DOE/BC/14939--5

INCREASING HEAVY OIL RESERVES IN THE WILMINGTON OIL FIELD THROUGH ADVANCED RESERVOIR CHARACTERIZATION AND THERMAL PRODUCTION TECHNOLOGIES

Cooperative Agreement No.: DE-FC22-95BC14939

Contractor Names: City of Long Beach Department of Oil Properties (City) and Tidelands Oil Production Company (Tidelands), Long Beach, CA.

Date of Report: August 5, 1996

Award Date: March 30, 1995

Anticipated Completion Date: March 29, 1999

DOE Award: $3,408,216 (1995 Actual)
$2,184,000 (1996 Projected)
$496,058 (1996 YTD Actual)

Principal Investigator: Scott Hara - Tidelands

Program Manager: Edith Allison - Bartlesville Project Office

Reporting Period: April 1, 1996 to June 30, 1996

DISCLAIMER

Objectives

The project involves improving thermal recovery techniques in a slope and basin clastic (SBC) reservoir in the Wilmington field, Los Angeles Co., Calif. using advanced reservoir characterization and thermal production technologies.

The existing steamflood in the Tar zone of Fault Block (FB) II-A has been relatively inefficient because of several producibility problems which are common in SBC reservoirs. Inadequate characterization of the heterogeneous turbidite sands, high permeability thief zones, low gravity oil, and nonuniform distribution of remaining oil have all contributed to poor sweep efficiency, high steam-oil ratios, and early steam breakthrough. Operational problems related to steam breakthrough, high reservoir pressure, and unconsolidated formation sands have caused premature well and downhole equipment failures. In aggregate, these reservoir and operational constraints have resulted in increased operating costs and decreased recoverable reserves. The advanced technologies to be applied include:

(1) Develop three-dimensional (3-D) deterministic and stochastic geologic models.
(2) Develop 3-D deterministic and stochastic thermal reservoir simulation models to aid in reservoir management and subsequent development work.
(3) Develop computerized 3-D visualizations of the geologic and reservoir simulation models to aid in analysis.
(4) Perform detailed study on the geochemical interactions between the steam and the formation rock and fluids.
(5) Pilot steam injection and production via four new horizontal wells (2 producers and 2 injectors).
(6) Hot water alternating steam (WAS) drive pilot in the existing steam drive area to improve thermal efficiency.
(7) Installing an 2400 foot insulated, subsurface harbor channel crossing to supply steam to an island location.
(8) Test a novel alkaline steam completion technique to control well sanding problems and fluid entry profiles.
(9) Advanced reservoir management through computer-aided access to production and geologic data to integrate reservoir characterization, engineering, monitoring, and evaluation.

Summary of Technical Progress

This is the fifth quarterly technical progress report for the project. Through June, 1996, the project is making good progress but is slightly behind schedule. Estimated costs are on budget for the work performed to date. Technical achievements accomplished during the quarter including a petrophysical rock-log model and a geochemical study of

the scale minerals being created in the wellbore. Steam injection into the two horizontal injection wells began in mid-December 1995 utilizing the new 2400 ft steam line under the Cerritos Harbor Channel. Initial oil production from the project is expected in July 1996. Work on the basic reservoir engineering is completed with reports on various aspects of the study expected to be completed by September 1996. Work has commenced on the stochastic geologic and reservoir simulation models. High temperature core work will commence in September 1996.

Regarding technical transfer, four poster sessions and a field tour were presented at the 1996 Annual American Association of Petroleum Geologists Convention in May. A new home page was created on the Internet (http://www.usc.edu/peteng/doe.html) for the project. A CD-ROM of the project has been completed for content and is in the editing process which should be completed by November 1996.

- **Compilation and Analysis of Existing Data**

A computer database of production and injection data and previous reservoir studies were compiled for the FB II-A Tar zone. Digitized and normalized log data were completed for 171 wells (over 600 wells penetrate the Tar zone in the fault block). The digitized logs include the electric or induction and the spontaneous potential (SP) and/or gamma ray (GR). The log data from the 171 wells are distributed throughout the fault block and will provide the base case log file for developing the 3-D stochastic geologic and reservoir simulation models. Another 100 logs will be digitized and normalized to use as "confirmation" logs for the stochastic modeling. Conventional cores throughout the zone were obtained from the previous operator in nine of the 171 wells which were used to correlate the formation rock and log data.

