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Recent advances on the redefinition of the kilogram

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Abstract

The International System of Units (SI, [1]) still relies on an artifact standard to define the unit of mass, the kilogram. The unit of electrical current, the ampere, is defined in terms of a force in newtons, which in turn is traceable to the kilogram. It has long been appreciated that the mass of any artifact, such as the international prototype of the kilogram, will certainly vary with respect to a so-called “fundamental” constant of mass, such as the mass of an atom of carbon-12. Until recently, however, there was no highly accurate experimental method that might link the mass of a macroscopic artifact to the mass of a fundamental constant. However, this situation is changing rapidly. Simultaneously with these developments, electrical metrology is now firmly based on fundamental constants, but these constants have rather large uncertainties due to the need to link the ampere to the kilogram in the present SI. Finally, in the field of fundamental constants, the need to measure certain of the constants in terms of the artifact kilogram in order to arrive at their SI values is becoming increasingly cumbersome. The present situation, as outlined above, has led to proposals to redefine a number of the SI base units (for an example, see [2]).

For the fields of electrical metrology and fundamental constants, the proposed changes to the SI will bring immediate benefits with, it seems, little or no negative consequences. Indeed, such changes could have been instituted 15 years ago if mass metrology were not a consideration. So what do mass metrologists need? Historically, we may look back to Resolution G1 of the 1993 meeting of the Consultative Committee for Mass and Related Quantities (CCM). This resolution asks for a redefinition of the kilogram in terms of a fundamental constant or atomic mass, with the new definition realized to an uncertainty sufficiently small to monitor the long-term stability of the international prototype of the kilogram.

Progress made during the past decade led the International Committee for Weights and Measures (CIPM) to publish a recommendation in 2005, entitled “Preparative steps towards new definitions of the kilogram, the ampere, the kelvin and the mole in terms of fundamental constants” [3]. Specifically, the CIPM has asked the CCM and other relevant consultative committees to consider the implications of such changes and report back by June 2007. These reports should therefore be available at the time of IMEKO Conference in Merida. Nevertheless, it is already clear that a redefinition of the kilogram will benefit mass metrology to the

extent that improved experimental results expected by 2010 from watt balance (WB) experiments and the International Avogadro Coordination project (IAC) are realized.

After an overview of proposed changes to the SI, experimental results from WBs and the IAC will be presented, as well as projected progress until 2010 (the CIPM considers 2011 as the earliest possible date for a re-definition of the kilogram, provided certain conditions are met). Although it is premature to define exactly how a mass of 1 kg would be realized in a new SI, it is nevertheless possible to imagine the challenges that such a realization will present to the community of mass metrology. Thus the presentation will end with speculations about possible ways of realizing a new definition of the kilogram.

References

- [1] The International System of Units (SI), <http://www.bipm.org/en/si/>
- [2] Mills, I.M., Mohr, P.J., Quinn, T.J., Taylor, B.N. and Williams, E.R., "Redefinition of the kilogram, ampere, kelvin and mole: a proposed approach to implementing CIPM Recommendation 1 (CI-2005)", *Metrologia* **43** (2006) 227-246.
- [3] CIPM Recommendation 1 (CI-2005), <http://www.bipm.org/cc/CIPM/Allowed/94/CIPM-Recom1CI-2005-EN.pdf>