015, at the BIPM, chaired by Dr Lewis, with Dr Thalmann as rapporteur.

The topics discussed in the meetings included: KC/SC planning and reports; work on CMC foresight; how to manage corrective actions after comparison reports; how to change CMC categories in the DimVIM; next steps with Coordinate Measuring Machine ‘generic’ CMCs and comparisons (DG6); and greying out of CMCs after poor comparison results.

Dr Lewis mentioned the important work to be done between meetings, such as KC and SC progress, instigating detailed ‘peer review’ of comparison reports, CMC review, CMC corrective actions and technical discussions in DGs.

Dr Lewis commented that there had been 39 comparisons in the ‘active’ status in the last 3 years, and reported the table with the individual comparisons with the different timing. A detailed summary and plan of all length comparisons is available in an Excel file. Guidance documents and templates are available on the open access site - the sWG-KC had prepared and updated eight guidance documents to aid pilots with the operational aspects of running comparisons and reporting on them.

The WG-MRA decided that in order to speed up the reporting of comparisons all results will be due six weeks after the end of circulation, the Draft A report is due within one month after all results have been received (unless outlier checking is required, in which case 1.5 months is allowed), and the Draft B report within six months after Draft A. The Final Report is due within 12 months of the first Draft B report (Draft B often requires significant discussion). The Executive Report is due three months after the Final Report (90 days for any corrective actions to be listed).

The CCL WG-MRA sWG-CMC: Sub-group on CMCs and the DimVIM had prepared and updated a guidance document ‘GD5’ with writing rules and rules for reviewing CMCs. It is responsible for examining comparison reports and reviewed the new Executive Reports of eight key comparisons and three supplementary comparisons. The sWG-CMC discussed actions on CMCs after poor comparison performance and a new procedure was agreed.

The WG-MRA decided to reword the line 1.1.1 of DimVim called “stabilized lasers of the *mise en pratique*” to “frequency stabilized lasers” and to delete line 1.1.2 “other stabilized lasers”. This would have important benefits since it reflects actual calibration capabilities: the uncertainty values are not limited by the MeP. This interpretation of CMCs is in line with the main part of DimVIM: there is no

need to implement new categories as new technologies emerge and finally it avoids danger of confusion.

*The CCL agreed to this decision on amending the DimVIM (Decision CCL 1).*

The task group on linking, TG-L, proposed and applied three linking schemes for comparisons:

- (1) Primary comparison links into secondary comparison (classical MRA), one comparison provides the reference value into another comparison; (shown as an example in *Metrologia* **45** 2008, 223-232).
- (2) Independent loops need to be linked and both loops are treated equally – distributed linking (Bayesian); (technique published in [arxiv.org/abs/1501.07134](https://arxiv.org/abs/1501.07134))
- (3) Visual linking (common graph approach) the two reference lines are lined up (shown in *Metrologia* **47** 2010, 473).

In TG-L there had been further work on the Bayesian approach and some correlation analysis used in the gauge block comparison [EURAMET.L-K1.2011](#).

Dr Lewis introduced the five recommendations from the WG-MRA that had been referred to the CCL for approval.

Regarding the first recommendation “On the procedure on discrepant results/corrective actions”, Dr Lewis introduced the subject by saying that the sWG-CMC had collected from all published comparison reports, all of the discrepant results raised by pilots in Executive Reports (more than 30 items). It was found that not all corrective actions were at the same level: corrective actions had not always been proposed and sometimes the source of any problem was never identified. Furthermore, it was sometimes difficult to chase NMIs/RMOs for information about what is going on. The question is whether there is a more efficient way to handle these issues.

By checking official documents the WG-MRA had noted slight discrepancies between MRA T.7 and [CIPM MRA-D-05](#); according to T.7 the NMI should ‘grey out’ the CMC (no time limit), whereas according to D-05, the RMO of the affected NMI should ‘grey out’ the CMC (time limit of 90 days + 6 months). Since the WG-MRA had noted that there was no formal requirement to inform anyone other than the JCRB when 1) RMO requests greying out of a CMC due to failed corrective action and 2) a RMO requests reinstatement of a CMC after previous greying out, the WG had decided to follow CIPM MRA-D-05 guidance in outline but with some reduction in administration, after having asked the JCRB Secretary.

The WG-MRA decided that there is no requirement for immediate greying out of CMCs. The email pointing out the problem is copied to the affected NMI, TC-L and sWG-CMC. The NMI and TC-L decide the corrective action. The WG-MRA will not provide advice on what is an appropriate corrective action, however the WG-MRA will give advice on what is a ‘significantly discrepant result’. The TC-L or other RMO organization should request reinstatement (if a CMC is greyed out) and this request is to be copied to the sWG-CMC. The existing discrepant results listed in the sWG-CMC document will be sent to RMOs for action.

**Recommendation WGMRA 1 (2015)**

The CCL Working Group on the MRA (WG-MRA),

**considering** that:

- the RMOs through their Technical Committees are best placed to investigate, agree upon, and monitor any necessary corrective actions (proposed by member NMIs) for solving issues of poor performance in comparisons;
- the guidance on this matter, given in document CIPM MRA-D-05 and section T.7 of the MRA Technical Appendix is not always followed and may not be detailed enough;
- NMI Directors are considering ways to improve the efficiency of the MRA processes;

**recommends** the following procedure on discrepant results/corrective actions be adopted in CCL:

- after a discrepant result is confirmed in an agreed Final Report, this is communicated to the NMI, their RMO TC-Length and the sWG-CMC;
- the NMI proposes corrective actions which are agreed by the RMO (e.g. TC-L) within 90 days, informs the pilot of these (for inclusion in the Executive Report) and then implements them;
- successful implementation of corrective action allows the RMO (e.g. TC-L) to immediately request CMC reinstatement via the JCRB for any greyed out/enlarged uncertainty CMCs;
- unsuccessful corrective action (in the opinion of the RMO) requires the RMO to request greying out of CMCs via the JCRB;

**recommends** the sWG-KC to develop guidance for pilots on what constitutes a significantly discrepant result;

and **asks** CCL to ratify this procedure.

*The CCL agreed to this recommendation (Decision CCL 2).*

Dr Lewis presented the remaining four recommendations from WG-MRA.

### **Recommendation WGMRA 2 (2015)**

The CCL Working Group on the MRA (WG-MRA),

**considering** that:

- the CCL has accepted Recommendation WGMRA 1 (2015);
- the WG-MRA and in particular its sWG-CMCs have drawn up a list of discrepant comparison results casting some doubt on the validity of the relevant CMC claims;
- these discrepant comparison results have not yet been officially processed according to document CIPM MRA-D-05;
- there is now an agreed procedure for use within WG-MRA for handling these items;

**asks** the CCL to decide that:

- the WG-MRA shall inform the affected NMI/DIs of the problem with their comparison results, according to the list drawn up by sWG-CMC with this information being copied to the relevant TC-L committees in the RMOs;
- the NMI/DIs will propose (if not done so already) necessary corrective actions for these items to their local TC-L and these will be implemented and monitored by the RMO following the procedure outlined in RECOMMENDATION WGMRA 1 (2015);
- the Terms of Reference of WG-MRA and sWG-MRA should be amended to reflect the change in emphasis from ‘coordinating’ the CMC corrective actions to ‘monitoring’ them.

*The CCL agreed to this recommendation (Decision CCL 3).*

### **Recommendation WGMRA 3 (2015)**

The CCL Working Group on the MRA (WG-MRA),

**considering** that:

- in many fields of length metrology, the same equipment and measuring process may be used to measure artefacts which are currently listed in separate CMC categories and that customer items sent for measurement may have similar features to standard artefacts but are unlikely to have existing CMC categories;
- a variety of artefacts all sharing the same feature of being essentially mono-dimensional are able to be calibrated by the same equipment/procedure, with very similar resulting uncertainties;
- these capabilities could be represented by a single generic one-dimensional length CMC;

**decides** that:

- the use of generic one-dimensional length CMCs in Appendix C of the MRA should be supported by CCL and that these CMC claims may be used for non-standard artefacts;
- these generic one-dimensional length CMCs shall each declare the lowest uncertainty possible with the technique on the best quality available artefact and the real uncertainty for

each type of artefact shall be calculated by the respective NMI/DI at the time of actual measurement;

**asks** DG6 to elaborate the definition of the allowed boundaries for such generic CMCs, and to prepare the relevant guidance documentation and procedures;

and **requests** the CCL to ratify this decision.