- **Advanced Reservoir Characterization**

The basic reservoir engineering technical work was completed and several reports covering the various aspects of the study should be completed in September 1996. Historical problems with oil, gas, and water production allocations to each well and to each zone completed in the wells are evident in the material balance calculations. Work was performed on evaluating the aquifer for water influx and determining original oil in place from gas saturations to support the material balance work. Work completed includes an analysis of the primary and waterflood recoveries, permeability estimates from performance data, comparing water injection profile surveys to the allocated injection volumes for each sub-zone, determining the quality of the new and old well logs, determining the vertical communication between sands, evaluating the aquifer and solution gas, and performing correlation studies on projected steam drive recoveries from vertical and horizontal wells.

The tracer program has been delayed because the main hot water distribution line

was temporarily disconnected to accomodate the surface landowner. Lab work has been completed to identify non-radioactive reservoir tracers effective in high temperature (500°F) environments. The tracer program includes two tracers, ammonium thiocyanate and sodium nitrate which will be bulk injected into the "T" and "D" zone by November 1996 when the hot water injection system will be reconnected. The tracers will follow the liquid phase of the injected steam. Computer software has been developed to map formation permeability in 3-D from production and injection data. The software is being tested using a compositional model at a major research company in California.

The high temperature core work has been delayed until lab procedures for measuring rock compaction due to steamflooding can be incorporated into the original proposal. The rock compaction data will be used in the thermal reservoir simulation model and in a study on the possible causes of surface subsidence due to steamflooding. Lab work on the cores should commence in September 1996.

A 3-D deterministic geologic model was completed which is being used to develop the 3-D stochastic geologic model and was used for drilling the observation and horizontal wells[1]. The deterministic model correlates eighteen sand tops in the Tar zone. A report on the deterministic model, including computerized 3-D visualizations, should be completed in October 1996. All existing cores were visually inspected and the core and log data were evaluated to develop a core-based log model, a porosity-permeability model and a rock-log model[2]. These models will provide the rock and reservoir data for the stochastic geologic model in locations where only well log data exists. A report on the rock-log model should be completed in October 1996.

Other deterministic geologic studies underway include the barrier characteristics of the geologic faults and correlating the stratigraphic characteristics of the Tar zone with similar deposits in neighboring fields. The technical work for both of these studies is finished and reports should be completed in September 1996.

On the stochastic geologic model, a neural network analyzer has been developed to analyze the similarities of various zones and sub-zones in terms of sequence stratigraphy using GR and spherically focused logs. Sample stochastic grid block models are being test run on FB II-A logs using the 3-D Earth-Vision™ visualization software to ensure compatibility. The work on actual examination of the FB II-A well log data for variogram modeling requirements of geostatistical modeling has started. The application of facies distribution and heterogeneity description is being examined using indicator modeling. The technical work on using production data to condition stochastic images has been finished and a report should be completed in September 1996.

- **Reservoir Simulation**

The STARS™ thermal reservoir simulation software by the Computer Modelling

Group (CMG) of Calgary has been tentatively selected. Benchmark tests performed by the project team and CMG confirmed the capabilities of the software and several hardware platforms. The effort to select and negotiate terms for a thermal reservoir simulator program were more problematic than anticipated. A conventional bid proposal for the software was not possible because each program and company have particular strengths and weaknesses which required detailed individual evaluation. Also, the software programs have generally not been benchmark tested on the latest computer hardware making hardware selection much more diffficult. All of the commercial thermal reservoir simulation programs are being improved to varying degrees to include the modules needed for the planned stochastic model including for horizontal wells, local grid refining, and reservoir compaction. Final selection of a hardware platform should be completed in August 1996. Purchase and installation of the simulation software and computer hardware should be completed in September 1996.

- **Reservoir Management**

Four horizontal wells (two steam injectors and two producers) were drilled in late 1995. The two injection wells were selectively completed with a total of 11-12 quarter inch limited entry perforations over the last 600 ft of the horizontal section to inject a calculated 1500 barrels of cold water equivalent steam per day (BCWESPD). Cyclic steam injection began in December 1995 at low rates of 300 BCWESPD per well and increased to 1500 BCWESPD per well after breaking down the perforations with high pressure water. The purpose of the cyclic steam injection is to consolidate the formation sands around the perforated completions[3] and to stimulate initial oil production. At the end of this quarter, injection well 2AT-61 was off cyclic steam injection and being prepared to initially produce in early July after injecting about 100,000 BCWES. Injection well 2AT-63 was still on cyclic steam injection at the end of the quarter with an anticipated initial production date in August 1996. Production well UP-955 was completed with 44-0.29 in. perforations and placed on cyclic steam injection during the quarter. Production well UP-956 will be completed and placed on cyclic steam injection in August 1996.

