"“Weighing" a Gas with Microwaves and Sound, II. Measuring the Average Temperature with Acoustic Waves

Keith Gillis [C, S], James Schmidt and Michael Moldover
Sensor Science Division, NIST, Gaithersburg, MD, U.S.A.
keith.gillis@nist.gov

Often, a calibrated pressure vessel is used as a gas source and/or a gas collector to calibrate gas-flow meters. With flow calibrations in mind, we established the feasibility of determining the mass of the argon contained within a 0.3 m^3, commercially-manufactured, pressure vessel (a “tank”) with an uncertainty of 0.14 % by combining measurements of the argon pressure, the frequencies of microwave and acoustic resonances within the pressure vessel, and an equation of state for argon. Previously published microwave measurements determined the tank’s internal volume V_{micro} with a standard uncertainty of 0.06 % and they also determined the thermal and pressure expansion of the volume. [M. R. Moldover *et al*., *Meas. Sci. Tech*. (in press).] The microwave results accurately predict the lower acoustic resonance frequencies f_{calc}. In the zero-pressure limit, the average deviation $<(f_{\mathrm{meas}}/f_{\mathrm{calc}} - 1)> = 0.00025 \pm 0.00051$ based on the five lowest-frequency acoustic modes. At 0.6 MPa, $<(f_{\mathrm{meas}}/f_{\mathrm{calc}} - 1)> = -0.00071 \pm 0.00082$ for the lowest three modes, after correcting f_{meas} for the tank’s calculated pressure-dependent center of mass motion. The relative uncertainty of the argon density is twice the uncertainty of $f_{\mathrm{meas}}/f_{\mathrm{calc}}$; therefore, these three modes determine the mass of the argon in the tank at 0.6 MPa with an estimated error of 0.16 %. The values f_{meas} determine the average speed of sound (and therefore the average temperature) of the argon in the tank. First order perturbation theory predicts that the values of f_{calc} are insensitive to uniform temperature gradients. We confirmed this insensitivity by imposing a temperature gradient (in one case, 13 K top to bottom) on the tank. We conclude that resonance techniques can be used to weigh compressed gas in much larger tanks and at higher pressures in un-thermostatted environments; therefore, these techniques will have many applications in gas metrology.