Density of standards

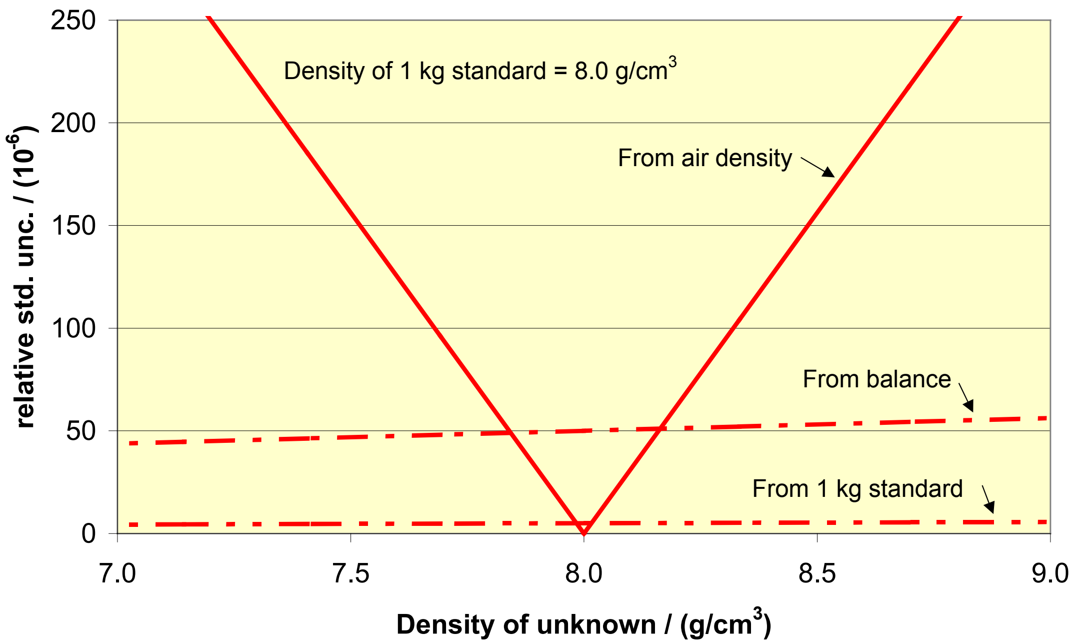
A 1 kg prototype made of platinum/iridium displaces about 46 cm^3 of air. A 1 kg mass standard made of stainless steel displaces about 125 cm^3 of air. Comparison weighings carried out in air must be corrected for the effect of air buoyancy. Near sea level, this correction amounts to about 95 mg. Making an accurate correction requires highly accurate measures of the air density at the time of weighing and of the volumes of the standards being compared.

At the BIPM, we have developed a hydrostatic balance for the determination of volumes near room temperature. The technique used, which is well known, requires that the apparent mass of the object whose volume is to be determined is first determined in air and then in doubly-distilled water. The density of both air and water can be determined to sufficient accuracy.

A view of the hydrostatic weighing device is shown in the photo. At the top is a commercial mass comparator. Suspended from the balance pan are two auxiliary pans, connected in series. One of these (seen in the upper chamber) is used for weighings in air and the second (seen in the lower chamber) is used for weighings in water. In the photo, two cylindrical mass standards have been loaded onto a weight exchanger. The whole assembly will then be immersed in a thermostated water bath. There exchanger can accommodate up to four mass standards.

The weighing sequence is fully automated. The combined standard uncertainty in determining the density of a 1 kg stainless steel standard using this device is about 0.4 mm^3.

A second technique for determining density has been developed independently by ourselves and our colleagues in MSL (New Zealand) : Clarkson M.T., Davis R.S., Sutton C.M., Coarasa J., "Determination of volumes of mass standards by weighings in air", *Metrologia*, 2001, **38(1)**, 17-23. The principle is the following: if the volume assigned to one of two standards being compared is incorrect, then the correction applied for air buoyancy will be incorrect as well. Consequently, the mass difference between the two standards will appear to depend on the particular value of air density during the comparisons. Thus it is possible to determine an unknown volume by artificially changing the air density within an airtight enclosure and measuring the consequences when a mass of unknown volume is compared with a standard of known mass and volume. Our typical uncertainties using this method are shown schematically below, where the density of the standard is assumed to be 8 g/cm^3 (8000 kg/m^3).



There are three principle components:

1. Uncertainty in the determination of the air density within the balance enclosure. This becomes the limiting uncertainty if the density of the unknown is not close to that of the standard;

2. The reproducibility of the balance readings under the experimental conditions;

3. The uncertainty in the volume (or density) assigned to the 1 kg standard mass.

Since the third uncertainty component is the result of hydrostatic weighing, it is clear from the graph that hydrostatic weighing is capable of much lower uncertainties than comparisons in air. Nevertheless, the latter can be useful for many applications where the lowest possible uncertainty is unwarranted or when submersion of the unknown in water is undesirable.