Improved Characterization of Fluid Phase Behaviour Using an Advanced Microwave Re-Entrant Cavity

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To advance the thermodynamic models needed for many industrial processes, accurate measurements of fluid phase behaviour are essential. Therefore, we present a newly designed microwave re-entrant cavity apparatus to deliver improved phase-behaviour measurements of pure and multi-component fluids. The re-entrant geometry has spatially distinct resonant modes, which are used to determine the dielectric permittivity of the liquid phase, vapour phase, and the liquid volume fraction (L). The first mode (f_{vac} » 320 MHz) is sensitive to small liquid volumes, the second (1.86 GHz) is sensitive to small vapour volumes, and a third mode (6.57 GHz) is sensitive to the interface location. At equilibrium, a system of three equations, one for each mode, allows for the dielectric permittivity of each phase and L to be determined from the measured resonant frequencies. The cavity's suitability for solving this inverse problem was explored using finite element analysis and experiments with pure propane and pentane. A primary limitation of the method was the dependence of the mode shape functions (G_n) on phase permittivities, which becomes measurable for high frequency modes. We propose a solution to account for this dependence using finite element simulations that map the G_n surface as a function of L and the ratio of phase dielectric permittivities.