Viscosity Study of Hydrocarbon Liquids at Extreme Conditions

Robert M. Enick [C, S], Hseen O. Baled, Peter Koronaios, Randy Miles, Isaac Gamwo, Deepak Tapriyal, Ward A. Burgess, Mark A. McHugh, Babatunde A. Bamgbade and Yue Wu

US DOE-National Energy Technology Laboratory, Pittsburgh, PA, U.S.A.

rme@pitt.edu

New experimental data on the viscosity of pure n-octane, isooctane, cyclooctane, squalane, and the binary mixture cyclohexane/n-hexadecane are presented at temperatures up to 523 K and pressures up to 242 MPa. These extreme conditions are representative of those encountered in ultra-deep formations such as in the Gulf of Mexico. The measurements were taken with a novel, variable-volume, windowed Inconel rolling-ball viscometer designed by our team and calibrated with various hydrocarbon fluids over wide ranges of temperature and pressure. The estimated accumulated uncertainty in the reported viscosity data is 3 % at a 95 % confidence level. The reported viscosity results are in good agreement with limited lower temperature, lower pressure literature data. The results are modeled with numerous viscosity models suitable for incorporation in compositional reservoir simulators that are capable of estimating viscosity of multiple-component mixtures of changing composition, such as the correlations of Chung-Lee-Starling, Lorenz-Bray-Clark, Pedersen et al., and Aasberg-Petersen et al. Several less common used but more accurate viscosity models were also considered; including free volume theory and friction theory models. Because density input is required for some of the viscosity models, density was estimated with several equations of state; including the Peng-Robinson (PR), the perturbed-chain, statistical associating fluid theory (PC-SAFT), and two models developed by our team; the high temperature-high pressure, volume-translated Peng-Robinson equation of state (HTHP VT-PR) EoS, and the HTHP PC-SAFT EoS. The free volume theory, used in conjunction with either HTHP density model, appears to give the best results.