

BIRTH OF A NEW KILOGRAM

By Vincent van der Wel

In the 18th century French scientists decided to create a coherent system of measures, decimally organised and based on physical characteristics. Initially the 0-meridian over Paris was used to establish the unit of length and so by means of triangular measurement from church tower to church tower, a 1/20th part, in other words 9°, was measured from Calais to Barcelona. You will appreciate that this was quite an adventure at the time, since the French Revolution had just started. Despite of this, defined as a part of this meridian and translated into a platinum iridium rod, the “meter” was borne.

As a next step of standardized measurement, it was decided to relate a unit of mass to a cube of 1dm³ filled with water. Similarly the other five primary units, time (s), electrical current (A), temperature (K), quantity of matter (mol) and intensity of light (candela) were established. It became apparent however, that in daily practice a 1dm³ of water was not ideal. Some grease, spilled water, a concave or a convex meniscus etc., caused ambiguity in accuracy. So another standard had to be found. As an experiment, a cylinder of platinum iridium was casted in London. Why platinum iridium? Well, thanks to its high density, 21.4 kg/m³, it is hardly influenced by barometric effects or air buoyancy. As a matter of interest, the density of lead is 11.3 kg/m³ and steel 7.9 kg/m³. The mass piece was perfect, at least by historic standards, and so it was archived, never to be seen again. Subsequently it is known as the “Kilogram des Archives”. Instead two additional kilograms were casted as working standards, of which the number “two” proved to be most suitable and still serves as the world standard today. But it is the third kilogram weight which is actually put to use as the “comparative working” kilogram. It is kept at the Bureau International des Poids et Mesures in Sèvres, near Paris. Each country, using the metric system, has a platinum iridium kilogram with a unique number used as its own national standard. The national standard for the Netherlands is number 53.

From time to time all national kilogram standards are checked with extreme care in a ring comparison procedure. The mass pieces may only be wiped off with special silk towels, the operators have to wear special gloves, clean rooms are used etc. All these measures are taken to ensure that no molecules of platinum iridium are lost or any pollution is added.

During the last International Verification it became apparent that in spite of all these measures, all national standards increased by 50 micrograms weight when compared with the world



standard (i.e. 0,000050kg). The hypothesis is that carbon molecules penetrate into the intermolecular spaces of the mass standard. In conclusion it was agreed that accuracy of a tangible object is no longer suitable as a world standard of measurement. Similarly to time and length, a physical constant should be used and for some time now, the resonance frequency of a caesium atom travelling in a vacuum by means of light, has become the new acceptable norm. This standard does not rely on a physical object somewhere in the world, but can be reproduced in any laboratory irrespective of external influences.

However, despite investigations and even comparisons with the mass of the moon, so far no device has come anywhere close to the accuracy of the initial “good old kilogram”. At the moment there are two alternative definitions in a race for acceptance; one based on the Watt-balance, the other based on the Avogadro-constant. For the latter, a remarkable result can be reported: its accuracy is coming close to the present one. The old fashioned method achieves 2.10⁻⁸,; while with the Avogadro project, 3.10⁻⁸ has been achieved. Not good enough, but coming close! This result has been attained with a single crystal made of extremely clean silica 28Si (99,99 %). Once accepted world-wide, the new definition for the kilogram will be:

$$N_A = 6,02214078(18) \cdot 10^{23} \text{ mol}^{-1}$$

Don't worry; it is selected as close as possible to the present kilogram, so you won't really notice the difference. The supreme authorities deciding over changes of international SI-systems meet every four years; the next meeting coming up in October 2011. It is unlikely that the required accuracy will be achieved by then. So the earliest possible “birth date” of a new kilogram is expected to be in 2015.