



Response to the CECIP paper of 15 May on the new SI

The 24th meeting of the CGPM, in October 2011, approved Resolution 1 on the proposed revision to the SI (often referred to as the “proposed new SI”). This includes proposed revised definitions for the kilogram, ampere, kelvin and mole.

This is a reply to the CECIP paper, dated 15 May 2012, signed by Veronika Martens and Vincent van der Wel in which they expressed some doubts about the proposed revisions to the SI. We recognize the importance of satisfying the doubts expressed in their paper, and we offer this brief reply that addresses the specific questions asked in their letter. By delaying this reply until now, I am able to include news from an important workshop held last week on exactly how the proposed new definition of the kilogram can be efficiently implemented in the field of mass metrology.

I preface more detailed remarks by stating that, although the upcoming changes to the SI will greatly benefit science, the legitimate concerns of important trade organizations such as CECIP will of course be respected. In particular, it is evident that the market place must not be disrupted and that public confidence must not be undermined. This has been a guiding principle for the many previous changes made to the SI during the past half-century and it remains a guiding principle for any future changes. It is for this reason that the CGPM has asked for the advice of all communities which might be affected by the proposed new SI. We thus welcome the CECIP expression of concern on various points. I hope to assure you in this reply that they are also concerns of the CIPM and ultimately the CGPM.

The CECIP paper poses the following questions:

Q1 Can the CGPM or the CIPM guarantee that this high level of worldwide confidence and agreement of calibrated mass standards be kept with a redefined kilogram?

Q2 Is it guaranteed that calibration certificates issued in different Member States will remain consistent, as it is the case now?

Q3 is it guaranteed that a redefined kilogram will not “jump” by more than 4.10^{-8} which is the smallest relative measurement uncertainty provided in calibration certificates issued by accredited mass laboratories at the moment?

With respect to the first two questions, the present worldwide confidence and agreement of mass standards and consistency of calibration certificates will, after the proposed redefinition, continue to be guaranteed under the CIPM MRA¹ just as they are now. The new definition will be referenced to the value of the Planck constant, which is a constant of nature, believed to be a true invariant, whereas the present definition is referenced to the mass of an artefact, the IPK, which is known to be drifting since it was adopted as the unit of mass more than 120 years ago although we do not know by exactly how much. It is also possible that the IPK and all its copies are drifting in mass together by much more than the 50 μg to 100 μg they have drifted apart

¹ CIPM MRA, the Mutual Recognition Arrangement for National Measurement Standards and Calibration Certificates issued by National Metrology Institutes, see <http://www.bipm.org/en/cipm-mra/>

compared to a true invariant like the Planck constant. The current definition simply ignores and “brushes under the carpet” the known instability of the IPK, and is unsatisfactory for this reason.

As regards the third question, when the new definition is adopted there will be *no jump whatever* in the value of the unit kilogram. This is because the value of the Planck constant adopted, which will appear in the new definition, will effectively be chosen to make the value of the new kilogram identical to the best estimate of the kilogram as it is defined in the current definition at the time of making the change. With regard to possible changes in the future, the new SI will define the kilogram by reference to a true invariant, which will never change. In some sense, that is the easy part.

As regards the details of the traceability to the new definition, it is stated in Resolution 1 that the CGPM encourages the BIPM to continue its work on relating the traceability of the prototypes it maintains to the international prototype of the kilogram, and to develop a pool of reference standards to facilitate the dissemination of the unit of mass when redefined. Other dissemination schemes following the rules of the CIPM MRA will also be developed.

The Consultative Committee for Mass (CCM) is at present engaged in drawing up a detailed description of how the new definition should be realized and disseminated, the so-called *mise en pratique* of the new definition. This will be made available for public discussion as soon as it is ready. A preoccupation of the CCM, which is not mentioned explicitly in the CECIP document but which I am sure that we all share, is that the uncertainties of the best mass calibrations in legal and industrial metrology should not be significantly enlarged due to the implementation of the redefined kilogram.

The CECIP is concerned that a “broadly accepted, well functioning, world-wide system, as the current SI is, might be jeopardized ...”.

