SPE 114913

Fluid Characterization for Miscible Floods

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This paper was prepared for presentation at the 2008 SPE Annual Technical Conference and Exhibition held in Denver, Colorado, USA, 21–24 September 2008.

Abstract

The compositional simulation of a miscible gas injection process depends on an equation of state (EOS) model. An EOS model should not only predict traditional black oil PVT experiments for reservoir fluids but also experiments that give gas-oil compositional information, such as swelling tests, multi-contact tests, and slim-tube MMP. The two most common methods used to estimate MMP with an EOS model are traditional slim-tube simulation and, more recently, the analytical tie-line method. In most cases, the MMP computed from a slim tube simulation agrees well with the analytical tie-line method, but on some occasions, the MMP computed from the analytical method differs significantly from the value derived from slim-tube simulation. Additionally, for some gas floods, slim-tube simulation seems to identify an apparent MMP, but the analytical tie-line method fails to give a solution. In this paper, we identify the reason behind these apparent discrepancies: physical dispersion and phase behavior. Thereafter, we propose a reservoir fluid characterization procedure for miscible gas floods that more accurately represents the interaction of flow and phase behavior. We demonstrate this approach for two different gas floods.

Introduction

Phase behavior governs miscible gas flood process (Stalkup 1983) and fluid characterization is one of the most important issues in the compositional simulation of the process (Whitson and Brule 2000). Different methods of fluid characterization (Whitson and Brule 2000, Wang and Pope 2001, Christensen 1999) have been proposed to match black oil experiments such as differential liberation expansion, constant composition expansion, and separator tests, as well as experiments that contain gas-oil compositional information such as swelling tests and multi-contact experiments. In addition to these measurements, Stalkup and Yuan (2005) proposed that an experimental MMP is also an important measurement that needs to be predicted in the EOS development. MMP is usually determined by a series of slim-tube displacements. A typical slim-tube apparatus consists of a 40-60 ft quarter-inch diameter tube. In most versions of the apparatus, an observation window is available so that single or two-phase fluid effluent can be observed by a camera. Recovery is calculated at 1.2 hcpv gas injected and plotted against pressure. MMP is determined at a bend or break-over point in the plot. Besides the experimental method, two numerical methods can be utilized to estimate MMP when an EOS is available: 1D slim-tube simulation and the analytical key tie-line method (Wang and Orr 1997, Jessen *et al.* 1998, Yuan and Johns 2005, Johns *et al.* 1993). In 1-D compositional simulation, recoveries at 1.2 hcpv gas injected are plotted against pressure. As for the experimental slim-tube, MMP is determined at the bend or break-over of the plot. In the analytical method, key tie-lines along the displacement path are traced and MMP is determined when any of the key tie-lines first intersect the critical locus. If the oil tie-line controls miscibility, it is a vaporizing drive, and if the gas tie-line controls miscibility, it is a condensing drive. Anything else is a mixed mechanism.

The MMP computed from the tie-line method is a dispersion-free thermodynamic MMP. The MMP determined by slim-tube experiments or estimated by 1D simulations is influenced by dispersion. Physical mixing, mostly by convective dispersion, exists in slim-tube displacements. Therefore, the MMP from a slim-tube experiment is an apparent MMP, which is affected by dispersion, as contrasted with the MMP computed by the analytical tie line method which is dispersion free. The MMP predicted by 1D compositional simulation is affected by numerical dispersion due to truncation error. The magnitude of numerical dispersion is proportional to the number of grid blocks. In single-phase flow, the numerical equivalent of the physical longitudinal dispersivity is $\Delta X/2$ if the IMPEM method is used to solve mass balance equations in compositional simulators (Lantz 1970). To correctly predict the slim-tube MMP, the numerical dispersivity from numerical dispersion in