The 2400 ft steam transmission line under the Cerritos Channel was placed in service in mid-December 1995 and has performed very well with no problems to date.

Four existing steam injection wells were converted to hot water injection from March, 1995 to February 1996. Hot water injection rates ranged from 500-3000 BCWESPD during this period. No incremental production response was observed. Hot water injection was discontinued in February due to surface owner requirements to move the hot water injection lines. Hot water injection is planned to be reinitiated by November 1996.

Detailed thin section, scanning electron microscope, and x-ray diffraction work on wellbore fill samples from the existing steam drive wells show several types of scale including calcites, dolomites, barites, anhydrites, and magnesium-silicates. A study of the

cores, produced fluids, and injection water has been completed that determined the mineralogy and source of the scales and how to prevent their occurrence[4,5].

- **Operational Management**

Most of this work is dependent upon the results of the high temperature core work to be performed.

- **Technical Transfer**

Four poster sessions and a field tour were presented at the 1996 Annual American Association of Petroleum Geologists Convention in May[1,2,3,4,6] and a paper was presented at the Improved Oil Recovery Symposium in Tulsa in April[5](see references).

The project team is conducting an innovative program to transfer the dozens of anticipated technological advances from the project. Several project team members are significantly involved in the planning of the 1997 Society of Petroleum Engineers Western Regional Meeting scheduled in June, 1997 in Long Beach, California and on a two-volume book on the geology and operation of slope and basin clastic oil and gas reservoirs. A new home page was created for the project on the Internet (http://www.usc.edu/peteng/doe.html). A CD-ROM of the project has been completed for content and is in the editing process which should be completed by November 1996. The technical transfer commitment for this and other DOE projects has induced the project team members to establish a Regional Lead Organization office of the Petroleum Technology Transfer Council (PTTC) at the University of Southern California and restructure the 1997 Western Regional Meeting of the Society of Petroleum Engineers to provide more practical and timely presentations to a broader industry audience.

References

1. Abstract and exhibits (original and additional annotations provided for exhibits) for a presentation given by Don Clarke, Chris Phillips and Linji An as a poster session entitled "Tertiary Development of Heavy Oil Sands Through Thermal Stimulation in the Wilmington Oil Field, California: a Geological Perspective" at the 1996 Annual Meeting of the American Association of Petroleum Geologists (AAPG) in San Diego.

2. Abstract for a presentation given by D. K. Davies as a poster session entitled "Flow Unit Modelling in Complex Reservoirs" at the 1996 Annual Meeting of the American Association of Petroleum Geologists (AAPG) in San Diego, California in May 1996.

3. Abstract for a presentation given by Julius Mondragon and Scott Hara as a poster session at the 1996 Annual Meeting of the American Association of Petroleum Geologists (AAPG) in San Diego, California in May 1996 entitled "Novel Sand

Consolidation Completion Technique Using Alkaline Steam Injection in the Tar Zone, Wilmington Field, California".

4. Abstract for a presentation given by D. K. Davies as a poster session at the 1996 National AAPG Convention in San Diego in May 1996 entitled "Mineralogy and Origin of Well-bore Scales in an Active Steamflood: Tar Zone, Fault Block IIA, Wilmington Field, California".

5. Davies,D. K., et al: Nature, Origin, Treatment and Control of Well-bore Scales in an Active Steamflood, Wilmington Field, California, SPE Paper No. 35418 presented at the SPE/DOE Improved Oil Recovery Symposium in Tulsa, OK, 21-24 April 1996.

6. Field trip guidebook consisting of fourteen papers on geologic and operational aspects related to slope and basin clastic reservoirs in the Los Angeles Basin entitled "Old Oil Fields and New Life: a Visit to the Giants of the Los Angeles Basin". The field trip was given in conjunction with the 1996 Annual Meeting of the American Association of Petroleum Geologists (AAPG) in San Diego.