*The CCL agreed to this recommendation (Decision CCL 4).*

#### **Recommendation WGMRA 4 (2015)**

The CCL Working Group on the MRA (WG-MRA),

**considering** that:

- the second cycle of length key comparisons is already underway with the gauge block (CCL-K1) comparison having been started in 2011;
- according to the planning frequency, comparisons in angle metrology (K3), diameter (K4) and 1-D CMM artefacts (K5) are due to start very soon and their protocol documents are available or being prepared;
- the guidance document on key comparisons in length metrology (WG-MRA-GD-2) allows for comparisons of both classical and inter-RMO design;

**recommends** that:

- the CCL approves the K3, K4 and K5 key comparisons of the second cycle according to their tabled protocol documents and those to be submitted post meeting;
- the CCL approves the K3 and K4 comparisons to be of classical design (CCL comparison followed by RMO comparisons);
- the CCL approves the K5 comparison to be operated as two inter-RMO comparisons organised by EURAMET (EURAMET.L-K5.2015) and APMP (APMP.L-K5.2014).

*The CCL agreed to this recommendation (Decision CCL 5).*

#### **Recommendation WGMRA 5 (2015)**

The CCL Working Group on the MRA (WG-MRA),

**considering** that:

- the CCL has the authority (as described in CIPM MRA-D-01) to define the membership of CCL working groups;
- the CCL Working Group on the MRA (WG-MRA) has almost entirely *ex officio* membership (comprising two sub Working Groups containing RMO TC chairs or their Delegates, the Discussion Group moderators and comparison pilots);

- a small number of persons have requested ‘named’ (not *ex officio*) membership of WG-MRA (as detailed in tabled document CCL-15-09);
- the CCL now meets less frequently (every 3 years rather than every two years);

**recommends that:**

- the *ex officio* membership of WG-MRA may be refreshed when required (reflecting internal changes within the RMOs) without prior approval of the CCL, but with the CCL being kept informed of any changes;
- the 2 persons requesting membership of WG-MRA as non *ex officio* members be admitted as named members;
- the CCL ratifies these recommendations.

*The CCL agreed to this recommendation (Decision CCL 6).*

Some questions were raised by the delegates regarding the recommendation adopted by the WG-MRA. Dr Milton considered that “flexible scope” is used with different meanings in other communities and he proposed adding some clauses in the final text of the recommendation to explain it better. Moreover, he asked for clarification of the difference between “measurement” and “calibration” in the text. Dr Milton proposed looking towards document CIPM MRA-D-05 instead of T.7 regarding how to handle poor comparison performance.

Dr Riehle considered that it might be possible to change the membership of the WG without prior approval of the CCL since it would be sufficient with the approval of the President of the CCL. Dr Inguscio agreed with Dr Riehle that it would be possible with the approval of the president of the CCL.

According to action A.1 of the previous CCL meeting in 2012, WG-MRA carried out a survey on radiations to be added to the WGFS list of recommended radiations. The following three proposals were reported.

- 1) NPL proposed transitions in  $H^{13}C^{14}N$  over the range 1530 nm to 1565 nm to provide traceability for a range of absolute distance measuring interferometers for which there are many applications in dimensional metrology.
- 2) NMIJ proposed for absorbing atom  $^{85}Rb$ ,  $5S_{1/2} - 5P_{3/2}$  ( $F_g = 2 \rightarrow F_e = 2$ ,  $F_g = 2 \rightarrow F_e = 3$ ) crossover resonance, the frequency 384 227 981 877.3(5.5) kHz. A Rb-stabilized diode laser was developed for use in a high-precision interferometer at the NMIJ. The light source is a commercially available external-cavity tuneable diode laser. The laser frequency was stabilized to a Doppler-free absorption line of Rb by the third-harmonic technique. The practical performance of the developed Rb stabilized diode laser was confirmed by measuring the lengths of gauge blocks up to 1000 mm. The laser was used for high-precision interferometers at NMIJ and it would be useful to have the values of the transition included in the list.
- 3) NMIJ proposed for the absorbing molecule  $^{127}I_2$ , a1 component, R(36)32-0, the frequency 564 074 632 419(8) kHz.

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

The co-chairmen of the CCL Working Group on Dimensional Nanometrology (WG-N) are Dr Dixon and Dr Bosse. Dr Dixon presented the report of the WG-N.

Dr Dixon recalled that four meetings had taken place after the formation of WG-N. The first meeting was held on 8 June 2010 at A\*STAR (Singapore) with Dr Lewis as rapporteur. It was held along with a one day symposium: 'Challenges and Trends in Nanometrology'. The second meeting took place on 19 September 2012 at the BIPM, with Dr Bergmans as rapporteur. The third was held on 12 November 2013 at the CMS/ITRI (Chinese Taipei), with Dr Lewis as rapporteur. The fourth and most recent meeting took place at the BIPM on 23 September 2015.

Dr Dixon presented comparisons organized by predecessor group DG7. In June 1998, Discussion Group 7 (DG7) for Nanometrology of the CCL/WGDM decided to perform a comparison for five different types of artefacts among interested NMIs: Photomask Linewidth (NANO1), Step Heights (NANO2), Linescales (NANO3), 1D Gratings (NANO4), 2D Gratings (NANO5). All the comparisons have been completed except NANO1.

In 2006 at the DG7 meeting, NIST proposed a linewidth comparison using AFM and measuring on a silicon wafer, called NANO6 that would be less ambitious in scope than NANO1.

With regard to planned and running comparisons, supplementary comparisons and pilot studies, there had been two comparisons on linewidth, NANO1 (photomask), NANO6 (silicon wafer) with one laboratory yet to make measurements and the Draft A report would be available in 2016. There had been one comparison APMP.L-S5 on Nanoparticle characterization where size is in the range 10 nm to 300 nm, and from three different materials (Au, Ag and PSL) to be measured with AFM, EM, DLS, DMA and SAXS. The open question is the measurand definition since the different measurement techniques have a small discrepancy.

Furthermore, Dr Dixon commented that there is a running comparison of EURAMET #1239 on surface roughness measured by AFM, which is coordinated by PTB and five samples have been circulated. There is a proposed activity on comparison of the nano roughness power spectrum. There is an ongoing activity to complete a guidance document on the use of transmission electron microscopy (TEM) as a conduit to link the Si lattice constant with nanostructure dimensions measured by AFM to achieve small MU. The current plan is to have a version ready for discussion with the CCQM in early 2016 and to publish the guidance document on the WG-N website in spring 2016.

A few slides regarding work on TEM and Si lattice traceability were presented.

The Nanoscale conference 2013 was held in Paris and the next one will be held in Wroclaw (Poland) in March 2016, the flyer is document CCL-WG/-N-15-71.

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

The WG-S meeting had taken place at the BIPM on 22 September 2015 with Dr Inguscio as chairman, Dr Stone presented the report of the meeting.

Dr Stone recalled that three meetings had taken place after the last CCL. The first was in November 2013 in Chinese Taipei chaired by Dr Stone. A document entitled “issues of concern to the CCL” was produced in this meeting. The strategy document was updated and made public. One question raised at the meeting was whether the operation of K11 is actually a false economy since the cost of the calibration has been transferred to the node laboratories (from the closed length section at the BIPM). It was discussed whether a single KC on laser frequencies could reduce the workload but the other comparisons should be carried out anyway.

The second meeting took place in October 2014 in Austria and was chaired by Dr Lewis. He noted that the strategy document was updated and there was a CCL report, presentation and poster prepared for the CGPM and a discussion on closer interaction with VAMAS.

The last meeting took place on 22 September 2015 at the BIPM and was chaired by Dr Inguscio. Dr Stone informed the delegates that discussions at the meeting will be included in future revisions of the strategy document. It was decided to generate a short version for public viewing on the website with more impact for communicating with stakeholders and which is more easily updated, and a comprehensive original version to be updated only as required for future needs. There were discussions on the CIPM MRA review survey and feedback. It was noted that information on the practical realization of the metre is missing from the BIPM webpage, dealing with appendix 2 of the SI brochure, where the practical realizations are reported.

