

Why do we need a new prototype after 100 years?

Background

When the metric system was new, Sweden was allotted one of the first batch of Pt-Ir kilogrammes in 1889. These kilogrammes were considered as prototypes, distributed to all countries which had signed the Metre Convention, copies as exact as possible of the international kilogramme. The Swedish kilogramme (K40) has served us well. In the three General Verifications of the prototype kilogrammes, which have been performed during this century, K40 has belonged to a group of kilogrammes which have shown the least differences in mass with respect to the international kilogramme at BIPM (Bureau International des Poids et Mesures) in Sèvres. These differences have been within the uncertainties of the weighings, that is, less than just a few μg (equivalently, a few parts in 109).

During 1999, SP has been elected as a new member of CCM (Consultative Committee for Mass and Related Quantities), the group of the leading national metrology institutes which advises CIPM (Comité International des Poids et Mesures) on changes and advances in primary mass metrology. This election is a recognition by the international community of SP for its contributions to the science of weighing and primary mass metrology.

The remarkable stability of prototype kilogrammes such as K40 should however be regarded against the following background.

A new definition of the kilogram?

The International kilogramme, to which all mass standards should be traceable, is itself an "ordinary" kilogramme as all the other national prototypes. According to the present SI definition, if the International kilogramme changes its mass, then all other kilogrammes change instead. But the prototype kilogrammes do change their mass. Looking at all the national prototypes, it is clear that on the average, the kilogrammes have increased their mass on the order of several tens of μg during the last hundred years - or alternatively, the International kilogramme has decreased in mass by a corresponding amount. To date there has not been a method to check the stability of the kilogramme, such as would lead to a new definition of the kilogramme.

During 1998 a research group at NIST (National Institute of Standards and Technology, USA) has reported the results of a balance of gravitational and electromagnetic forces. They claim with these experiments to be able to monitor the stability of the kilogramme at the level of 108/year, relating mass weighings to the new quantum standards of the electrical units of resistance and voltage, which are expressed in terms of the absolute standards of the fundamental physical constants of Nature.

Even with a possible new definition of the SI unit of mass on the horizon, in the foreseeable future the Pt-Ir kilogrammes will continue their leading role as key standards in primary mass metrology.

A more accurate definition will put more pressure for better accuracy on the kilogrammes as standards of mass.

Kilogramme mass stability

The prototype kilogrammes (including the international kilogramme) do change their mass, both in the long term (as above) and in the short term. In fact the mass of each national prototype kilogramme is today calculated as a function of the time since it was last washed.

Here there are two facts about an average Pt-Ir kilogramme:

1. On washing (lavage), its mass changes by about 10 $\mu\text{g}/\text{year}$ with respect to the time since it was last washed.
2. After washing, its mass increases at various rates, with the faster rate immediately after wash.

The Swedish kilogramme, K40, has according to this model, increased in mass by about 30 μg since its last lavage in the early 1990's.

These mass changes have to be understood, and much research is in progress at the national metrology institutes to study, understand and control these mass changes using various means of surface analysis.

An extra Pt-Ir kilogramme will enable a study of the relative changes of our national prototype as well as giving us a research object of study.

Air buoyancy

In disseminating traceability from the primary level to secondary standards, there are appreciable corrections and uncertainties associated with differences in air buoyancy for kilogrammes of different volumes, such as when weighing in air a small Pt-Ir kilogramme against a much larger stainless steel kilogramme.

Two Pt-Ir kilogrammes will allow mass comparisons with little difference in air buoyancy. We will also be able to weigh the second Pt-Ir kilogramme at reduced air pressure against our secondary stainless steel standards, without exposing the national prototype for the rigours of vacuum weighing.

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