Ethane: A Viscosity Surface Correlation Convenient for Engineers

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The exact knowledge of thermophysical properties of fluids with industrial importance is needed for a more accurate design of compressors, gas turbines, gas pipelines, as well as cooling and air-conditioning cycles. In addition, algorithms have to be adequately provided for the use by engineers. In contrast to thermodynamic properties, the transport properties of ethane, particularly near to the critical point, are not well-known. The viscosity-surface correlation for ethane [1] implemented in REFPROP [2] is based on an equation of state from 1991 [1]. On the contrary, a reference equation of state published in 2006 [3] is nowadays used in REFPROP for thermodynamic properties of ethane. Furthermore in 1994, Hendl et al. [4] generated a viscosity surface correlation, using theoretically based ways to correlate the data in different regions. The treatment of the critical enhancement contribution to the viscosity in Reference [4] requires a non-classical equation of state and was somewhat cumbersome.

The new representation of the viscosity for the fluid phase of ethane includes a zero-density correlation and a contribution for the critical enhancement, initially both developed separately, but based on experimental data. The higher-density contributions are formed by a combination of double polynomials in the reduced density and reciprocal reduced temperature, some of them combined with a negative exponential function of the reduced density. The final formulation contains 14 coefficients using a state-of-the-art linear optimization algorithm. The new viscosity surface correlation makes use of the reference equation of state for the thermodynamic properties of ethane by Bücker and Wagner [3] and is valid in the fluid region from the melting line to temperatures of 675 K and pressures of 100 MPa.

The viscosity in the limit of zero density is described with an uncertainty of 0.5% (coverage factor k=2) for temperatures $290 < T/K < 625$, increasing to 1% down to 212 K. The uncertainty of the correlated values is 1.5% in the range $290 < T/K < 430$ at pressures up to 30 MPa on the basis of recent measurements judged to be very reliable and increases to 4% for $95 < T/K < 500$ at pressures up to about 55 MPa. In regions in which no experimental data exist, but the equation of state is valid, an uncertainty of 6% is estimated. The uncertainty in the near-critical region ($1.001 < T/T_c < 1.010$ and $0.8 < \rho/\rho_c < 1.2$) increases to 3% with decreasing temperature.

[1] Friend, D. G.; Ingham, H.; Ely, J. F., *J. Phys. Chem. Ref. Data* **1991,** 20, 275-347.

[2] Lemmon, E. W.; Huber, M. L.; McLinden, M. O. *REFPROP, NIST Standard Reference Database 23, Version 9.1.* National Institute of Standards and Technology, Gaithersburg, 2013.

[3] Bücker, D.; Wagner, W., *J. Phys. Chem. Ref. Data* **2006**, 35, 205-266.

[4] Hendl, S.; Millat, J.; Vogel, E.; Vesovic, V.; Wakeham, W. A.; Luettmer-Strathmann, J.; Sengers, J. V.; Assael, M. J., *Int. J. Thermophys.* **1994**, 15, 1-31.