

## **GENERATION OF H<sub>2</sub>S AND OTHER GASES DURING THERMAL RECOVERY OF HEAVY OILS**

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Significant heavy oil resources available in the industry may not be candidates for conventional thermal recovery application such as cyclic steam (huff-and-puff) or continuous steam drive due to issues associated with depth, reservoir pressure, or remote locations. In-situ combustion (fireflood) offers an alternative recovery process for heavy oils. The in-situ combustion process tends to induce oil cracking in reservoirs, which not only yields light oil and hydrocarbon gases for improved oil recovery but also generated undesirable products such as H<sub>2</sub>S, CO<sub>2</sub>, organic sulfur species, and possibly coke. These products will undoubtedly impact the oil recovery, facility design, and environmental considerations. The degree of oil cracking and the distribution of the products are most likely dependent on many variables such as temperature of the process, the type of heavy oil involved, and rocks in the reservoir. A good understanding of oil cracking associated with the thermal recovery processes, particularly fire flood, is therefore crucial in predicting chemical and physical properties of produced fluids, which can help optimize the designs of the recovery process and production facilities.

Chemistry and kinetics of oil cracking associated with fire flood are the focus of the study as the in-situ combustion is likely to involve more severe oil cracking than steam assisted recovery processes. Combustion and pyrolysis are two essential chemical reactions involved in the fireflood recovery process. Combustion generates the heat that not only mobilizes the heavy, viscous oil in the reservoir but also cracks the oil reservoired in the zones near the combustion zone yielding lighter oil, hydrocarbon gases, and some non-desirable products such as CO<sub>2</sub>, H<sub>2</sub>S, and other sulfur species.

Extensive laboratory pyrolysis of heavy crude (9.7 API gravity) from Cymric Field in San Joaquin Valley, CA, has been conducted with and without the presence of the reservoir rock. Based on the results, a detailed reaction network scheme for hydrocarbons and sulfur compounds was proposed and kinetics parameters were derived. The proposed kinetics scheme is expected to facilitate the prediction of the changes in the composition of Cymric

heavy oil, gas generation ( $\text{H}_2\text{S}$ ,  $\text{CO}_2$  and hydrocarbon gases), organic sulfur formation, and coke formation under the fireflood conditions. The catalytic effect of the reservoir rock on oil cracking and sulfur compounds generation was also evaluated. Oil cracking and yields of some early formed products such as methane,  $\text{CO}_2$ , and sulfur compounds are significantly increased with the presence of the reservoir rock. The other fractions, such as  $\text{C}_2\text{-C}_5$  (LPG),  $\text{C}_6\text{-C}_{14}$  (light oil),  $\text{C}_{14}^+$  (intermediate oil) and coke, are generated in similar amounts with or without the reservoir rock. The kinetics scheme can be readily integrated into reservoir simulation for production forecast and planning. The distribution of organic sulfur species in produced oils has the potential to be used in monitoring the progress of the combustion front in fireflood reservoirs.