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Note

Viscosity of Water at 20°C[1]

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The viscosity of water in the 19.5–25.5°C temperature range was redetermined by a group of workers at the Norwegian Institute of Technology in 1988, under the stimulus from the IUPAC Subcommittee on Transport Properties headed by Professor J. Kestin. This Note explains an apparent discrepancy, reported in the original work, between the damping-sensitive and the period-sensitive solutions of the working equations employed. The disagreement between the two viscosities reduces to 0.0001 mPa · s, or 0.01 %, when the appropriate corrections to the period are introduced.

KEY WORDS: oscillating-disk viscometer; viscosity; water.

In 1988 Berstad et al. [1] published a redetermination of the viscosity of water entitled "Accurate Measurements of the Viscosity of Water in the Temperature range 19.5–25.5°C," a work initiated under the stimulus from the IUPAC Subcommittee on Transport Properties headed by Professor J. Kestin. The workers employed an oscillating-cylinder technique and obtained a viscosity for water at 20°C that is 0.13 % lower than the currently recommended value, which is based on capillary-type measurements.

Their reported values are based on the imaginary, damping-sensitive solution of the characteristic equation describing the oscillation of disks in a viscous medium. Viscosities derived from the real, period-sensitive solution are discussed only as checks on the internal consistency of the experimental data. The authors noted that their period-sensitive viscosity

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for water was significantly lower than the reported damping-sensitive value, without being able to explain the missing 25 μs that is required to make the two types of calculated viscosities agree at 20°C. They assumed that the error could be attributed entirely to the period as measured in water and increased the uncertainty of this period to 25 μs while retaining a 2-μs error for the period in air.

As one of the authors, I have recently realized that the Appendix "Corrections to T_0 and Δ_0 in a Gas" in the 1987 article by Nieuwoudt et al. [2] explains this apparent discrepancy. We made the error of calculating the various corrections to the measured decrements, as described in our paper [1], without considering that similar corrections to the periods are also needed to obtain correct viscosities from the real solution.

Thus, a general procedure would be to calculate the correction to the logarithmic decrement as one-half the left-hand side of Eq. (2) in Ref. 1, with the use of appropriate values for the radius-to-height ratio and for the viscosity and density of the surrounding medium. This correction is then input to Eq. (3) in Ref. 1, which is solved for ω, the ratio of the corrected period to that measured [Eq. (3) contains a typographical error—the sign before the term Cpx^{-3} should be negative]. The ratio Δ_0/ω, where Δ_0 is the uncorrected decrement, is taken as Δ_0, which is a safe approximation. This procedure also applies to the oscillating cup, substituting the left-hand side of Eqs. (2) and (3) with the corresponding cup equations, which in this case may be either the approximate solutions [3, 4] or the imaginary and real part of the exact solution for the viscous drag obtained by Kestin and Newell [5].

One of the corrections concerns the drag of the air around the cylinder. This must be calculated from the known viscosity and density of air and subtracted from the measured damping and period in air, since this drag vanishes when the cylinder is immersed in water. Calculating a new, corrected period in air from the experimental data in Fig. 5 in Ref. 1, I arrive at a value that is 27.2 μs lower than that employed in calculating the period-sensitive viscosity. The second correction is due to the drag of water around the thin rod holding the cylinder, which, for the same example, gives a 1.9-μs negative correction to the period in water. Thus, the total correction is 25.3 μs, or only 0.3 μs from the 25-μs value needed to make the damping and period sensitive viscosities agree exactly. This is within the assigned experimental error of 2 μs. The corresponding discrepancy between the two viscosities then reduces from 0.8 to 0.01% (0.0001 mPa · s).

As noted, Berstad et al. [1] have reported damping-sensitive viscosities. They are not affected by these missing corrections to the periods. The implications of the excellent agreement found on introducing the corrections are otherwise: the resulting internal consistency of the experimental data lends added support to our redetermined values for the viscosity of water in the range 19.5–25.5°C and, if need be, to the accuracy of the theoretical expressions provided by Kestin, Newell, and co-workers [3, 5–10] in the late fifties for the motion of a disk in a fluid medium that underlie our working equations.

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