Force Transmission Errors in Magnetic Suspension Densimeters

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The combination of the Archimedes bouyancy technique with a magnetic suspension coupling has yielded some of the most accurate data for fluid p-ρ-T behavior over wide ranges of temperature, pressure, and density. But the magnetic suspension coupling is slightly influenced by the magnetic properties of the materials of construction and by any external magnetic fields. These give rise to a force transmission error (FTE) which must be accounted for to realize the full accuracy of this technique. The magnetic properties of the fluid under study also affect the measurement (fluid-specific effect). For densimeters with two sinkers, the differential nature of the measurement largely cancels these effects, and errors in density are on the order of 20 ppm. But for single-sinker densimeters, compensation for the force transmission error should be made to avoid errors up to about 100 ppm. For the few strongly paramagnetic fluids, such as oxygen and air, the errors can be two orders of magnitude higher.

We present techniques to determine and compensate for the force transmission error (FTE), including the magnetic effects of the fluid being measured, in magnetic suspension densimeters. For a two-sinker densimeter, the forces on the balance are written out for each of the weighings comprising a density determination (i.e., the two sinkers plus balance calibration and tare weights). This yields a system of four equations, which are solved for the fluid density, a balance calibration factor, a coupling factor (related to the FTE), and a quantity related to the balance tare. For a single-sinker densimeter, an in situ weighing of the sinker in vacuum compensates for the FTE of the apparatus itself. A determination of the fluid-specific effect requires measurements with two different sinkers—analogous to the two-sinker analysis, but with the measurements spread out over time.

The apparatus part of the FTE is generally less than ±20 ppm. Measurements on propane, helium, neon, nitrogen, argon, toluene, and air are analyzed for the fluid-specific effect; this effect is correlated with the magnetic susceptibility of the fluid together with an apparatus constant. With this analysis, the force transmission “error” becomes an effect that can be accounted for rather than a significant source of uncertainty in density measurements carried out with magnetic suspension densimeters.