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RESEARCH ON OIL RECOVERY MECHANISMS IN HEAVY OIL RESERVOIRS

Quarterly Report for the Period
April-June 1991

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RESEARCH ON OIL RECOVERY MECHANISMS IN HEAVY OIL RESERVOIRS

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Stanford University Petroleum Research Institute
Stanford, California

Contract Date: February 1987

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Reporting Period: April 1 - June 30, 1991

OBJECTIVES

The goal of the Stanford University Petroleum Research Institute is to conduct research directed toward increasing the recovery of heavy oils. Presently, SUPRI is working in five main directions:

1. FLOW PROPERTIES RESEARCH - Assess the influence of different reservoir conditions (temperature and pressure) on the absolute and relative permeability to oil and water and on capillary pressure.
2. IN-SITU COMBUSTION STUDIES - Evaluate the effect of different reservoir parameters on the *in-situ* combustion process. This project includes the study of the kinetics of the reactions.
3. ADDITIVES TO IMPROVE STEAM INJECTION - Investigate the mechanisms of the process using commercially available surfactants for reduction of gravity override and channeling of steam.
4. RESERVOIR DEFINITION - Investigate and improve techniques of formation evaluation such as tracer tests and pressure transient tests.
5. FIELD SUPPORT SERVICES - Provide technical support for design and monitoring of DOE sponsored or industry initiated field projects.

GENERAL INFORMATION

Three papers will be presented or published:

1. Demiral, B.M.R., L.M. Castanier, and W.E. Brigham: "CT Imaging of Steam and Steam Foam Laboratory Experiments," SPE 22644, paper to be presented at the Annual Technical Conference, Society of Pet. Engrs., Dallas (October 6-9, 1991).
2. Hornbrook, J.W., L.M. Castanier, and P.A. Pettit: "Visualization of Foam/Oil Interactions in a High Resolution Sandstone Replica Micromodel," SPE 22631, paper to be presented at the Annual Technical Conference, Society of Pet. Engrs., Dallas (October 6-9, 1991).
3. Riley, M. and W.E. Brigham: "Determining Barrier Distance Using Type Curves," submitted for publication in the SPEFE Journal.

Two reports will be published:

1. Lim, Kok Thye: "Steam Distillation Effect and Oil Quality Change During Steam Injection."
2. Alvarado, D.: "Numerical Simulation Study of Well-to-Well Tracer Flow Test with Nonunity Mobility Ratio."

SUMMARY BY PROJECT

Project 1: Flow Properties Studies

Software development for CT data interpretation is in progress. The transfer protocol from the CT computer to the work stations was completed last quarter. The work this quarter has focused on edge detection and subtraction methods included in Shell's CATPIX program. Several cores are being calibrated. The donut-shaped sleeve has been tested for CT measurements in linear cores. The water filled sleeve results in significant reduction in beam hardening. Consequently, the image quality around the relative permeability core holder is better, which should improve the accuracy of the saturation data.

Several runs were made on the flow properties apparatus to measure the end effect saturations in relative permeability studies. Presently, we are trying to determine the conditions under which inlet end effects can cause significant problems in oil/water systems. Numerical simulation of the experiments has started using the ECLIPSE simulator. It may be necessary to use a three-dimensional grid to properly match the experimental results.

Project 2: In-situ Combustion

Three combustion runs using Cymric (California) 11° API oil and metallic additives have been completed this quarter. The runs were as follows: no additive, ferric nitrate and zinc nitrate. Qualitative results show that iron has a greater effect than zinc. We noticed increases in combustion efficiency and fuel deposition and a decrease in H/C ratio of the fuel burned when iron is present. Because of the small effect of zinc, aluminum will be used instead of zinc for the next series of runs.

A kinetics run was made on Huntington Beach oil. Emphasis was on testing the equipment for repeatability and in investigating the high temperature reaction region. It appears that in this region the reactions need to be modeled by two types of reactions instead of only one as previously thought. Previous data will be analyzed in detail to verify this point.

A technical report presenting the distillation correlations results is in the draft stage. Using US DOE data bank distillation data, we were able to develop correlations relating distillation and gravity of California crude oils. This work will be useful to determine residual saturation to steam drive and fuel concentration in in situ combustion. This work focuses on California oils but will be extended to other crudes in the near future.

Project 3: Steam with Additives

A study has been initiated on the mechanisms involved in steam injection in fractured reservoirs. The objective is to combine numerical and experimental techniques to improve knowledge of matrix/fracture transfer functions in thermal recovery operations. The first stage was a literature review. The second stage, now in progress, is using fine grid simulation with a commercial simulator, STARS, from the CMG group. The third phase will involve designing and building the experiment which will include saturation measurements by CT. The study will conclude by comparing numerical and experimental results.

A report on further results of steam injection with additives in the presence of residual oil is in the draft stage. Publication is expected in October 1991.

A paper summarizing the results to date on the three dimensional steam injection model will be presented at the fall meeting of the SPE (see above). This publication presents details on this project.

A number of high resolution micromodels were made which replicate in two dimensions a Berea flow path. The pore throats are as small as 1 micron and the grain surface resolution is 0.5 micron. The models are etched in silicon wafers. Runs were made to investigate oil displacement by a surfactant slug and by high quality foam. The wettability of the medium changes depending on the injection method used. Under surfactant slug injection, the oil is the wetting phase. Under foam flow, the foam is destroyed by contact with the oil and the surfactant wets the porous medium. The foam is more stable if a slug of surfactant is injected prior to foam displacement.

A few more experimental runs were made on foam flow in the one-dimensional model. These were gas displacements of surfactant-laden solutions, and three runs were made to measure the adsorption of the surfactant onto the sand using 0.01, 0.1 and 1% concentrations. The effluents were analyzed by titration, and the data were generalized into a Langmuir curve. Two foam runs were made at surfactant concentrations of 0.1 and 1%. Saturations were obtained using the Cat-scanner at various locations and pressure drops were recorded. To get the fractional flow curves, the gas displacement data was analyzed and matched in many different ways. A program was written to calculate the saturation profiles and recovery given the experimental parameters. The goal is to produce a semi-analytical foam model that will match the fractional flow curves and include the effects of adsorption and mixing.

Project 4: Formation Evaluation

A report on the use of the numerical simulator UTCHEM for tracer test interpretation is in the draft stage. This study will be concluded by the publication of this report.

Two projects on tracers started in March, 1991. The first concerns the design and analysis of tracer tests in irregular patterns and the second concerns fractional flow curves for an isolated five-spot pattern. In the first project, a program has been developed to compute tracer production profiles. It was tested on the example given by Brigham and Smith for field data and generated the same production curve. Nonlinear regression will be used to analyze the response. In the second project, it is theoretically possible to generate the fractional flow curve for an isolated five-spot pattern based on the complex potential concept. To date, the program gives a cluster of curves close to each other. Better numerical methods are needed.

Another project in formation evaluation concerns well testing in low pressure gravity drainage systems. The literature search and preliminary statement are in progress for this problem for well testing in gravity drainage situations.

Project 5: Support Services

Design has begun on a small flow loop for multiphase flow rate measurements. The first tool to be tested is a commercial sonic flow meter for oil/water measurements. Construction is expected to begin in October 1991.

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