DENSITY DETERMINATION OF PROTOTYPES AND MASS STANDARDS AT THE BIPM

C. Goyon and R.S. Davis

Bureau International des Poids et Mesures, Pavillon de Breteuil, 92312 Sèvres Cedex, France

Summary

The BIPM provides new 1 kg prototypes to its Member States. Density is determined by hydrostatic weighing at the BIPM during the manufacturing process of the prototype. The change in manufacturing process of the Pt/Ir ingots appears to have increased the variability in density between samples from the same ingots.

Principle

- weighing in air $W_{air} = M - \rho_{air} \cdot V$
- weighing in water $W_{water} = M - \rho_{water} \cdot V$

$$\rho = \frac{W_{air} \cdot \rho_{water} - W_{water} \cdot \rho_{air}}{W_{air} - W_{water}}$$

W_{air} : apparent mass in air,
W_{water} : apparent mass in water,
M : mass,
V, ρ : volume and density of the unknown artefact at the reference temperature,
ρ_{air}, ρ_{water} : density of air and density of water.

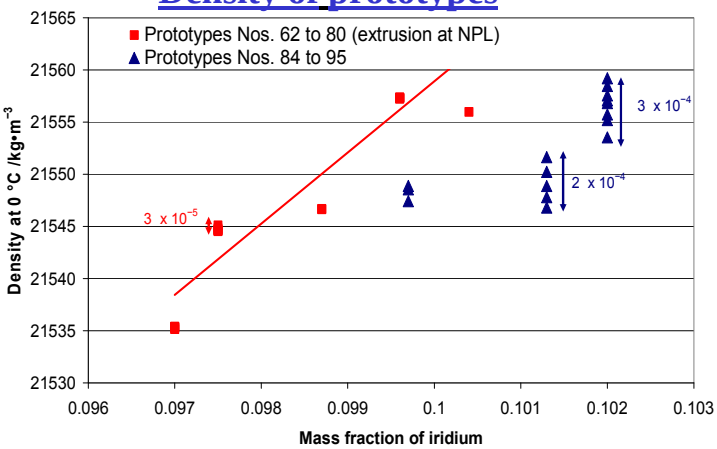
Apparatus

Density standard is doubly distilled tap water for which we assume that the maximum density at 4 °C and standard atmospheric pressure is 999.972 kg·m^{-3}. This is the density of VSMOW as given in the CIPM-2001 formula [1], corrected for the isotopic abundance of our doubly distilled tap water, and is the same density that was measured directly at the BIPM in 1907 [2].

The thermal expansion of water as well as formulas to correct for dissolved air and pressure different from 101.325 kPa are given in [1].

Combined standard uncertainty (k=1)	$u_{r,c}$ /10^{-6}	u_c /kg·m^{-3}	u_c /mm^3
1 kg Platinum-Iridium	6.7	0.144	0.31
1 kg Stainless steel	3.5	0.028	0.44

Density of prototypes



Densities of prototypes Nos. 62 to 95 function of mass fraction of Iridium

Discussion

The maximum relative difference between densities of prototypes issued from the same ingot is ten times higher for recently manufactured prototypes. (We test only for axial variation in the density of a single ingot). In addition, the density seems no longer to be correlated with the iridium content as it was in the past. We note however, that the red fitted line does not extrapolate well to the densities of pure platinum and pure iridium. The slope is almost an order of magnitude too large for this extrapolation to succeed, which is an indication that the apparent correlation with iridium content as shown in the red curve cannot yet be explained quantitatively.

References

[1] M. Tanaka and al., "Recommended table for the density of water between 0 °C and 40 °C based on recent experimental reports", *Metrologia*, Vol. 38, pp. 301-309, 2001.
[2] Ch-Ed. Guillaume, *L'œuvre du Bureau international des poids et mesures*, Paris : Gauthier-Villars, 1927, ch. 7, pp. 208-226.
[3] G. Girard, "The third periodic verification of national prototypes of the kilogram (1988-1992)", *Metrologia*, Vol. 31, pp. 317-336, 1994.
[4] T.J. Quinn, "New techniques in the Manufacture of Platinum-Iridium Mass standards", *Platinum Metals Review*, Vol. 30, pp. 74-79, 1986.
[5] R. S. Davis, "The SI unit of mass", *Metrologia*, Vol. 40, pp. 299-305, 2003.