A New Apparatus for Combined Measurements of the Viscosity and the Density of Fluid Substances for Temperatures from 233 K to 523 K at Pressures up to 30 MPa

A. Docter, H.W. Lösch, and W. Wagner
Lehrstuhl für Thermodynamik
Ruhr-Universität Bochum
D-44780 Bochum, Germany

A new apparatus for combined measurements of the viscosity and the density of fluids is presented. This instrument combines a viscometer and a densitometer in one measuring cell and can operate in a large range from gas to liquid viscosities. The main element of the instrument is an electronically controlled magnetic coupling. This coupling freely suspends a slender cylindrical body and enables the contactless transfer of all vertical forces acting on the cylinder to an analytical balance. Besides this, the coupling serves as an almost frictionless bearing for the cylinder. The measuring cell coaxially surrounds the cylinder, which is immersed in the sample fluid and can be rotated by a cyclic magnetic field. When this drive mechanism is turned off the rotation of the cylinder is slowed down by the surrounding fluid. The damping of the rotation due to the coupling is very small compared with the viscous damping and can be precisely calibrated in the evacuated measurement cell. The rotational frequency of the cylinder is accurately measured with an inductive pickup coil and a precise timing system. The viscosity of the fluid can be directly determined from the decay of the rotational frequency. The density is measured with a buoyancy method. This method is based on the single-sinker method, which was previously developed in our group. For this purpose a sinker (buoy) can be contactlessly coupled to the balance by the magnetically suspended cylinder. The buoyancy force exerted by the fluid on the sinker is directly related to the density of the fluid and can be determined with high accuracy by weighing the sinker. The new combined viscometer-densitometer covers a viscosity range up to 150 μPa· s and a density range from 20 kg·m^{-3} to 2000 kg·m^{-3} at temperatures from 233 K to 525 K and pressures up to 30 MPa. Test measurements on the viscosities and densities of nitrogen and carbon dioxide at 253 K, 293 K, and 523 K at pressures up to 30 MPa show that the estimated total uncertainty of ± 0.63 % to ± 1.0 % in the viscosity and ± 0.03 % to ± 0.05 % in the density is clearly met.