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**MODIFICATION OF RESERVOIR CHEMICAL AND
PHYSICAL FACTORS IN STEAMFLOODS TO INCREASE
HEAVY OIL RECOVERY**

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University of Southern California

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MASTER

Principal Investigator: Yanis C. Yortsos

Contracting Officer's Representative (COR): Thomas B. Reid

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MODIFICATION OF RESERVOIR CHEMICAL AND PHYSICAL FACTORS IN STEAMFLOODS TO INCREASE HEAVY OIL RECOVERY

OBJECTIVES

Thermal methods, and particularly steam injection, are currently recognized as the most promising for the efficient recovery of heavy oil. Despite significant progress, however, important technical issues remain open. Specifically, still inadequate is our knowledge of the complex interaction between porous media and the various fluids of thermal recovery (steam, water, heavy oil, gases, and chemicals). While, the interplay of heat transfer and fluid flow with pore- and macro-scale heterogeneity is largely unexplored.

The objectives of this contract are to continue previous work and to carry out new fundamental studies in the following areas of interest to thermal recovery: displacement and flow properties of fluids involving phase change (condensation-evaporation) in porous media; flow properties of mobility control fluids (such as foam); and the effect of reservoir heterogeneity on thermal recovery. The specific projects are motivated by and address the need to improve heavy oil recovery from typical reservoirs as well as less conventional fractured reservoirs producing from vertical or horizontal wells.

VAPOR-LIQUID FLOW

During this quarter, work continued on the development of relative permeabilities during steam displacement. Most of the work concentrated on the representation of the three-phase flow in terms of a double-drainage process (1). A technical paper is still in preparation. In parallel, we continued our investigation of the effect of gravity override during injection of a gas phase (such as steam) in porous media was continued. We developed a fundamental approach using pore network models and concepts from gradient percolation to describe the effect of gravity, capillarity and viscous effects on the thickness of the gravity tongue. We studied both stable and unstable displacements and developed scaling laws that express the tilt and the thickness of the gravity tongue in terms of the capillary number and the gravity Bond number. This problem has implications to the prediction of gravity override.

A technical paper is in preparation (2). In addition, we have considered the modeling of the countercurrent flow of liquid and vapor in the presence of gravity using a pore network approach. The results are compared to continuum theory predictions using the more conventional relative permeability formalism (2).

In parallel, we have started two new investigations, one in diffusion-controlled evaporation processes and another in condensation processes. We use an approach similar to our previous work on bubble growth in porous media (3), which combines pore-network simulations, theory and experiments. This work is at a preliminary stage. Finally, we are in the process of completing a theoretical work, to express the variation of the critical gas saturation in solution-gas drive processes as a function of the applied pressure decline rate, and the nucleation frequency. During this quarter, a technical paper was presented on steam injection in fractured systems (4).

HETEROGENEITY

Work continued on the optimization of recovery processes in heterogeneous reservoirs by using optimal control methods. The effort at present is concentrating in fine-tuning the optimization algorithm as well as in developing control methodologies with different constraints. In parallel, we continued experiments in a Hele-Shaw cell with two controlled injection wells and one production well. In addition, we are continuing to address the problem of targeted delivery of fluid parcels by optimizing the design of the injection rates in a three-well system. Experiments were conducted to test the theory in a Hele-Shaw cell. It was found that the effect of dispersion can be significant. Currently, we are investigating the use of a packed cell in these experiments.

On the subject of heterogeneity, we developed a new approach to establish the validity of stabilized displacements in immiscible displacements in porous media from pore-network level studies. A technical paper on this subject was completed (5). Work is also continuing on the identification of permeability heterogeneity from tracer profiles (e.g. those obtained from a CT scan). A new technique was developed, which is still being tested with synthetic data. Currently, we are trying to improve the numerical algorithm, which is based on the solution of a non-linear Laplace equation.

CHEMICAL ADDITIVES

In the area of chemical additives work continued on the behavior of non-Newtonian fluid flow and on foam displacements in porous media. We have completed and presented a technical paper on the subject of foam formation and mobilization (6). A parallel effort is being made to the problem of Bingham plastic flow in porous media.

REFERENCES

1. Halbhavi, N., *M.S Thesis*, University of Southern California (December 1996).
2. Zhang, Y. , *M.S Thesis*, University of Southern California (expected August, 1997).
3. Li, X., and Yortsos, Y.C., *Multiple bubble growth by solute diffusion in porous media*, Chem. Eng. Sci., **50**, 1247 (1995).
4. Haghighi, M. and Yortsos, Y.C., *Visualization of steam injection in fractured systems using micromodels*, paper SPE 37520 presented at the International Thermal Operations and Heavy Oil Symposium, Bakersfield, CA (Feb. 10-12, 1997).
5. Yortsos, Y.C., Xu, B., and Salin, D., *Phase diagram of fully developed drainage in porous media*, submitted to Phys. Rev. Lett. (1997).
6. Kharabaf, H., and Yortsos, Y.C., *A Pore-Network Model for Foam Formation and Propagation in Porous Media*, paper SPE 36663, presented at the International Thermal Operations and Heavy Oil Symposium, Bakersfield, CA (Feb. 10-12, 1997).

FACULTY

Y. C. Yortsos

STUDENTS

Youngmin Choi

Bagus Sudaryanto

Lang Zhan

Yuyong Zhang