Dr Stone presented a summary of the CCL Strategy document. He showed that it dealt with the structure and history of CCL working groups; the principal techniques matrix for proposing which CCL key comparisons should be carried out; the CCL pioneered the creation of the DimVIM that represents the classification scheme of length service, this forms a template adopted by other CCs and accreditation bodies; and the concept of the scheme of interlinked CCL-RMO comparisons where RMO comparisons would try to include members of other regions to provide linkage between the regions in order to provide a more efficient scheme.

Dr Stone reminded the meeting of other tools which had been prepared to help streamline the CIPM MRA processes within the CCL such as guidance documents on formatting CMCs, methods of key comparison analysis, comparison protocols and templates.

Regarding future trends, Dr Stone presented several items identified in the CCL WGs and DGs. In nanotechnology several new comparisons are planned together with work on crystal lattice-based standards. In coordinate metrology, flexible measuring systems, such as CMMs, can measure many types of 1D object with the same technique and a single ‘generic 1D’ CMC entry is expected for such services, rather than treating them as separate artefacts. Other issues were: automated uncertainty analysis, new coordinate measurement via X-ray tomography, articulating arms, laser trackers and scanners, and indoor GPS. DG6 is undertaking actions on preparing for flexible scope CMCs for ‘1D generic’ measurements.

Regarding angle measurement technology, the encoder technology is becoming more important while traditional artefacts such as angle blocks had been rapidly decreasing in importance. There are current



actions for DG3: to give advice whether an optical encoder could be included in the next angle key comparison in addition to a polygon standard.

It was noted that in the field of absolute laser frequency measurements there had been widespread adoption of optical comb technology that might require new comb verification methods. Combs would be used not only in the laboratories but also in other fields.

There had been other needs and drivers for change: high data density; digital manufacturing; shop floor refractive index and thermal compensation; large areas assessment in manufacturing; intrinsically traceable metrology; and process metrology.

Dr Stone concluded by saying that WG-S attempts to anticipate future needs and works with other WGs to streamline/improve the CIPM MRA processes.

Dr Milton recalled that there is already a short version on the BIPM webpages. Dr Stone proposed writing a medium length version.

Dr Milton said that the webmaster should be informed of the problem regarding the SI brochure and Dr Stone would write a document describing the realization of the metre which could be uploaded to supply the missing information.

*Dr Stone would write a document describing the realization of the metre to be included in the SI brochure (Action 1).*

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

The WGFS 2015 meeting had taken place at the BIPM on 14 September 2015. The Report, prepared by both Dr Riehle and Dr Gill, which had been presented to the CCTF, was presented to the CCL by Dr Riehle. Dr Gill started by describing the different activities realized by the WGFS as the List of Recommended Frequencies (LoR), the Optical Frequency Ratios, and the Protocol for traceability of the metre directly from the Cs clock (K11 comb validation). Dr Gill informed the meeting that the CCTF had accepted the entries when the report had been presented to it.

Dr Gill mentioned that three meetings had taken place after the last CCL: the first in 2013 in Prague at the EFTF where there was discussion of the issue regarding how to deal with optical ratio, since direct measurements are limited by Cs realization with a limit of about  $2 \times 10^{-16}$ , but optical frequency ratio measurements could be better than  $10^{-17}$ . The second meeting had taken place in 2014 in Neuchatel at the EFTF where there had been a first attempt to deal with frequency values and ratios and with a review of the status of optical frequency standards. A subgroup for ions and neutral atom clocks had been established.

The most recent meeting had been held on 14 September 2015 at the BIPM where the new frequency values for the list were reviewed. No new entries were recommended in the list by the CCTF, but the meeting considered the request from the CCL to add new transitions. Several values were updated ( $^{171}\text{Yb}^+$  octupole,  $^{171}\text{Yb}^+$  quadrupole,  $^{88}\text{Sr}^+$ ,  $^{40}\text{Ca}^+$ ,  $^{87}\text{Sr}$ ,  $^{171}\text{Yb}$ ,  $^{199}\text{Hg}$ ,  $^1\text{H}$ ,  $^{87}\text{Rb}$  microwave), and the value and uncertainty of a secondary realization of the second ( $^{87}\text{Sr}$ ,  $^{171}\text{Yb}$ ,  $^{171}\text{Yb}^+$  octupole,  $^{171}\text{Yb}^+$  quadrupole,  $^{88}\text{Sr}^+$ ,  $^{87}\text{Rb}$  microwave) was updated.

The following transitions are relevant to the CCL (as was presented by Dr Lewis in the WG-MRA report).

- 1) NPL would like to include in the WGFS LoR frequencies of hydrogen cyanide [ $\text{H}^{13}\text{C}^{14}\text{N}$ ] transitions (at around 1530 nm to 1565 nm) for absolute distance interferometry using frequency-swept lasers.
- 2) NMIJ would like to include in the LoR a particular saturated absorption crossover resonance at 384 THz (780 nm) in the  $^{85}\text{Rb}$   $D_2$  line. There are previous publications with 3 kHz ( $\sim 1$  in  $10^{11}$ ) reproducibility. This line is a crossover line.
- 3) NMIJ would like to include in the LoR a particular saturated absorption in  $^{127}\text{I}_2$  at 531 nm, which is used to stabilize a compact frequency-doubled 1062 nm DFB laser. The laser system has applications as a wave meter reference, a laser gravimeter, and as an absolute frequency marker for an astro-comb. The absolute frequency, pressure / power / modulation width data have been measured for the system.

WGFS has set up a study group comprising P. Gill, F. Riehle, F.-L. Hong and K. Hosaka to evaluate these requests and they had decided that:

- 1) Regarding the linear absorption band in the range 1530 nm – 1565 nm of  $\text{H}^{13}\text{C}^{14}\text{N}$ , NIST had characterized this linear transition for telecom purposes at the 5-10 in  $10^8$  level. NPL would like to use these lines as reference for swept wavelength interferometry, but with lower uncertainty. This will require absolute measurements of saturated spectra of these transitions and measurements of shift and broadening coefficients for HCN pressure, laser intensity, electronic modulation and offsets. Data from Swan and Gilbert showed a mid-band measurement relative uncertainty of  $\sim 7 \times 10^{-9}$  ( $\sim 1.5$  MHz). Calculated data from the paper showed mid-band relative uncertainties of  $5 \times 10^{-9}$  ( $\sim 1$  MHz). Since there is an important difference between the NIST and previous values, WGFS considered that more work should be done on the Doppler-free absorption and the transitions were not added to the LoR.
- 2) Regarding the  $^{87}\text{Rb}$  d/f crossover saturated absorption at 780 nm  $D_2$  line, there was a previous measurement from the JILA group with 5.5 kHz uncertainty. NMIJ had stabilized a tuneable ECDL commercial laser to this crossover via the 3rd derivative technique, for use in high-precision interferometers for long gauge blocks. Some shift coefficients had been investigated but there appeared to be more needed (e.g. temperature dependence of laser). NMIJ has measured the stabilities from  $4 \times 10^{-10}$  (0.01 s) to  $3 \times 10^{-12}$  (50 s).

The WGFS considered that the  $^{87}\text{Rb}$  crossover absorption for stabilizing a commercial 780 nm laser could be added to the LoR and recommends an enlarged uncertainty of 80 kHz ( $2 \times 10^{-10}$ ) in view of possible variability in laser design and the need for further characterization of crossover shifts with parameters.

*The WGFS will undertake necessary actions to include the  $^{87}\text{Rb}$  d/f crossover saturated absorption at 780 nm  $D_2$  line in the LoR at its next update. (Action 2).*

- 3) NMIJ developed a coin-sized frequency-doubled DFB laser stabilized to an  $^{127}\text{I}_2$  saturated absorption at 531 nm for different applications. NMIJ has measured stabilities of  $3 \times 10^{-12}$  at 1000 s together with the pressure shift, power shift, modulation shift and servo offset coefficients, and developed an uncertainty for certain conditions of 8 kHz ( $1.4 \times 10^{-11}$ ). NMIJ had measured the transition frequency over several measurement periods via a comb, giving a frequency of 564 074 632 419 (8) kHz. The recommendation of WGFS is that the uncertainty should be enlarged to 50 kHz ( $10^{-10}$ ).

