PROJECT FACT SHEET

CONTRACT TITLE: Pore-Scale Flow and Examination of the Effects of Scaling on Improved Oil Recovery Processes (PARTNERSHIP)

ID NUMBER: FEW 9999

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DOE PROGRAM MANAGER:
NAME: Arthur M. Hartstein
PHONE: (301) 903-2760

DOE PROJECT MANAGER:
NAME: Rhonda P. Lindsey
LOCATION: BPO
PHONE: (918) 337-4407

PROJECT SITE:
Los Alamos, NM

CONTRACTOR: Los Alamos Nat'l Lab
IIOR, Mobil
ADDR: P.O. Box 1663
EES-DO/MS D446
Los Alamos, NM 87545

CONTRACT PROJECT MANAGER:
NAME: Dr. Robert J. Hanold
PHONE: (505) 667-1698
FAX: (505) 667-3494

CONTRACT PERFORMANCE PERIOD:
05/10/1991 to 07/04/1995

PROGRAM: Supporting Research
RESEARCH AREA: Partnership

FUNDING (1000'S)	DOE	CONTRACTOR	TOTAL
PRIOR FISCAL YRS	670	0	670
FISCAL YR 1996	0	0	0
FUTURE FUNDS	0	0	0
TOTAL EST'D FUNDS	670	0	670

OBJECTIVE: A collaboration with industry to apply new computational techniques to the problem of more accurately predicting relative permeability for application in simulation of waterflooding and other enhanced oil recovery processes. A novel computational tool developed at Los Alamos is used for modeling pore scale phenomena and studying the scaling of these phenomena from the micro scale to the continuum scale.

METRICS/PERFORMANCE:
Products developed:

PROJECT DESCRIPTION:

Background: This work concentrates on waterflooding because it is the most common improved recovery technique used by both majors and independents in stimulating petroleum flow from primary produced fields. Estimates of reservoir performance obtained from simulations are very sensitive to the relative permeability functions used for the displacement processes. Therefore, more accurate relative permeability estimates for waterfloods can provide a significant benefit to industry when making economic decisions related to continued development of a field.

Work to be performed: This work will apply a pore-scale simulation tool being developed at Los Alamos to compute relative permeabilities and displacement efficiencies for real porous systems. The simulation method used is lattice Boltzmann hydrodynamics which supplies solutions in the Navier-Stokes equations for single-phase or multi-phase fluid flow in arbitrarily complex pore space geometries. In this work high-resolution digitization of pore geometries from actual porous media are used. The pore space data is provided by the industrial collaborators, and includes 2-D micromodels, 3-D glass beadpacks, and 3-D samples of Berea sandstone and other reservoir rocks. We plan to predict the effects of variable and changing wettability on the relative permeability of these systems for water and oil phases. These results will be verified through comparison against data from core-flood experiments. The influence of both wettability and capillary number on displacement efficiency will also be studied. This work is possible due to the availability of the pore space data, the computational technique, and the massively parallel computing capability (Thinking Machine CM5) at Los Alamos Advanced Computing Laboratory.

PROJECT STATUS:

Current Work: The project is continuing on schedule.

Scheduled Milestones:

Conduct core flood experiments	09/93
Simulate experimental results and derive constitutive relationships at the core scale	12/93
Derive constitutive relationships at the core scale	12/93
Provide experimental data against which model result	12/94
Simulate experimental results	06/95
Examine sweep efficiencies and pressures behavior during waterfloods	06/95

Accomplishments: At this time we have a very robust pore scale multiphase lattice Boltzmann flow code, capable of simulating flow through systems of arbitrary geometry, arbitrary surface characteristics, and arbitrary fluid properties. The model has been shown to reproduce contact angles through a full 180 degree range, thus allowing an entire range of surface wettability. Arbitrary, mixed wettability configurations can be assigned to the walls of the pore spaces to reproduce real surface characteristics. Further, we are able to simulate injection of wettability and non-wettability phases at arbitrary ratios into high-resolution pore spaces. The code capability has also been extended to efficiently calculate flow for fluids with density ratios of as much as 500-700, arbitrary viscosity ratios and arbitrary interfacial tensions. This results in an ability to accurately and efficiently model almost any fluid of interest.

Analysis of the dependence of relative permeabilities on capillary numbers and wettabilities using lattice Boltzmann multi-phase porous media codes has begun. Both steady and unsteady flow calculations have been carried out for both two and three-dimensional digitized geometries, provided by Mobil in Dallas, Texas. The relative permeability curves obtained for both wetting and non-wetting fluids obtained have the correct qualitative form as predicted by real experimental measurements. The wettability effect on the relative permeability versus saturation is under study. These results will furnish a better understanding of the flow of multi-phase fluids through arbitrary porous media.

We have also begun to study the relationship between relative permeabilities and the pressure difference applied to the system. Particularly we have observed that the traditional linear relationship is valid for high pressure differences and for high capillary numbers. For small capillary number flows, however, it appears that the cross term in the constitutive relation becomes important, and Darcy's simple linear relationship should be modified to include a non-linear term in order to account for underlying physics, such as surface-surface and surface-rock interactions.