Meeting of the CCM Task Group on the Phases for the Dissemination of the kilogram following redefinition (CCM-TGPfD-kg)

Monday 3rd October 2022, 12.00 to 14.00 (BST),

(On-line Teams meeting)

Present: Stuart Davidson (Chair)
Hao Fang (CCM Executive Secretary)
Richard Green (NRC)
Dorothea Knopf (PTB)
Naoki Kuramoto (NMIJ)
David Newell (NIST)
Michael Stock (BIPM)

Apologies: Lars Nielsen (DFM)

1. **Opening, agenda**

Agenda was adopted with no changes.

2. **Membership, Terms of Reference**

Membership and rationale were outlined. It is intended that the Task Group remain relatively small but to try to represent a range of RMOs, and NMIs with Kibble and XRCD experiments and also those who have no short term aims to develop/acquire realisation experiments. Since the last meeting Nieves Medina from CEM Spain had left but this was not seen as a major issue.

Terms of reference have been updated to reflect the current situation re. the use of the Consensus Value and the merger of the WGD-kg and WGR-kg (see Appendix 1).

3. **CCM.M-K8.2021 KC of realisation experiments**

Michael Stock presented the results of the comparison, noting that the report was still at the Draft A stage pending resolution of an issue raised by PTB regarding the calculation of the uncertainties with regard to the stability of the travelling standards. MS noted that the resolution of this issue should not have a significant effect on the overall results.

The Changes of the masses of the travelling standards during the comparison was presented, two results had been discarded due to large changes in the standards, one from METAS and one from NIM. Differences between the mass determinations of each travelling standard with the NMI's realization experiment and the BIPM working standards were also examined. A larger discrepancy between the measurements of PTB and BIPM for the mass of the Si-sphere was noted, and this will be the subject of future investigations between the laboratories.

The (provisional) KCRV for the comparison was -16.2 µg relative to the mass unit maintained by the BIPM working standards. The uncertainty is 7.4 µg, and the largest statistical weights were attributed to NRC (45%) and PTB (26%).

4. **Calculation of the new Consensus Value for the kilogram**

MS outlined the calculation of the new Consensus Value for the kilogram; an arithmetic mean of the reference values from the 2016 pilot study and 2019 and 2021 key comparisons. The value (based on the provisional 2021 KCRV) is -7.5 µg relative to the kilogram based on the BIPM as-maintained mass unit. It was noted that a step of about 30 micrograms existed between the 2016 pilot study and the relatively stable KCRVs of the 2019 and 2021 comparisons. If the KCRV for the proposed 2023 comparison remains similar this will give a Consensus Value in 2024 of about -18 µg relative to the kilogram based on the BIPM as-maintained mass unit.

5. Impact of changes to the Consensus Value for the kilogram

Noting that the CCM Detailed note on the calculation and use of a consensus value for the SI unit of mass following the redefinition of the kilogram states:

It is envisaged that the process by which the Consensus Value evolves will mean changes in the value are small. However, to ensure the continuity of the mass scale changes in the Consensus Value between iterative Key Comparisons will be reviewed and if necessary limited to ± 5 ppb.

There was a discussion on the implementation of the new Consensus Value, with regard to whether the change could be accommodated within the uncertainty, or a correction needed to be made to the global mass scale. An added consideration was this if KCRVs remained the same, the Consensus Value after the next key comparison would be about -18 µg and then a larger correction would certainly be necessary.

It was decided that, given the magnitude of the change in the 2022 Consensus Value and that a potential (large) step change of -18 µg in 2024 would be undesirable, NMIs should be advised to apply the -7.5 µg correction to the mass scale which will result from the implementation of the 2022 Consensus Value.

The planned approach will be to inform NMIs of the implementation of the new Consensus Value (once finalised) and advise of the need to adjust the values of their kilogram standards in line with the new value. Advice on wording for certificates to outline the use of the updated Consensus Value would also be provided. Given that the best uncertainty being offered to end users is about 50 µg, the 2022 change in the Consensus Value should not have a significant effect and so no further action in this area, apart from updates to future NMI calibration certificates, should be necessary.

6. Adoption of new Consensus Value for the kilogram

Provisional adoption of the new Consensus Value, subject to adjustments to the KCRV of CCM.M-K8.2021 and therefore to the Consensus Value of 2022, was agreed.

Additionally, an adjustment to the mass scale to account for the difference between the Consensus Value 2022 and the kilogram based on the BIPM as-maintained mass unit was agreed.

7. Dissemination of information on the new Consensus Value

A draft document outlining the adoption of the new Consensus Value, giving details of what actions are necessary for NMIs and providing guidance on wording for certificates regarding traceability will be prepared by the Task Group.

