Water & Air Calibration of Vibrating-Tube Densimeter at Temperatures from 0 to 90 °C and Atmospheric Pressure

Olga Prokopova, Ales Blahut, Miroslav Censky, Monika Souckova and Vaclav Vins [C, S]
Thermodynamics, Institute of Thermomechanics of the CAS, Prague 8, Czech Republic
vins@it.cas.cz

Vibrating tube densimeter (VTD) is a popular instrument providing quick and relatively accurate measurement of density for large variety of liquids and gases [May et al. Rev. Sci. Instrum. 85 (2014); Fortin et al. J. Chem. Thermodynamics 57 (2013)]. The commercial instruments have resolution of down to 0.001 kg/m^3 and their accuracy is declared to reach 0.007 kg/m^3 under ideal conditions at temperatures close to ambient. However to our experience, the uncertainty of the obtained data can be significantly higher than the accuracy stated by the manufacturers when it comes to measurements over wider temperature range.

In this work, we present thorough calibration procedure for a commercial borosilicate glass VTD (Anton Paar DMA 5000M) over wide temperature range from 0 to 90 °C. The approach is similar to that of Fritz et al. [J. Phys. Chem. B 104 (2000)] when the density can be obtained from the relative oscillation period PQ and two calibration constants A and B as: density = A*PQ^2 – B. Temperature dependencies of the calibration constants A and B and the damping of dry air were determined from a series of precise measurements with dry air and ultrapure water correlated to the densities calculated from the IAPWS-95 equation of state for water and in terms of the IAPWS G8-10 guideline for humid air. The calibration procedure is verified on measurements of several pure liquids; namely toluene, ethanol, ethylene glycol, and glycerol. A detailed analysis of the uncertainty budget resulted in the standard uncertainty below 0.03 kg/m^3 for typical low-viscosity samples. In case of highly viscous liquids such as low-temperature ethylene glycol or glycerol, the uncertainty can reach 0.06 kg/m^3 or even 0.15 kg/m^3 at the viscosity exceeding 600 mPa.s, respectively. These results are considerably different from the manufacturer's typical declarations. Additional influences such as relation between the liquid viscosity and the damping, the isotopic composition of the employed ultrapure water, the measurement procedure covering VTD cleaning and filling are also discussed.