**RESEARCH ON OIL RECOVERY MECHANISMS
IN HEAVY OIL RESERVOIRS**

CONTRACT NO. DE-FG-22-93BC14899

Stanford University Petroleum Research Institute
Stanford, California

Contract Date: February 8, 1993

Principal Investigators
William E. Brigham

Technical Manager SUPRI
Louis M. Castanier

Technical Project Officer (DOE)
Thomas B. Reid

Reporting Period: April 1 - June 30, 1995

RECEIVED
USDOE/PETC
95 AUG 16 AM 10:39
ACQUISITION & ASSISTANCE DIV.

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 STUDIES** — To 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** — To 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. **STEAM WITH ADDITIVES** — To develop and understand the mechanisms of the process using commercially available surfactants for reduction of gravity override and channeling of steam.
4. **FORMATION EVALUATION** — To develop and improve techniques of formation evaluation such as tracer tests and pressure transient tests.
5. **FIELD SUPPORT SERVICES** — To provide technical support for design and monitoring of DOE sponsored or industry initiated field projects.

MASTER

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

GENERAL INFORMATION

A seminar on Pilot Flooding was given at University of Southern California on April 27, 1995..

A paper, "Foam Field tests: State of the Art and Critical Review by L.M.Castanier and J.E.Hanssen was presented at the Eighth European Improved Oil Recovery Symposium at Vienna on May 15-17, 1995.

Informal cooperation on the use of SUPRI X-ray CT scanner has been initiated with Professors Patzek and Radke at University of California at Berkeley.

PROJECT 1: Flow Properties Studies

The report on end effects during unsteady state oil water displacement experiments is still in the draft stage.

Calibration of the new CT-scanner for three-phase saturation measurements is almost complete. The sandstone phantoms containing pure fluids (air, water and mineral oil) are now scanned at various energy levels to assess the best protocol. Dopants will also be investigated. Various research projects involving fracture determination and two phase flow observation now routinely use the CT scanner equipment and interpretation software.

Construction of the flow system for isothermal studies of flow through fractured media is almost complete with the exception of the data logging equipment. Calibration

of the pumps and pressure transducers is in progress. Dry scans of the cores have been made and local porosity will be determined by water saturation and scanning. Attempts to obtain local permeability will be made by miscibly displacing two fluids with a good contrast under the CT scanner.

Construction of the equipment for the steam water relative permeability studies is still in progress. Preliminary runs in a Nitrogen /water system are progressing satisfactorily.

PROJECT 2: In-Situ Combustion

The report describing five in-situ combustion tube runs with Saudi tar and metallic additives is being prepared and scheduled for DOE review in the Fall, 1995.

We are now preparing the equipment for two new tube runs involving a sulfur rich middle eastern oil. One of the runs is a control run and the other will contain a metallic additive. As one of our industry associate has offered to perform spectroscopy analysis of the products of combustion, we will use tin as the metallic additive. The burned cores as well as the combustion products will be analyzed in detail to better understand the additive transport and the combustion process.

PROJECT 3 : Steam Injection With Additives

Water flood and steam flood experiments were completed in the three-dimensional model. Despite a leak that developed at the bottom of the model during the steam drive

experiment, good saturation data were obtained by the cat scan. The CT scanning interpretation programs previously developed in house were used to interpret the results and verification will be done by using mass and heat balances on the model. A report on those results is expected by Winter, 1995.

History matching of the steam injection experiments in fractured media has continued. Heat losses from the experiment were successfully matched by using the convective heat loss model of the STARS simulator and the predetermined convective heat loss coefficients from analytical models. Different steam water relative permeability curves were used in the simulations. They have a significant effect on the matrix steam saturation. The main conclusion to date from both the simulations and the experiments is that almost no steam is in the matrix and the heat transfers to the matrix by conduction. Pressure cycling did not increase the steam saturation in the matrix. The case where no heat flow to the boundary is closer to field problems and is now being investigated by simulation. An abstract on this work is going to be submitted for presentation at the SPE/DOE meeting on Enhanced Oil Recovery in April 1996.

A report is being sent to DOE on the observations of foam flow at low surfactant concentration in realistic sized silicon micro models. When weak foams are flowing in our system we did not observe thin lamellae created by snap off. Instead most of the gas flow resistance seems to be caused by liquid lenses remaining in the pore necks. In order to better understand the threephase flow problems associated with these displacements, drainage and imbibition displacements will be made with pure oil and water. In the drainage, air will be injected in the model saturated with water at residual oil saturation while in the imbibition experiments the model will have all three phases present initially and water will be injected.

PROJECT 4: Formation Evaluation

No work was performed on this subject during this reporting period.

PROJECT 5: Field Support Services

A report is being drafted summarizing work done on the thermal project in the Wilmington field. Previous work consisted in heat balance calculations and determination of the heat losses. The current project includes an economic analysis and a risk evaluation carried out using Monte Carlo simulation on both the technical and the economic analysis.