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Identification of the Compositional Path Followed During Reservoir Simulation Improves the Accuracy and Accelerates the Phase Behavior Calculations

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ABSTRACT

For depletion-drive reservoirs, which constitute the vast majority of the running projects, many operators still use black-oil simulation to speed up calculations during which the PVT values are obtained from prior defined Black Oil Tables (BOT). These Tables are generated a) by use of correlations, b) by transforming computationally the Differential Vaporization (DV) laboratory data to take into account the transfer of fluids from the reservoir to surface via the so called Composite Vaporization path (CV) thus emulating the Composite Differential Vaporization (DVC) process or c) are produced by using tuned EoS models simulating the DVC as it is widely believed that the differential liberation path represents more closely the variation of the reservoir gas and liquid phase compositions within the reservoir during pressure decline. When the dependence of equilibrium k-values with composition becomes significant, compositional simulation is required and an EoS model is used to provide phase behavior. In that case, the solution of the phase behavior problem during simulation runs consumes a considerable part of the total CPU time required accounting up to 70% for Implicit Pressure Explicit Concentration (IMPEC) realizations. In fact, for solving the non-linear problem, the EoS based phase equilibrium computations usually need to be repeated two to four times per grid block and time step, depending on the timestep size and the proximity of the reservoir conditions to the critical ones, to achieve convergence of the Newton-Raphson algorithm.

In this work, the application of the different approaches for generating BOT for oils are reviewed and guidelines are issued for different type of fluids. Several reservoir simulation runs were conducted using a 3-component synthetic oil, a volatile and a near critical oil and the compositional path that is followed by the equilibrium oil and gas phases was monitored both spatially and timewise. It is shown that down to relatively low pressures this path follows very closely that of the Constant Composition Expansion (CCE) study although at pressures close to the abandonment one it might shift slightly towards the DV path. As a consequence, the reservoir equilibrium phases at each cell were found to exhibit PVT values very close to those obtained by flashing the equilibrium phases produced from the CCE path to the surface separation conditions (CCES). Only at low pressures the volumetric factors exhibit an increased variance and are shown to lie between the values obtained from CCES and DVC. Moreover, the PVT values of the equilibrium phases of the reservoir fluids obtained from the simulations were compared to those obtained either by traditional DV-to-CV converting methods (such as those of Dake and McCain) or by established correlations.

The above findings render the selection of the CCE compositional path as the most suitable one for generating BOTs. They also demonstrate that the compositions encountered during a compositional simulation run can be described by a limited set of tie-lines, thus increasing the confidence in the utilization of promising phase behavior accelerating methods such as k-value generating models and the Tie-Line Tabulation approach (CSAT).