8. Updates on evolution of realisation experiments (and discussion)

SD reiterated the Conditions to enter Phase 3 of the transition (see Appendix 2). Updates from LNE, METAS and UME were received and presented by SD. All members of the TG (BIPM, NIST, NMIJ, NRC, PTB) presented updates for their experiments.

It seems that if the realisation experiments evolve as predicted there will be at least six experiments reaching the 40 ppb level with three or more below 20 ppb by 2023. Thus all criteria to advance to phase 3 will be met apart from the agreement of the experiments with the KCRV.

There was a discussion on whether it would be possible to enter phase 3 (dissemination from individual realisation experiments) if the current conditions, where the experiments with the two smallest uncertainties do not agree, persist. A number of options were discussed including;

- Assigning a 20 µg uncertainty (as for the Consensus Value) to any realisation experiments with uncertainties lower than this

- Expanding uncertainties either by a multiplication factor or by adding a fixed uncertainty contribution
- Allowing dissemination from individual experiments but adding a correction factor to those experiments which do not agree with the KCRV (if they have demonstrated that they are providing stable results).

The consensus was that none of these options were very satisfactory and that it is hoped that the realisation experiments continue to evolve, and that agreement is improved. Additionally, with more experiments reaching the 20-40 ppb level, identification of the reasons for discrepancies may become easier.

Richard Green proposed an assessment of the fundamental details of the experiments by external reviewers. This was seen as good idea. In particular NMIJ and PTB could exchange ideas on the XRCD experiment as the determination of the input parameter use similar methods and are directly comparable. David Newell noted that the lattice spacing parameter for this realisation had only been determined once, by INRIM, and while not addressing the difference between the PTB and NMIJ results it would be good to have an independent determination. Dorothea Knopf noted that PTB were working in this area but the timeframe for delivering a result is not set.

9. **Schedule for next Key Comparisons of realisation experiments**

The periodicity of the KC was discussed as it was felt that a biennial comparison may be impacting NMIs ability to move their experiments forward. However, the need for the Consensus Value to follow the evolution of the experiments was noted as a driver for regular comparisons as was the need at NMI level to demonstrate progress on the experiments.

It as agreed that the next comparison should take place in 2023 but then (probably) after a 3-year gap. Also taking into account the need to run a CCM comparison of stainless-steel kilogram in the interim period.

10. Any other business

None

11. Date of next meeting

This will be scheduled after the completion date for the 2023 comparison of realisation experiments is known.

APPENDIX 1: TG Terms of Reference (updated)

Background

~~The dissemination of the kilogram after 20 May 2019 will take place in three consecutive phases:~~

- ~~Present traceability (taking into account the additional uncertainty coming from the new definition),~~
- ~~Dissemination of the consensus value,~~
- ~~Dissemination of individual realizations.~~

The dissemination of the kilogram after 20 May 2019 is taking place in three consecutive phases:

- Traceability to the IPK (taking into account the additional uncertainty coming from the new definition) (May 2019 to February 2021),
- Dissemination of the consensus value (from February 2021),
- Dissemination of individual realizations (in the future).

Terms of Reference

Based on "the *mise en pratique* of the definition of the kilogram" and on "the CCM short note on the dissemination process after the proposed redefinition of the kilogram" the task group will:

- Ensure the correct implementation of the present traceability across the period of the redefinition of the kilogram,
- Propose a detailed calculation of the consensus value and its uncertainty and oversee the transition for the "present traceability" to the use of the consensus value,
- Propose methods to maintain the best possible stability of the consensus value over time (including comparison periodicity),
- Propose clear criteria for moving from the consensus value dissemination phase to the individual realization dissemination phase,
- Maintain a detailed document describing the three dissemination phases for the CCM and the mass community. This document includes the calculation of the consensus value, its uncertainty and time scale as well as any other relevant information related to the dissemination of the kilogram,
- ~~Provide advice to the CCM-WGD-kg and CCM-WGR-kg in all questions regarding traceability of the kilogram during the first two phases above.~~
- Provide advice to the CCM-WGM in all questions regarding traceability of the kilogram during the first two phases above.

APPENDIX 2: Conditions to enter Phase 3 of the transition

a) A minimum of five consistent realization experiments which:
   I. Achieve Key Comparison results with a relative standard uncertainty of 40 parts in 10^9 or better
   II. Demonstrate consistency with the KCRV
   III. Demonstrate stability by producing consistent (equivalent) results for two consecutive Key Comparisons

b) At least three of the realization experiments meeting the above criteria should have uncertainties less than or equal to 20 parts in 10^9.

c) The consistent set of experiments must include two independent methods of realizing the SI unit of mass (e.g. Kibble balance and X-ray crystal density experiments)

d) The difference between the Consensus Value for the kilogram (determined from three last 3 Key Comparison results) and the KCRV for the final Key Comparison is less than 5 parts in 10^9.