A Windowed, Variable-Volume, Rolling Ball Viscometer Rated to 260 C and 275 MPa

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Hydrocarbon viscosity data at the high temperature, high pressure (HTHP) conditions associated with ultradeep petroleum reservoirs are required for accurate predictions of reserves and production rates. Therefore we have designed a windowed, variable-volume, rolling ball viscometer rated to ~260oC and 275 MPa. This apparatus incorporates several modifications to the horizontally mounted, variable-volume, Inconel 718 densimeter with a large sapphire window at its end. The viscometer modifications include the introduction of a precisely machined Inconel 718 ball to the cylindrical sample volume, the addition of three sets of small opposing sapphire windows for the determination of the ball velocity at these three points, and the mounting of the viscometer on a tilting table. Pyrex tube inserts and Pyrex balls can be used for measurements of low viscosity gases. The large window at the end of the viscometer is used to verify that only one phase is present in the sample volume and to confirm that the ball does not slide or stop during its roll. This HTHP rolling ball viscometer will be used to measure the viscosity of hydrocarbon fluids ranging from methane to C40. Because our initial experiments will be conducted with normal alkanes with 5 to 18 carbon atoms, the viscometer was calibrated with n-octane (n-C8) with tilt angles ranging from 7o to 30o. The viscometer constant K, which is dependent on geometry, exhibits temperature- and pressure-dependency because HTHP conditions cause slight changes in the viscometer dimensions. The magnitude of these changes was calculated using the material properties of Inconel 718 and the equations governing the pressure- and temperature-induced changes in ball diameter and tube inside diameter. K values at HTHP conditions were then determined and found to correlate to calculated values of Dball/Dtube. The calibrated viscometer was then used to determine the HTHP viscosity of n-C10. The density values of this alkane, which must be known to determine viscosity with a rolling ball viscometer, were previously determined with our densimeter and correlated with our HTHP PC SAFT and HTHP VT SRK EOS. The experimental viscosity values for n-C8 and n-C10 were then compared with predictions obtained with the free volume theory and a modified friction theory.