Authors' Reply to Discussion of Reservoir Simulation: State of the Art

SPE 12290

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Regarding chemical flooding, Mr. Khatib is apparently referring to the Bell Creek micellar/polymer pilot simulation as compared to the field results.[1] It is surprising that the simulation came as close as it did to the actual field results because (1) values of remaining oil saturation used to characterize the reservoir for simulation were higher than those existing in the field,[2] (2) there is a permeability barrier between the central injector and one of the producers that was not entirely accounted for in the simulation, (3) the coreflood selected for history matching[3] and used to describe the process for the simulator was optimistic, (4) the interfacial tension, phase viscosity, and phase behavior data used in the simulation were for the most part assumed and were not based on actual laboratory data, and (5) the equivalent weight of the injected sulfonate may have been below design specifications.[2]

Chemical flood simulation of the El Dorado pilot yielded a somewhat better comparison with the results at an observation well, but even here process data were limited.[4]

Although many of the mechanisms operative in chemical flooding are not well understood, a final judgment of currently available simulators cannot be made until adequate laboratory data are available to exploit the mechanisms that are known.

In deference to Mr. Khatib's closing remarks, the paper's statement "Numerical simulation provides a reliable means to predict chemical flood..." might better state "...provides the best available means to..." That is, while the process complexity (or insufficient laboratory data) currently introduces uncertainty in numerical model results, it also widens the gap between reliability of intuitive or rule-of-thumb and model predictions.

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References

1. "Bell Creek Field Micellar-Polymer Pilot Demonstration," Final Report (June 1976–March 1982) U.S. DOE, DOE/SF/01802-61 (Sept. 1982).
2. "An Evaluation of the Bell Creek Field Micellar-Polymer Pilot," U.S. DOE, DOE/BC/10033-5 (Dec. 1982).
3. Todd, M.R. *et al.*: "Numerical Simulation of Competing Chemical Flood Designs," paper SPE 7077 presented at the 1978 SPE Symposium on Improved Methods for Oil Recovery, Tulsa, April 16–19.
4. "Data Requirements for EOR Surfactant-Polymer Process Simulation and Analysis of El Dorado Pilot Project Simulation, Butler County, Kansas," U.S. DOE, DOE/ET/10145-74 (Jan. 1983).

pressurizes the space and differentially vaporizes the condensate. Then the first withdrawal of gas would start at the end without gas injection, giving a higher yield of liquid than Mode 1. The gas from the injection end when the wells are needed for deliverability would have lower yields. It is possible to reach an equilibrium dewpoint before reaching the full reservoir pressure by using pressure above discovery. Then the added gas can be introduced where desired to give an option of withdrawing for peaking dry gas that does not require processing to make it of pipeline quality, a Mode 3.

Well positions and completion depths along with geologic variations in permeability thwart attempts for an ideal behavior of gas contacting the condensate wetting the rock, reducing yields and preventing ideal recoveries.

Recovery of Condensate

Retrograde condensate and residual crude oil in secondary gas caps of non-water drive oil fields defy recovery except by vaporization. The use of circulating low-pressure gases to recover natural gasoline has been practiced for a long time. The use of high-pressure gas to recover heavier hydrocarbons generally has had insufficient economic incentives until this miscible oil-recovery process could be coupled with a gas storage project.

Examination of the data on the Cold Springs 12 and Rapid River 35 reservoirs (Table 1 and Figs. 1 and 2) shows considerable condensate recovery, but far short of the equalized mixing assumed in the calculated yields. The decreases in yield on successive years is in general accord with repetitive retrograde processes. However, the injected gas is contacting only a portion of the reservoir rock. Normally, gas storage wells are drilled to obtain deliverability with minimum interference in flow. For condensate recovery, the spatial relationship could be designed for more effective sweep by using Mode 2. Experiences in condensate recovery in cycling may be helpful in understanding a method of more complete sweep of the full reservoir.

The condensate recovered in 3 years of storage operation represents 35 to 57% of the primary production.

References

1. Firoozabadi, A., Hekim, Y., and Katz, D.L.: "Depletion Calculations for Gas Condensate Reservoirs," *Cdn. J. Chem. Eng.* (1978) **56**, 610-16.
2. Peng, D.Y. and Robinson, D.B.: "A New Two Constant Equation of State," *Ind. Eng. Chem. Fund.* (1976) **15**, 59-64.
3. Katz, D.L. and Firoozabadi, A.: "Predicting Phase Behavior of Condensate/Crude-Oil Systems Using Methane Interaction Coefficients," *J. Pet. Tech.* (Nov. 1978) 1649-55.
4. Bergman, D.F., Rek, M.R. and Katz, D.L.: "Retrograde Condensation in Natural Gas Pipelines," AGA, Arlington, VA (1975).
5. Katz, D.L.: "Overview of Phase Behavior in Oil and Gas Production," *J. Pet. Tech.* (June 1983) 1205-1214.
6. Katz, D.L. and Tek, M.R.: "Overview on Underground Storage of Natural Gas," *J. Pet. Tech.* (June 1981) 943-51.

SI Metric Conversion Factors

bbl/Mscf	× 1.330 11	E−01	= $dm^3/kmol$
°F	(°F−32)/1.8		= °C
psi	× 6.894 757	E+00	= kPa

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