It must be remembered that the present system is only “accepted and well functioning” by ignoring the drift known to be present in the value of the reference used in the definition, i.e. the mass of the IPK. In addition, the IPK and all its official and national copies in platinum-iridium increase in mass due to accumulated surface contamination. The contamination must be removed from the IPK by cleaning before it is used to calibrate its various copies. The last time the IPK was cleaned, in 1989 after some forty five years since its previous cleaning, its mass decreased by 64 micrograms due to the removal of accumulated surface contamination. It is an unproven assumption that the effect of cleaning is to return the IPK to its original mass of 1889. The maintenance of a stable system over many years based on artefacts whose mass is known to increase by surface contamination is by no means simple. The present system, even for CECIP, is thus not without risk. The proposed new definition has been discussed and developed over the last 10 to 15 years by many experts, and is now widely agreed to provide the best solution to the weakness of the current definition of the kilogram referenced to the IPK. It was supported unanimously by the 24th meeting of the CGPM, in October 2011, and was similarly approved by the CIPM and its various Consultative Committees.

Thus the question now turns from the new definition of the kilogram to its practical dissemination, keeping in mind concerns such as those of CECIP and other user bodies. In other words, the redefinition of the kilogram in terms of a fundamental constant of nature is necessary

but is by no means sufficient. It will be crucial to devise dissemination schemes that preserve the functioning of the present system that you currently enjoy. The CIPM accepts this position and embraces it.

The CECIP has reservations about adopting as a reference an “anonymous” fundamental constant “ h ” that is not well known by the general public ...

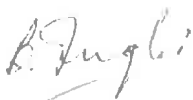
In response to this comment, note that we live in an age of high precision science and technology in which our lives are governed in many ways by precision measurements. It is simply not possible to pursue the requirements of metrology today without making use of modern developments in quantum physics. The Planck constant, h , is no more anonymous than the speed of light in vacuum, c , which is accepted as the reference for defining the metre. (The reference to c for the definition of the metre actually defines the unit m/s, which is a speed and not a length, so that the definition of the m/s has to be combined with the definition of the second to define the metre. In a similar way the reference to h actually defines the unit of action, $\text{kg m}^2 \text{s}^{-1}$, which has to be combined with the definitions of the second and the metre to define the kilogram. Note that since 1968 the definition of the second has been in terms of “ $\nu(\text{hfs Cs})$ ”, the hyperfine splitting between two electronic states of the caesium atom. This constant is much more obscure to both the general public and the broad scientific community than is the Planck constant, but this definition of the second has allowed us to use atomic clocks efficiently for time-keeping, satellite navigation, etc.) We do acknowledge that educating that part of the general public which is interested in having an appreciation of the new SI units—particularly the new definition of the kilogram—is a duty that we have not yet discharged; but I assure you that we are working on this. Resolution 1 of the 24th meeting of the CGPM has charged the CIPM with continuing its work “towards improved formulations for the definitions of the SI base units in terms of fundamental constants, having as far as possible a more easily understandable description for users in general, consistent with scientific rigour and clarity”.

You might take some comfort in a comment that appeared in a prominent American newspaper regarding redefining SI units in terms of natural constants: “We get the feeling that important matters are being taken out of the hands, and even the comprehension, of the average citizen.” The comfort, I believe, comes from knowing that these words were written more than 50 years ago when the metre was first redefined based on a natural constant rather than the distance between two scratches in the original prototype metre kept at the BIPM. It is difficult to imagine that the SI would have survived without this and the subsequent change to the metre definition. I am sure that history will repeat itself with regard to the kilogram.

It should be noted that the 20th meeting of the CCU (Consultative Committee for Units), held in September 2010, produced the first draft proposal for the new SI, including the new definition of the kilogram. In the report of this meeting it is recorded that Dr Arnold Leitner (who was representing the OIML at the meeting of the CCU) commented that the new definition of the kilogram will be more honest with respect to fundamental physics, but it will require a careful revision of the *mise en pratique* for realizing the definition of the kilogram in order to satisfy the requirement for E1 mass standards in R111. This revision is at present in progress. In a later discussion at the CCU on the needs of the OIML and future uncertainties of mass metrology, it was made clear that the contacts already exist between the CCM (the Consultative Committee for

Mass) and the relevant OIML Technical Committees. Since this time, these contacts have been maintained and strengthened. I believe that CECIP has, and will continue to have, an advocate in the OIML. Finally, as part of our on-going efforts to resolve these issues, the CCM held a two-day workshop last week where sufficient time was set aside to hear many technical talks as well as many points of view regarding the *mise en pratique* to implement the new definition of the kilogram. Dr. Roman Schwartz, vice-president of the CIML, presented the concerns of the legal metrology community, including the concerns expressed in the CECIP letter.

Obtaining a broad consensus takes effort. Based on understandings reached during this workshop, I believe that all parties are committed to making this effort.

A handwritten signature in cursive script, appearing to read "B. Inglis".

Dr. Barry Inglis, CIPM President

26 November 2012