*The WGFS will undertake necessary actions to include, with 50 kHz ( $10^{-10}$ ) uncertainty, the  $^{127}\text{I}_2$  saturated absorption at 531 nm in the LoR at its next update. (Action 3).*

There had been an ongoing joint research project on International Timescales with Optical Clocks (ITOC) funded by EMRP that aimed to carry out an absolute optical frequency measurement relative to caesium, local measurement optical against optical, transportable clock comparison and finally direct clock comparison via satellite. The optical fibre link was not guaranteed at the moment of the project preparation. There had been links between PTB and Syrte, a link between NPL, a link between INRIM and Florence and INRIM to the Alps towards France.

Considering absolute measurements, it would be possible to deduce some frequency ratios from several different measurements. For example, Yb+ / Sr could be measured either directly or indirectly by combining two or more other frequency ratio measurements.

There were different optical clocks with the absolute measurement with respect to caesium and some ratios between them. The aim is to develop methods for analyzing all available data from clock comparison experiments to check the level of internal self-consistency and to derive optimal values for the ratios between their operating frequencies. The methodology is to use a least-squares adjustment procedure, based on the approach used by CODATA to provide a self-consistent set of recommended values of the physical constants. All data will be stored as frequency ratios (optical frequency ratios, microwave frequency ratios or optical-microwave frequency ratios). The methodology was tested and produced results that confirmed that the prudent approach adopted by the WGFS proved to be justified. The effect of correlation had to be taken into account in the methodology used to build a self-consistent set.

Dr Gill presented the updated values of the LoR that were relevant to Time and Frequency (mostly secondary representations of the second). WGFS had the approval of the CCTF for the updated frequencies and provided a draft recommendation of the CCTF to the CIPM.

The WGFS asked the CCL to consider the recommendations in respect of those frequencies in which the CCL had indicated an interest, and also to indicate its support, with the CCTF, for the updated frequencies for the LoR for last week's CCTF-approved LoR values, and recommendation to the CIPM.

Dr Lecoq asked whether the WGFS had discussed the fact that the crossover line in Rb is the average of two atomic lines. Dr Riehle considered that it was the same issue with overtone lines. Dr Lewis asked, with regard to the HCN lines, what the situation is for this transition and considered that it would be useful to use the values of some transitions to have traceability in the measurement. Dr Riehle recalled that the situation was different for the recommended unstabilized He-Ne laser that is useful for length metrology where there is considerable expertise in the field and a specific group had published the results in a paper. Instead for HCN it is a linear absorption and the unique publication is not enough to support the recommendation. Dr Gill added that when the results are obtained by the fitting of Doppler curves of linear absorption, there are important sources of errors. Dr Inguscio commented that there are two important aspects in the list, optical clocks with the accuracy issue and stabilized lasers, the workhorse for length metrology and he stressed that the fibre link is important to compare clocks. Dr Gill commented about the success of ITOC where campaigns of comparisons with satellites were carried out that needed a lot of effort.

## 8 REPORTS FROM THE DISCUSSION GROUPS

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

**DG1 - Gauge blocks.** The report was presented by Dr Lewis who mentioned that discussion groups are not only designed around MRA issues but also around technical discussions. In this discussion group there were 34 members because the calibration of gauge blocks is one of the most popular services across all the regions.

The technical discussions since the last CCL meeting were:

- discretization of allowed nominal lengths in the KCDB;
- range of uncertainties offered to customers by CMC claims;
- range of measurands offered by different NMIs;
- errors and improvements in international standards.

There had been a certain number of comparison activities on gauge blocks by the RMOs and CCL.

There are new trends in recent research papers:

- a move towards the use of double-ended interferometers for non-wrung gauge blocks, though this showed that other effects such as phase correction and alignment became more important;
- the operation of precision interferometers for non-gauge block items, over extended temperatures;
- updating of older styles of interferometer either to use lasers or phase-stepping;
- new phase-stepping algorithms being applied to gauge block interferometers;
- studies on long-term trends and stabilities;
- use of new light sources e.g. fs combs.

The presentation concluded with a list of papers published on this topic.

Dr Lewis commented about the trend of customers in the different CMCs offered by NMIs.

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

Dr Takatsuji informed the delegates that there had been no requests to start new comparisons but following the discussion in the group some activities could be started. Dr Takatsuji considered that coefficient of thermal expansion (CTE) is not a hot topic, but it is an important parameter in some fields, such as the space industry. Calibration of CTE at room temperature is not often required in NMJJ, whereas long-term stability of materials is of interest.

Dr Bosse commented that the PTB carries out calibration of CTE at room temperature for industries with applications in precision engineering and there are also applications at cryogenic temperatures for materials used in space missions and at elevated temperatures for materials like piezo transducers.

Dr Lewis commented that the interest in CTE is cyclical over time and at NPL there is a group on materials that measure CTE over temperature ranges of more than 100 °C.

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

Dr Kruger said that most of the discussions in DG3 had been about comparisons of angle standards and presented a table with the angle calibrations as covered under the DimVIM and a table with the CMCs for angle calibration with the comparisons.

The DG had discussed the start of a new CCL comparison on an angular encoder, since these devices had smaller uncertainty with a larger range compared to autocollimators. Since only five NMIs have had this CMC the decision was to re-run a traditional polygon and an encoder comparison. A few polygons were investigated for use as an artefact. The previous comparison used a Starret Webber 12-sided polygon. It is likely that a 12-sided polygon will be used again.

Outcomes from European project EMRP SIB58 'Angle' will be included in the final protocol of the next comparison.

**DG4 – Diameter standards.** The report was presented by Dr Stone. He informed the meeting that there were 17 members in the group and that there had been four comparisons related to diameters:

[APMP.L-K4](#), measurements of internal and external diameter, was finished in June 2014 with the executive report accepted in 2015. It was piloted by CMS/ITRI and included 13 other participants.

[SIM.L-K4.2009](#): This SIM comparison of inner and outer diameter was completed with the acceptance of the executive report in July 2015. This comparison was piloted by NIST and included three other SIM laboratories (CENAM, INMETRO, and INTI). All results were well within the claimed uncertainties.

[EURAMET.L-K4.2005.1](#): The comparison was still in progress. This was a comparison of outer diameter measurements only, intended to assess corrective action of some laboratories that had problems in EUROMET.L-K4.2005. Measurements began in October 2013 and were scheduled to finish in June 2014. Participants are VSL (Pilot), INRIM, NPL, MIRS, and SMD.

[CCL-K4.2015](#): Planning was complete and the protocol was expected to be approved at this meeting. The pilot would be ready to begin circulating the artefacts in October, 2015. Measurements are scheduled to be finished in February 2017. Measurements included: external diameters of rings, cylinders, and spheres, internal diameters of rings, and roundness and straightness measurements. Artefacts included both steel and tungsten carbide with a range of diameters and surface finish. The scope is thus fairly ambitious. The participants are NIST(Pilot), METAS, INRIM, CEM, CMS/ITRI, NIM, NIMT, INMETRO, CENAM, VNIIM, and NMISA.

There is only one potential topic for discussion that had been communicated to the moderator. John Stoup (NIST) had recently asked if the state of art of sphere diameter measurement is such that spheres might usefully replace gauge blocks as mastering artefacts for CMM measurements.

**DG5 – Step gauges.** The report had been prepared by Dr Prieto who was not present at the CCL. The report was presented by Dr Lewis.

With regard to comparison activity, Dr Lewis presented [APMP.L-K5.2006.1](#), which was registered in the KCDB on 22 August 2012. It is a bi-lateral comparison on step gauge calibration, a follow-up of the previous [APMP.L-K5.2006](#). The comparison is complete and the final Report has been published but not yet submitted to WG-MRA.

The comparison [APMP.L-K5.2014](#) was registered in the KCDB on 24 February 2015. The comparison consisted of measuring a 620 mm length step gauge with a 10 mm step. Participants were: KRIS (Pilot), NIM, NIMT, NMIA and KIM-LIPI.

