Density Determination of Prototypes and Mass Standards at the BIPM

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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
  \[ W_{\text{air}} = M - \rho_{\text{air}} \cdot V \]
  \[ \rho = \frac{W_{\text{air}} \cdot \rho_{\text{water}} - W_{\text{water}} \cdot \rho_{\text{air}}}{W_{\text{air}} - W_{\text{water}}} \]
  \[ W_{\text{water}} = M - \rho_{\text{water}} \cdot V \]
- Weighing in water

\( \rho_{\text{water}} \) : density of water
\( \rho_{\text{air}} \) : density of air

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 (\( k=1 \))

<table>
<thead>
<tr>
<th>Material</th>
<th>( u_t /10^-6 )</th>
<th>( u_r /\text{kg·m}^{-3} )</th>
<th>( u_c /\text{mm}^{-3} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kg Platinum-Iridium</td>
<td>6.7</td>
<td>0.144</td>
<td>0.31</td>
</tr>
<tr>
<td>1 kg Stainless steel</td>
<td>3.5</td>
<td>0.028</td>
<td>0.44</td>
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</table>

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.

Density of prototypes

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

References