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# Experimental investigation of the extent to which different concentrations of $C_3H_8$, $CH_4$ and $CO_2$ affect CSI performance

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Cyclic Solvent Injection (CSI) technique holds great promise as a viable approach to produce heavy oil from thin reservoirs where thermal and gravity-dominated recovery methods fail to produce oil. $CO_2$ and $C_3H_8$ (due to their high solubility) are the main solvents that have been used in CSI. However, $CO_2$ is not always accessible and it causes corrosion problems during implementation. In addition, low saturation pressure of $C_3H_8$ limits the application of pure $C_3H_8$ for heavy oil extraction. On the other hand, $CH_4$ is widely accessible and has high saturation pressure. In this study, different concentrations of $C_3H_8$ in $CH_4$ stream (i.e., 15, 30, and 50 mole %) are tested. A sandpack model with porosity and permeability of 32.4% and 9.7 d, and a heavy crude oil with viscosity of 6430 mPa.s are used to represent a typical thin heavy oil formation. First, different ratios of $C_3H_8$ to $CH_4$ stream are examined to quantify the optimum solvent concentration. Second, $CO_2$ is introduced to the optimum $CH_4$-$C_3H_8$ concentration to investigate the extent to which CSI behavior changes by partially replacement of $CH_4$ with $CO_2$. Results show that ultimate recovery factor (RF) increases from 24.3% to 33.4% original oil in place (OOIP) when $C_3H_8$ concentration increases from 15 to 50 mole% in the $CH_4$ stream. CSI tests with higher $C_3H_8$ concentration reaches the maximum cyclic recovery with lower number of injection cycles due to higher solubility of $C_3H_8$ compared with $CH_4$. Solvent utilization factor (SUF) data also confirms this as lesser volume of solvent with higher $C_3H_8$ concentration is required to produce oil. Virtual observations also shows that the foamy oil produced during the process lasts longer with higher concentration of $C_3H_8$ (2 min for 85% CH4-15% C3H8 case and 180 min for 50% $CH_4$-50% $C_3H_8$ case). Upon addition of $CO_2$ to the mixture, the oil production is slightly improved as the ultimate RF increases to 35.9% OOIP. The produced foamy oil also lasts for 197 min for 50% $C_3H_8$-35% $CH_4$-15% $CO_2$ case. In general and for all cases, the solvent oil ratio (SOR) increases with cycle numbers, specifically during the last two cycles, highlighting that large portion of the injected solvent is produced instead of diffusing into the oil phase.

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