A technical protocol has been prepared for the comparison EURAMET.L-K5.2016. This is presented under agenda point 11 (document CCL/15-13). Twenty laboratories including the pilot had requested to participate in the comparison, 14 of these are EURAMET members, of whom, all but one have a current CMC for step gauges. The remaining six participants are from other regions. This includes all laboratories from SIM and AFRIMET with a step gauge CMC under the MRA, plus two from APMP to act as linking laboratories between EURAMET L-K5.2016 and APMP-K5.2014. Two artefacts (a 620 mm step gauge and a “new design” 1020 mm step gauge) will be circulated in two independent loops, both starting and ending at the pilot laboratory. For the longer loop, there will be intermediate measurements by the pilot laboratory in order to confirm artefact stability.

The new type of step gauge had similar metrological dimensions to a KOBA step gauge but had been machined from a single piece of ceramic (so the ‘slugs’ will not move during shipping) with a relatively low CTE (2.3 ppm/K), which is not common for step gauges. Measurements were estimated to last from December 2015 until December 2017.

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

Dr Balsamo presented the member list and recalled that there had been a decision to discontinue the K6 comparison topic because it was considered too expensive and not representative of the measurements performed for customers. There had been two topics of discussions: 1D flexible (or generic) artefacts and measurand and the opportunity to resume K6 on “true” coordinate standards. There were two possible interpretations for the term “flexible”. From the customer viewpoint since they are not interested in how calibrations are done but they are interested in extending the range of calibrated artefacts. From the NMIs’ viewpoint, they would like to calibrate various artefacts with the same CMC without submitting many conventional CMCs and they are also interested in extending the range of calibrated artefacts.

The future action will be to continue the discussion on this topic and prepare an updated document to submit to the CCL/WG-MRA at the next meeting.

With regard to the second topic of discussion, to resume K6 on “true” coordinate standards, since the metre is defined in 1D and the coordinate metrology is in 3D and there are no KCs about 3D artefacts, the question is whether a dedicated KC is needed. There had been no discussion on this topic; the discussion was mainly on the 1D flexible CMC.

**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. The discussion 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 MRA purposes were prepared and organized.

In February 2012 the final report of the results of [EURAMET.L-K7.2006](#) (Pilot: MIRS, 100 mm line scales, 31 participants; two loops in parallel) had been published on the KCDB website and in *Metrologia*. The Executive Report has also been distributed.

The line-scale comparison APMP.L-K7-2014, using a 500 mm scale was under way. The comparison, piloted by KRISS, started in April 2015 and the circulation of the transfer standard (owned by KRISS, manufactured by Mitutoyo using a low thermal expansion substrate material-Clearceram) was expected to be finished at the end of 2016. Fifteen NMIs participated, mostly from APMP with the addition of one laboratory from AFRIMETS, and two laboratories from EURAMET and SIM each.

The next CCL-K7 comparison on line scales is scheduled to start in 2018.

The topics that the DG7 had identified as interesting for industry are:

- setting up an infrastructure for an improved traceability chain for high-precision optical size reference measurements on well-defined structures (e.g. photomasks) to optical CMM measurements on different types of measurement objects;
- extending the analysis of line-scale comparisons with respect to condensed measurement results to be used for linking, where possible;
- extending the measurement capabilities of high precision line-scale comparators, e.g. for 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;
- calibration of length encoders in addition to classical line scales, possibly using a length encoder system as a transfer standard for DG 7 comparison measurements;
- how to 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, e.g. 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;
- customers frequently ask about line width and from edge-to-edge distances with line scale calibration. These would be useful for calibration of vision CMMs.

**DG8 – Surface Texture.** The report, prepared by Dr Baker, was presented by Dr Herrmann.

Dr Herrmann presented the membership list and inter-comparison scheme with three different loops.

Dr Herrmann presented a list of discussion topics regarding 2D stylus profilometry, microscopy / optical profiling, 3D (areal), software, industry and CMCs, in particular the risk of having an increase in the number of CMCs. One issue was whether numerous types of standards listed by the KCDB could be simplified.

Dr Lewis raised a point regarding software, where different versions of software give a different result with the same data.

Dr Thalman asked if the question regarding the KCDB could be addressed to DimVIM. Dr Matus, manager of the DimVIM, said that he had not been asked about the subject. Dr Herrmann will ask Dr Baker to clarify this point.

*Dr Herrmann will ask Dr Baker to clarify the point regarding simplification of the CMCs in the KCDB for the topic of surface metrology (Action 4).*

**DG11 – Lasers.** The report was presented by Dr Matus. There are 25 members in the DG11, most are CCL members, some are CCTF members. The aim is to discuss recent research relevant to the CCL, events and ideas for comparisons. Dr Matus recalled that there was a single key comparison active and showed the good results of the comparison starting from 2009. A total of 36 NMIs from all RMOs participated in the KC. The KC was distributed on five node laboratories and NMIT acted as a host laboratory. INRIM offered to be a node laboratory in case one of the (European) nodes decides to discontinue. The expected workload was about 4-5 per year (from published CMCs and the repetition cycle).

Dr Matus presented the list of reports and mentioned that revision of the technical protocol is a topic of DG11 that it is about to be drafted by the DG moderator according to the new CCL guidance document templates. A fourth measurement method called “self-confirmation” is planned to be included in the protocol. More and more lasers are operated according to method 2 and as a consequence they have a smaller uncertainty with respect to the lasers with method 3.

An important topic for the future is the fact that only the He-Ne laser at 633 nm is used outside NMIs in dimensional metrology and there is the possibility that it will no longer be produced in the future. For other wavelengths the situation could be even worse.

Dr Thalman asked whether the term *Mise en Pratique* laser should be abandoned in favour of traceable stabilizer laser. Dr Matus replied that this topic had been discussed.

## 9 CCL MEMBERSHIP AND MEMBERSHIP OF WORKING GROUPS. INCLUDING REQUESTS TO JOIN

Dr Lewis, as chair of WG-MRA, presented the question of membership of the CCL and the WGs.

The context of the topic is that according to document CIPM MRA-D-01 “The CIPM will carry out a formal review of the membership of the CCs every four years in the year following a meeting of the CGPM although the CC President may propose changes at each CIPM meeting” and since CGPM met in 2014, the CIPM should review CCL membership in 2015.

Currently there are 24 members of the CCL, one official observer (IPQ) and two requests to be official observers.



Dr Lewis presented the updated list of the WG-N and asked the CCL for approval. The CCL decided to accept the updated list of membership of WG-N as tabled in document CCL/15-05.

*CCL approves the membership lists of WG-N (Decision CCL 7).*

Dr Lewis presented the updated list of the WG-S, as tabled in document CCL/15-09, traditionally chaired by the president of the CCL, and asked the CCL for approval. The CCL decided to accept the updated list of membership of WG-S.

*CCL approves the membership lists of WG-S (Decision CCL 8).*

Dr Lewis recalled the current situation of the chairmanship of the different WGs: WG-S (CCL President), WG-Nano (joint chairs: Dr Bosse and Dr Dixon, started 2009), WG-MRA (chair Dr Lewis, started late 2012). The proposal is that WG chairs should state what they understand their current terms should be. WGs should nominate new chairs, when necessary, for approval by the CCL President. Nominations should include the anticipated term (maximum 4 years). Approval from the whole CCL meeting is not required.

Dr Thalman considered that 6 years is too long, because the workload is too important to do, he proposed either 3 years or 4 years, without the formal process of approving or electing a new chairman at CCL meetings, but between the meeting CCL and to give the WG the responsibility of choosing the candidate and proposing the person to the President of the CCL for approval.

Dr Balsamo supported Dr Thalman's proposal of 3 or 4 years. He added that the chairman could be confirmed and go to 6 years: if the cycling of the chair is dependent on the cycling of the CCL it is more efficient.

Dr Milton said that the length of term is not a matter for the BIPM, since other CCs have a very long term.

Dr Gill said that the chairmen of WGFS are in the third year of their term, ending in 2018.

After some discussions, the CCL decided that each CCL Working Group shall propose a new candidate for chairmanship together with the period for chairmanship that cannot be longer than 4 years. The formal approval of the proposed chairmanship is the responsibility of the President.

*CCL approves the Chairmanship of Working Groups (Decision CCL 9).*

There followed a presentation by two candidates (ITRI-CMS and SASO) to join the CCL as observers.

