

Title: Developing a practical means of disseminating the new kilogram

Abstract

The unit of mass, the kilogram, is the last of the seven base SI units to be defined in terms of an artefact rather than by relation to fundamental constants. Progress is being made towards a redefinition in terms of the Planck constant, realised via the watt balance and Avogadro experiments. Although the *mise en pratique* of a new definition of the kilogram depends on experimental results, which are not yet available, key issues need to be addressed now. To be able to implement the new definition a means of linking the realisation of the redefined kilogram under vacuum conditions to the current definition (the International Prototype Kilogram) in air needs to be in place. Furthermore the ongoing maintenance and dissemination of the unit of mass will rely critically on developing appropriate methods and apparatus for the fabrication, storage, comparison and cleaning of suitable mass standards.

Conformity with the Work Programme

This Call for JRP's conforms to the EMRP Outline 2008, section on "Grand Challenges" related to Health, New Technologies & Fundamental Metrology on pages 26 and 27.

Keywords

Mise en pratique, Kilogram, Avogadro constant, watt balance, realisation, dissemination, traceability, storage, surface analysis, surface effects, mass stability, mass transfer vacuum/gas, mass stability

Background to the Metrological Challenges

The preparation of the redefinition of the kilogram based on a fundamental constant or an atomic mass, its practical realisation, maintenance and dissemination are probably the most challenging tasks for mass metrology since the implementation of the present system of prototypes of the kilogram at the end of the 19th century.

A *mise-en-pratique* for the kilogram redefinition needs to be in place to ensure continuity in the mass scale by allowing the reliable fixing of the Planck constant with relation to the International Prototype Kilogram. Resolution 12 of the 23rd meeting of the General Conference on Weights and Measures (CGPM) specifically requests that a *mise-en-pratique* be in place before proceeding to the redefinition.

A key requirement is that following a redefinition of the mass unit; no problems should arise in the dissemination chain and the present system of accuracy classes of mass standards. This imposes a precondition that the maintenance of the redefined kilogram between two realisations and its dissemination is possible with uncertainties comparable to the required uncertainty of 2×10^{-8} of the best realisation. Independent of the uncertainty achieved by the best realisation, possible differences between future realisations may cause undesirable consequences for mass metrology.

The current definition of the kilogram is completely different from the potential new definition. Since it can be assumed, that the new definition of the kilogram will be realised under vacuum conditions, there will be at least one step in the dissemination chain, where a mass standard has to be transferred from vacuum to ambient air (with an optional intermediate storage under inert gas). At present, no long-term experience with respect to the mass stability of the artefacts used under vacuum for the determination of the Planck and the

Avogadro constants exists, and currently it is not possible to perform mass comparisons with artefacts stored and transferred (permanently) under vacuum or inert gas at different NMIs.

A metrological infrastructure for the maintenance and dissemination of a redefined kilogram based on primary and/or secondary mass standards stored under different environmental conditions (vacuum, inert gas) and made of different materials (silicon, Pt-Ir, stainless steel), with different shapes (spheres and cylinders) and surface properties/cleanliness does not currently exist.

Scientific and Technological Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the JRP-Protocol.

The JRP shall focus on the development of a metrological infrastructure for ensuring the continuity of the practical realisation of the mass unit between existing and new realisations of the kilogram. Dissemination at the level of the NMIs must be achievable with uncertainty contributions smaller than the required uncertainty of the best realisation ($U_{rel} < 2 \times 10^{-8}$).

The specific objectives are

1. To develop and evaluate artefacts suitable to provide maintenance and dissemination of a redefined kilogram
2. To provide appropriate procedures and techniques for the mass transfer between vacuum and air
3. To evaluate surface parameters and dynamic changes on the artefact surface between vacuum, air and selected gas atmospheres
4. To evaluate the mass stability of artefacts with a focus on the storage, cleaning and transport methods used
5. To identify and evaluate the uncertainty components inherent in the mise en pratique and in their propagation through the dissemination chain.

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research work, the involvement of the larger community of metrology R&D resources outside Europe is recommended.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

The total eligible cost of any proposal received for this SRT is expected to be around the 2.7 M€ guideline for proposals in this call.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the “end user” community (eg letters of support) is encouraged.

You should detail other impacts of your proposed JRP as detailed in the document “Guide 4: Writing a Joint Research Project”

You should detail how your JRP results are going to:

- feed into the development of urgent documentary standards through appropriate standards bodies
- transfer knowledge to the CIPM, CGPM, Consultative Committees and NMI/DI community.
- transfer knowledge to OIML and the legal metrology sector.
- transfer knowledge to the accreditation bodies, accredited laboratory sector, calibration laboratories and end users.

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.

The CGPM has indicated that a *mise-en-pratique* must be in place before the redefinition of the kilogram can be ratified. The current target date for ratification of the redefinition is 2015 so a *mise-en-pratique* would be required by this date.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

- [1] BIPM 2005 CCM Report of the 9th meeting (2005) to the CIPM, Recommendation G1 (2005), <http://www.bipm.org/utis/common/pdf/CCM9.pdf>
- [2] CCM 2007 Report of the CCM to the CIPM, 15 May 2007, <http://www.bipm.org/wg/AllowedDocuments.jsp?wg=CCM-WGSI-kg>
- [3] BIPM 2010 CCM Report of the 12th meeting (2010) to the CIPM, Recommendation G1 (2010), to be published on <http://www.bipm.org/utis/common/pdf/CCM12.pdf#page=23>
- [4] BIPM 2007 Resolution 12 of the 23rd meeting of the CGPM <http://www.bipm.org/en/CGPM/db/23/12/>