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Novel surfactants for mobility and conformance control CO2 foams

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The low viscosity of high pressure CO_2 injection in oil-bearing formations leads to a host of problems including viscous fingering, enhanced gravity override, loss of CO_2 to their zones, high produced gas-to-oil ratios, high CO_2 utilization rates and high gas re-compression costs. Water-alternating-gas (WAG) flooding remains the standard technique for reducing CO_2 mobility via reduction of CO_2 relative permeability, while gels can improve conformance control in stratified formations by diverting flow from thief zones. Surfactant-stabilized CO_2-in-brine foams (CO_2 is the high volume %, internal phase) remain a promising, low-cost means of mobility control and or conformance control. A review of the prior use of nonionic, anionic and cationic surfactants in lab tests and pilot trials will be presented, most notably the alternate injection of aqueous surfactant solution and CO_2 gas (SAG). A summary of our recent surfactant design developments will also be presented. Surfactant solubility studies, high pressure foam stability tests, static and dynamic adsorption experiments, flow-through-porous media pressure drop (i.e., mobility) results and CT imaging of foam formation in porous media will be used to illustrate the performance of the surfactants. For example, certain amphoteric surfactants appear to be excellent foaming agents at extreme temperatures (up to ~130o C) when dissolved in high (~250000 ppm) total dissolved solids (TDS) brines such as those found in Middle Eastern formations. With regard to non-ionics, one can employ specific non-ionic surfactants that dissolve appreciably in CO_2 but are even more brine-soluble. When a CO_2-non-ionic surfactant solution enters the formation, the surfactant will partition into the brine and stabilize the foam, thereby facilitating the continuous injection of a CO_2-surfactant solution (GS process) or the alternate injection of brine and a CO_2-surfactant solution (WAGS). To gain the greatest assurance that foams are generated *in-situ*, an operator could also inject surfactant in the brine phase and in the alternating CO_2 slugs (SAGS). Finally, we will include an assessment of the CO_2-soluble and brine-soluble "switchable" surfactants identified by Johnston and co-workers that exhibit a non-ionic to cationic transformation triggered by the carbonic acid that forms in the brine.

Biography

Robert Enick is the Professor of the Department of Chemical and Petroleum Engineering at the University of Pittsburgh. He is an ORISE Faculty Fellow at the National Energy Technology Laboratory, where he teams with NETL scientists to study high pressure phase behavior and viscometry related to primary and tertiary oil recovery processes. He also has expertise in improving the performance of CO_2 enhanced oil recovery by decreasing its mobility with CO_2-soluble thickeners, CO_2-soluble foaming agents and brine-soluble surfactants. He also studies the thickening of natural gas liquids for improved hydrocarbon miscible displacement.

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