#### **Presentation on ITRI-CMS (Chinese Taipei) by Dr Lan.**

The ITRI, founded in 1973, is a non-profit, non-government R&D organization and CMS was founded in 1985. Chinese Taipei was accepted as an Associated of the General Conference in 2002. In 2003 it posted its first entry in the CMC database. Currently, there are 58 items in 14 categories. In the dimensional metrology area there are 26 staff, divided between optical frequency, length, geodesy and nano. Some research applications were presented, in particular gauge block length measurement by dual-laser, absolute distance measurement by dual compact ultrafast fibre lasers, three-dimensional measurement systems and technology, AFM for critical dimensions and nanoparticle size.

Dr Lan presented the international comparisons where CMS is involved, the international meetings they hosted, and participation in International Standardization Committees.

Dr Inguscio asked whether geodesy is an activity in common with other laboratories and Dr Lan answered that it is a research activity for the length group only.

Dr Milton thanked him for the presentation and asked about involvement in APMP and the level of performance in comparisons. Dr Milton asked Dr Lan to forward this information to the secretary.

*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) (Action 5).*

#### **Presentation on SASO (Saudi Arabia) by Dr Alqahtani.**

Dr Alqahtani presented the activities of the Saudi Arabian NMI: National Measurement and Calibration Center (NMCC) part of the Saudi Standards, Metrology and Quality Organization (SASO).

Dr Alqahtani said that Saudi Arabia has a population of about 20 million. The Saudi economy is based on petrol and petrochemicals. NMCC was established in 1986 and is the first reference for measurement and calibrations in Saudi Arabia. The Center is responsible for maintaining and keeping national, reference, secondary and working standards, and enhancing their accuracy whenever required. It also calibrates measurement instruments and standards to the highest level of accuracy for governmental and private agencies as well as GCC member states.

There are different departments in the institute: mass, time, temperature, chemical, electrical, length laboratories and 50 people work at NMCC.

Dr Alqahtani presented the measurement capability of the different quantities together with the source of traceability. In particular for dimensional laboratory they have a different gauge block comparator and iodine stabilized He-Ne laser both traceable to UME (Turkey). For temperature and time/frequency they are also traceable to UME. NMCC participated in comparisons in mass, pressure and in particular in length with the comparison of the laser He-Ne/I2 at 633 nm where they have just received the draft a report of the inter-comparison under CCL. NMCC issues about 70 calibration certificates a year for gauge blocks and one for laser standards.

Following the two presentations, Dr Inguscio said he would report the situation to the CIPM and asked the candidate NMIs to complete the necessary documentation.

*Dr Inguscio to report on the situation of both candidates for CCL membership to the CIPM (Action 6).*

*Dr Lan and Dr Alqahtani to complete the documentation required for their applications for membership of CCL (Action 7).*

**10 REPORTS FROM THE REGIONS ON ANY NON-MRA ACTIVITIES, ITEMS OF INTEREST**

The report from AFRIMETS was presented by Dr Kruger.

The chairman is Dr Kruger and the vice chair is Dr Mutale. No meeting was held in 2015. There are a growing number of AFRIMETS countries joining the international metrology community with four countries as Member States and eight countries as Associates.

With regard to comparisons in length, the SADC MET comparisons LS1, LS7 and LS11 had ended with only four NMIs submitting their results. Two new end standards (gauge blocks) mechanical comparisons were registered in the BIPM KCDB. There are challenges in performing training as-well as writing technical guidelines.

In the area of length research, South Africa and Egypt submitted a joint research project on interferometry measurements of gauge blocks, using double ended interferometry. Part of the project is the comparison of end standards (gauge blocks).

Dr Kruger presented a Line scale system developed for AFRIMETS' NMIs. Dr Kruger showed the comparison database with the AFRIMET and SADC MET comparison.

The report from EURAMET was presented by Dr Bosse. He presented the EMRP and EMPIR research programmes co-funded by the European Commission and implemented by EURAMET. EMRP started in 2009 and will end in 2017 in the 7th EU Framework Programme: 23 states participated. EMPIR started in 2015 and has a duration of 10 years. It is realised as an Article 185 initiative, has an overall financial volume of 600 MEuro, equally contributed by EURAMET members and the European Commission and is under the Horizon 2020 Work Programme. Twenty states are participating. EMPIR is structured into four modules:

- science with Targeted Programme (TP) Fundamentals, Energy Environment and Health;
- innovation with TP industry;
- pre-normative;
- capacity building with TP for SI broader scope and TP Research potential.

In EMPIR external partners are funded.

A table with the different thematic calls in the different TPs was presented.

Dr Bosse presented the Strategic Research Agenda (SRA) for metrology in Europe. The drafted version is available for consultation on the internet.

For the EMPIR 2014 industry call, the Joint Research Projects (JRPs) related to TC-L were presented. The new EURAMET TC-L website was also presented.

Dr Bosse commented that the Nanoscale and Macroscale conference series are registered as EURAMET TC-L projects #1342 and #1343, they are co-located with TC-L and/or CCL-WG meetings. The next Nanoscale conference would be held in Wroclaw University of Technology (Poland), in March 2016.

Macroscale was held in 2014: Dimensional and related measurements at the macroscopic scale. It was organized by BEV and PTB in co-operation with CCL and EURAMET TC-L, and was held on 28-30 October 2014 at the BEV.

TC-L has contact persons from 35 NMIs and five NMIs participating as official observers. At the 2014 meeting at BEV (Austria) there were observers/guests from Saudi Arabia, Ukraine and South Africa. Occasionally TC-L has also had observers/guests from Tunisia and Egypt.

The next TC-L meeting will be at CEM (Spain) on 26-27 October 2015 with a half day TC-L workshop in preparation for EMPIR calls 2016. A full day workshop on Angle metrology (SIB 58) would be held the next day.

The TC-L meeting 2016 is planned to be held at the VSL (the Netherlands) on 17-19 October 2016.

Dr Bosse ended by thanking Dr Lassila for successfully chairing TC-L for the last 4 years.

The report from **APMP** was presented by Dr Kang.

A workshop from APMP DEC about temperature measurement for precise length metrology was held in 2012 at NIMT (Thailand) with 36 attendees from eight developing economies in APMP.

In 2012 a one day workshop was held before the APMP TCL in Wellington (New Zealand) with 14 participants from nine economies. The two themes were Large Scale Optics and Metrology Education for length metrology.

In 2013 at NIMT, there was a NIMT-NMIJ Joint Seminar on Coordinate metrology in Industry. It was organized by NMIJ, NIMT, and co-organized by the JICA Thai office. There were 142 participants.

In 2013 at NPLI, New Delhi (India) there was a NPLI-NMIJ Joint Seminar on Coordinate metrology in Industry. It was organized by NMIJ and NPLI and was sponsored by Dr Takatsuji and Dr Kang.

A workshop on Coordination of Industrial Standard to Metrological Standard, was held in Chinese Taipei in 2013. There were 28 participants.

In 2014 at NIMT, there was an APMP TCL-DEC training course on calibration of laser frequency using iodine stabilized He-Ne laser and optical comb, with 22 participants. It was sponsored by PTB, APMP-DEC and NMIJ,.

In 2014 at KRISS there was GMA Group Course, Metrology in Length & Dimensional Measurement, with 16 participants from 11 economies.

Dr Kang commented that some courses were supported, others were free.

The last TCL workshop was held in 2014 in the Republic of Korea with the themes: Angle Metrology, Surface and Form Metrology.

In 2014 the TCL chair was transferred from Dr Takatsuji to Dr Kang.

Regarding SIM. Dr Stone said that he will be replaced by Karina Bastida from INTI as the chair of SIM TC-L.

## 11 PROPOSALS FOR NEW KEY COMPARISONS

Dr Lewis presented the situation of the second cycle of key comparisons in length metrology.

K1 on gauge blocks is running as CCL-K1, the RMO versions will follow and some are already under way.

K2 is not active.

K3 (angle) is preparing for start in 2017. It will consist of classical CCL then RMO comparisons.

K4 (diameter), the protocol is ready for approval and the pilot will be NIST. It will consist of classical CCL then RMO comparisons. The participation list is under discussion.

K5 (step gauges), the protocol is ready for approval (minor post meeting edits). It will be a pair of inter-RMO comparisons (APMP, EURAMET).

K6 (CMM 2D), is not an active topic but is being discussed.

K7 (linescales) is not required until 2018.

K8 (surface texture) is not required until 2019.

The approval of cycle 2 for K3 and K4 was discussed and decided in agenda point 4 (Decision CCL 5).

