Characterizing Large Gas-Collection Volumes with Acoustic and Microwave Resonances

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We characterized a 1.8 m^3, quasi-spherical resonator (QSR), a pressure vessel informally known as the "big blue ball" or "BBB." The BBB will be the collection volume of a NIST-designed gas-flow standard that will operate at pressures up to 7 MPa. In contrast with the QSRs used in acoustic gas thermometry, the wall of the BBB is ferromagnetic (carbon steel) and thin (19 mm) relative to the radius (761 mm). In a typical application, the BBB will never be isothermal. Our analysis accounts for these differences. At 21.9 °C and 100 kPa, we determined the volume of the BBB using microwave resonance frequencies [V_{micro}=1.84740(1±4.8´10^{-5}) m^3] and also using conventional gas-expansion [V_{gas} =1.84736(1±9.2´10^{-5}) m^3]. Within combined uncertainties, the two measurements agree: (V_{gas}/V_{micro}-1) = (-0.2±1.0)´10^{-4}. (Uncertainties are one standard uncertainty corresponding to 68 % confidence level.) As determined from microwave frequencies, the volume expansion of the BBB with internal pressure [(dV_{micro}/dP)/V_{micro}=1.790´10^{-4} (1±0.013) MPa^{-1}] and with temperature [(dV_{micro}/dT)/V_{micro} = 5.24´10^{-5}(1±0.081) K^{-1}] are consistent with the properties of carbon steels. We filled the BBB with 220 kg of argon in increments of approximately 20 kg, where each increment was weighed with an uncertainty of 0.012 %. Following each increment, we also determined the mass m_{acoust} of argon in the BBB by measuring the pressure, the acoustic resonance frequencies f_{acoust} of 3 modes, and by using the known thermophysical properties of argon. These values of m_{acoust} were within ±0.03 % of the gravimetrically determined masses. Remarkably, m_{acoust} was determined without making any temperature measurements. [The values of f_{acoust} determine particular averages of the gas's temperature, as discussed by K. A. Gillis *et al.*, *Metrologia*, 52, 337-352 (2015)]. After the argon pressure in the BBB was raised from 6.3 MPa to 6.6 MPa, the top of the BBB was approximately 1.5 °C warmer than the bottom of the BBB. After waiting 0.5 hour, m_{acoust} settled to within 0.01 % of its final value. During a flow calibration, we will use the BBB to determine the mass difference Dm_{acoust} = $m_{\mathrm{acoust,final}}$ - $m_{\mathrm{acoust,intial}}$. If the dominant uncertainties of Dm_{acoust} result from the measurements of V_{micro}, f_{acoust}, and P, the BBB will determine an average gas flow rate with a relative uncertainty of 0.03 % in 2 hours.