Regarding K5, Dr Lewis presented the Draft protocol and informed that it will be run as two RMO comparisons:

- APMP.L-K5 piloted by KRISS with one loop with one artefact; a Mitutoyo 620 mm steel step gauge.

- EURAMET.L-K5 piloted by NPL with two artefacts in two loops; Mitutoyo 620 mm steel step gauge and Hexagon monolithic ceramic 1020 mm step gauge. It will run from December 2014 to August 2015. Dr Lewis pointed out that this is not strictly a CCL comparison, so CCL approval is not necessary, and WG-MRA has delegated authority to review and approve comparison protocols, but the protocol was shown to CCL for information.

The protocol has been tabled as meeting document CCL-15-13. It is ready for approval by the TC-L to be held in October 2015. No objections from the CCL were raised.

Dr Bosse informed that PTB has no longer CMCs, they stopped the service about ten years ago, and they have an accredited laboratory (Zeiss) and he wonders whether it could join the comparison. Dr Lewis said that they would contact the pilot of the comparison to ask. Dr Picard asked whether other commercial laboratories would like to join and Dr Bosse recalled that other laboratories had joined the other EURAMET supplementary comparison. Dr Milton said there are circumstances where CCs want to allow non-NMIs to participate in KCs, when there is high-level competence or when it is to provide an opportunity to demonstrate the performance. The commercial laboratory should sign a form that covers confidentiality disclosure. EURAMET has its own rules. Dr Bosse stated that in this case the accredited laboratory is not interested in being a DI. Dr Lewis added that there is an issue since the commercial laboratory could know the results of the comparison in advance.

## 12 CCL INPUT TO THE MRA REVIEW

Dr Lewis reported on the CCL members' responses to the CCL survey on review and revision of the CIPM MRA. The responses were anonymized by the CCL Executive Secretary and WG-MRA chair collated them and issued a summary document, which was discussed briefly at the WG-MRA meeting.

It was decided that a possible update/revision of the CIPM MRA should be discussed at the NMI Directors' meeting in October 2015. The CCL President asked WG-MRA to prepare a CCL version of the CCQM survey that was to be used via the Survey Monkey software/website. A set of standard questions, tailored to the needs of the CCL, were sent to NMIs to be returned in time for input to the NMI Directors' meeting that would be held in October 2015.

The WG-MRA prepared four questions on the following topics:

- the CMC review process;
- CMCs for which there is no direct comparison evidence;
- flexible scope CMCs (e.g. proposal for 1-D CMM measurements);
- numerical linking between different comparisons.

The summary document of extracted key comments sent in response to the survey is available as CCL-15-19-CCL MRA survey - short summary. The document contained the following conclusions on specific items.

- The CMC review process in length metrology works well at the intra-RMO stage but has had delays at the inter-RMO stage. It is now faster and a further gain could be made by removing the need for the inter-RMO review;
- CMCs for which there is no comparison evidence are already handled well, based on other evidence, and with further guidance, this should continue;
- Flexible scope CMCs should probably be allowed (as a way of bringing a wider range of popular measurements under the MRA) but procedures for assessing competence need to be developed;
- Numerical linking of artefact based comparisons (used to underpin CMCs) is not required. Numerical linking should be reserved for comparisons which are close to the SI metre realization (e.g. the former *mise en pratique*/single frequency list). Linking is not always necessary/recommended for other comparisons;
- Some additional improvements can and should be made to reduce the timescales of comparisons and more clarity is needed in the text of the CIPM MRA (remove ambiguities).

The document contains the recommendations from the CCL to the NMI Directors' Meeting.

Regarding the benefit of the MRA vs. the cost of delivery:

- the current workload of comparisons is already quite significant, especially for smaller NMIs and that time is expended at the expense of work on new developments - any efforts to reduce the workload of pilots are gratefully welcomed;
- flexibility in approaches to the MRA workload (such as the comparison schemes in CCL) whilst not strictly following MRA text, achieve the same goals at lower costs and should be allowed;
- inter-RMO review of CMCs that have already had detailed review adds cost and delays. Remove inter-RMO review but retain an appeal process or set up a single CMC review panel (across RMOs) for all CMCs in a field and replace both inter- and intra-RMO review by this panel.

Regarding the text of the CIPM MRA and its enforcement:

- improve the text of the MRA so that the requirements for supporting CMC claims are clearly differentiated from demonstrating equivalence of national measurement standards, e.g. optional numerical linking of non-SI realization comparisons;
- provide better clarity on the role of key and supplementary comparisons (MRA suggests that key comparisons are for national standards, supplementary are for CMC support);
- clarify the position on measurement CMCs (in addition to calibration CMCs);
- enforce shorter timescales, give detailed recommendations on some currently flexible terms e.g. significant deviation (KC results);
- bring more of the enforcement/procedural text into the MRA itself (so there are fewer updates to track across additional documents).

Regarding further improvements in terms of CMCs, comparisons, services:

- allow more flexible schemes of comparisons where suitable (not always the classical CCL and linked RMO comparisons);
- explicitly allow CMCs with non-comparison evidence (to discourage over-zealous accreditors);
- allow flexible scope CMCs – this would extend the coverage of the MRA to areas where this is in demand from accreditation agencies;
- CMCs should remain as being details of actual services and not reduced to underpinning generic concepts (as proposed in some recent position papers).

Regarding the governance level – by CIPM or by CC or by JCRB:

- broad support for higher-level governance on bringing the MRA up to date, revising text, clarify where possible;
- operation of KCs and decisions on CMCs should remain at the CC and RMO TC level – they have the detailed technical knowledge;
- reiterate that flexibility may be key to reducing costs of the MRA and governance at each level should be aware of this, e.g. CMC reviewers may have to expect that not all documents (e.g. local procedures) may be available in other languages.

Regarding the development of the actual KCDB technology:

- standardizing the units used for each service category e.g. range in mm, uncertainty in nm, would make it easier for users to directly compare results;
- suggestion (previously tabled at the CCL) to follow the guidance from ILAC and international standards and change CMCs from numerical value equations to quantity equations, so that they are in the same format as required by ILAC for accreditation scopes;
- offer better ways of exporting the data. For the more popular service categories, 17 screens of a small number of results is difficult to examine – better to export a table of values or allow just one large screen of data;
- easier search via synonyms would be useful. Could use existing translation documents e.g. CCL DimVIM.

Dr Lewis ended his presentation and Dr Milton thanked him for the work done on the survey and asked which document they would send to the meeting. Dr Lewis proposed sending the presentation and attaching the short summary as an appendix. Dr Milton proposed using the short summary itself and proposed the addition of a footnote to explain the meaning of flexible scope. Dr Milton considered that it is not likely that the text of CIPM MRA will be rewritten.

### **13 RECOMMENDATIONS TO THE CIPM**

Dr Lewis presented the updated version of the five recommendations from the WG-MRA that were discussed and approved in agenda point 4, which took into account the different contributions of the CCL delegates.

The CCL approved the text of the Recommendation presented by Dr Gill on new transition frequencies to be included or updated in the existing list of “Recommended values of standard frequencies for applications including the practical realization of the metre and secondary representations of the second”. Contrary to what happened in past CCL meetings, the list proposed by Dr Gill contained only the frequency of the transitions relevant to CCL, the frequency of the transitions relevant to CCTF will be merged in the final recommendation submitted to the CIPM.

This list of frequencies had been previously approved by the CCL-CCTF (FSWG), which was held on 14 September 2015.



**RECOMMENDATION CCL 1 (2015):  
Updates to the list of standard frequencies**

The Consultative Committee for Length (CCL),

**considering** that

- a common list of “Recommended values of standard frequencies for applications including the practical 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 included in the list of recommended values of standard frequencies:

- Absorbing molecule  $^{127}\text{I}_2$ , saturated absorption  $a_1$  component, R(36)32-0 transition.

The values  $f_{a_1} = 564\,074\,632.42$  MHz

$$\lambda_{\alpha_1} = 531\,476\,582.65 \text{ fm}$$

with an estimated relative standard uncertainty of  $1 \times 10^{-10}$  apply to the radiation of a frequency-doubled diode DFB laser, stabilized with an iodine cell external to the laser.

- Absorbing atom  $^{87}\text{Rb}$  crossover between the d and f hyperfine components of the saturated absorption at 780 nm (D2 transition)

The values  $f_{d/f \text{ crossover}} = 384\,227\,981.9$  MHz

$$\lambda_{d/f \text{ crossover}} = 780\,246\,291.6 \text{ fm}$$

with an estimated relative standard uncertainty of  $5 \times 10^{-10}$  apply to the radiation of a tunable External Cavity Diode Laser, stabilized using the 3<sup>rd</sup> derivative technique.

Note: The value of the standard uncertainty is assumed to correspond to a confidence level of 68 %. However, given the very limited number of available data there is a possibility that in hindsight this might not prove to be exact.

**and asks** the CIPM for approval.

**14 ANY OTHER BUSINESS**

None.

**15 NEXT MEETING OF THE CCL**

It was agreed that the next meeting of the CCL would be held in September 2018 just after the CCTF meeting.

The meeting was closed at 13:20.

## Appendix L 1.

### Working documents submitted to the CCL at its 16th 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:

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

Documents restricted to Committee Members can be accessed at the [restricted website](#).

#### Documents

CCL/15-02	Report from 15th CCL
CCL/15-02.1	List of actions from the 15th CCL meeting
CCL/15-04	Report from WG-MRA
CCL/15-04.1	Additional
CCL/15-08.1	DG1 report to the CCL
CCL/15-08.1-ppt	DG1 presentation to the CCL
CCL/15-08.11	DG11 report to the CCL
CCL/15-08.11 ppt	DG11 report to the CCL, presentation
CCL/15-08.2	DG2 report to the CCL
CCL/15-08.3	DG3 report to the CCL
CCL/15-08.4	DG4 report to the CCL
CCL/15-08.5	DG5 report to the CCL
CCL/15-08.6	DG6 report to the CCL
CCL/15-08.6-ppt	DG6 report to the CCL , presentation
CCL/15-08.7	DG7 report to the CCL
CCL/15-08.8	DG8 report to the CCL
CCL/15-09	CCL membership 17 September 2015
CCL/15-10.1	AFRIMETS report
CCL/15-10.2	EURAMET TC-L report to the CCL
CCL/15-11	Comparison cycle 2 introduction
CCL/15-12	CCL-K4. 2015 Technical protocol 18 September 2015
CCL/15-13	Proposal for K5 comparison, EURAMET

CCL/15-13.1	EURAMET.L-K5 2016 Tech. Prot. v 1.4
CCL/15-19.1	MRA survey, short summary
CCL/15-19.2	CCL input to the MRA review
CCL/15-20	Final recommendations CCL 2015
CCL/15-21	Resolutions from WG MRA
CCL/15-72	Proposal for CMC actions
CCL/15-ES-1	Some information

## Appendix L 2.

### List of decisions made by the CCL at its 16th meeting

This list is a summary of the decisions made by the CCL at its 16th meeting.

#### **DECISION CCL 1 (2015) – Amending the DimVIM**

CCL decided to approve the proposed amendment of the DimVIM, viz. merging service category 1.1.1 “stabilized lasers of the *mise en pratique*” with category 1.1.2 “other stabilized lasers” into a new entry 1.1.1 called “frequency stabilized lasers”.

#### **DECISION CCL 2 (2015) – Procedure for discrepant result corrective actions**

CCL decided that the WG-MRA proposal for dealing with corrective actions after discrepant results in comparisons will be adopted, viz.

after a discrepant result is confirmed in an agreed Final Report, this is communicated to the NMI, their RMO TC-Length and the sWG-CMC;

the NMI proposes corrective actions which are agreed by the RMO (e.g. TC-L) within 90 days, informs the pilot of these (for inclusion in the Executive Report) and then implements them;

successful implementation of corrective actions allows the RMO (e.g. TC-L) to immediately request CMC reinstatement via the JCRB for any greyed out/enlarged uncertainty CMCs;

unsuccessful corrective action (in the opinion of the RMO) requires the RMO to request greying out of CMCs via the JCRB;

the sWG-KC will develop guidance for pilots on what constitutes a significantly discrepant result.

#### **DECISION CCL 3 (2015) – Dealing with the existing list of discrepant results**

The CCL decided that the WG-MRA shall inform the affected NMI/DIs of the problem with their comparison results, according to the list drawn up by sWG-CMC with this information being copied to the relevant TC-L committees in the RMOs. The NMI/DIs will propose (if not done so already) necessary corrective actions for these items to their local TC-L and these will be implemented and monitored by the RMO following the procedure outlined in DECISION CCL 2 (2015). The Terms of Reference of WG-MRA and sWG-MRA should be amended to reflect the change in emphasis from ‘coordinating’ the CMC corrective actions to ‘monitoring’ them.

**DECISION CCL 4 (2015) – The use of generic 1-D CMCs in Appendix C**

The CCL decided that the use of generic one-dimensional length CMCs in Appendix C of the MRA should be supported and that these CMC claims may be used for non-standard artefacts. These generic one-dimensional length CMCs shall each declare the lowest uncertainty possible with the technique on the best quality available artefact and the real uncertainty for each type of artefact shall be calculated by the respective NMI/DI at the time of actual measurement. DG6 will elaborate the definition of the allowed boundaries for such generic CMCs, and to prepare the relevant guidance documentation and procedures.

**DECISION CCL 5 (2015) – Starting the K3, K4 and K5 comparisons (cycle 2)**

The CCL decided to approve the K3, K4 and K5 key comparisons of the second cycle according to their tabled protocol documents and those to be submitted post meeting. The CCL decided that the K3 and K4 comparisons will be of classical design (CCL comparison followed by RMO comparisons). The CCL decided that the K5 comparison will be operated as two inter-RMO comparisons organized by EURAMET (EURAMET.L-K5.2015) and APMP (APMP.L-K5.2014).

**DECISION CCL 6 (2015) – Membership of WG-MRA**

The CCL decided that the *ex officio* membership of WG-MRA may be refreshed when required (reflecting internal changes within the RMOs) without prior approval of the CCL, but with the CCL being kept informed of any changes. The CCL decided to admit as non-*ex officio* members two candidates which had been proposed through the WG-MRA chair: Brian Eves (NRC), Yushu Shi (NIM).

**DECISION CCL 7 (2015) – Membership of WG-N**

The CCL decided to accept the updated list of membership of WG-N as tabled in document CCL/15-05.

**DECISION CCL 8 (2015) – Membership of WG-S**

The CCL decided to accept the updated list of membership of WG-S as tabled in document CCL/15-09, namely the change of chair to be the new CCL President.

**DECISION CCL 9 (2015) – Chairmanship of Working Groups**

The CCL decided that each CCL Working Group shall propose a new candidate for chairmanship together with the period for chairmanship that cannot be longer than 4 years. The formal approval of the proposed chairmanship is the responsibility of the President.

### Appendix L 3.

#### List of actions resulting from the CCL 16th meeting

This is a list of the actions decided upon during the 16th meeting of the CCL, including those carried forward from the 15th meeting.

No	Action	Status
A.1	Dr Stone would write a document describing the realization of the metre to be included in the SI brochure.	
A.2	The WGFS will undertake necessary actions to include the $^{87}\text{Rb}$ d/f crossover saturated absorption at 780 nm $\text{D}_2$ line in the LoR at its next update.	
A.3	The WGFS will undertake necessary actions to include, with 50 kHz ( $10^{-10}$ ) uncertainty, the $^{127}\text{I}_2$ saturated absorption at 531 nm in the LoR at its next update.	
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.	
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).	
A.6	Dr Inguscio to report on the situation of both candidates for CCL membership to the CIPM.	
A.7	Dr Lan and Dr Alqahtani to complete the documentation required for their applications for membership of the CCL	

## Appendix L 4.

## Recommendation to the CIPM from CCL 16th meeting

RECOMMENDATION CCL 1 (2015):  
Updates to the list of standard frequencies

The Consultative Committee for Length (CCL),

**considering** that

- a common list of “Recommended values of standard frequencies for applications including the practical realization of the metre and secondary representations of the second” has been established;
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**recommends**

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

- Absorbing molecule  $^{127}\text{I}_2$ , saturated absorption  $a_1$  component, R(36)32-0 transition.

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The values  $f_{d/f \text{ crossover}} = 384\,227\,981.9$  MHz

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