IMPROVED OIL RECOVERY IN FLUVIAL DOMINATED DELTAIC RESERVOIRS OF KANSAS - NEAR-TERM

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Objectives

The objective of this project is to address waterflood problems of the type found in Morrow sandstone reservoirs in southwestern Kansas and in Cherokee Group reservoirs in southeastern Kansas. Two demonstration sites operated by different independent oil operators are involved in this project. The Stewart Field is located in Finney County, Kansas and is operated by PetroSantander, Inc. The Nelson Lease is located in Allen County, Kansas, in the N.E. Savonburg Field and is operated by James E. Russell Petroleum, Inc.

General topics to be addressed are 1) reservoir management and performance evaluation, 2) waterflood optimization, and 3) the demonstration of recovery processes involving off-the-shelf technologies which can be used to enhance waterflood recovery, increase reserves, and reduce the abandonment rate of these reservoir types.

In the Stewart Project, the reservoir management portion of the project conducted during Budget Period 1 involved performance evaluation. This included 1) reservoir characterization and the development of a reservoir database, 2) volumetric analysis to evaluate production performance, 3) reservoir modeling, 4) laboratory work, 5) identification of operational problems, 6) identification of unrecovered mobile oil and estimation of recovery factors, and 7) identification of the most efficient and economical recovery process.

To accomplish these objectives the initial budget period was subdivided into three major tasks. The tasks were 1) geological and engineering analysis, 2) laboratory testing, and 3) unitization. Due to the presence of different operators within the field, it was necessary to unitize the field in order to demonstrate a field-wide improved recovery process. This work was completed and the project moved into Budget Period 2.

Budget Period 2 objectives consisted of the design, construction, and operation of a field-wide waterflood utilizing state-of-the-art, off-the-shelf technologies in an attempt to optimize secondary oil recovery. To accomplish these objectives the second budget period was subdivided into five major tasks. The tasks were 1) design and construction of a waterflood plant, 2) design and construction of a water injection system, 3) design and construction of tank battery consolidation and gathering system, 4) initiation of waterflood operations and reservoir management, and 5) technology transfer. Tasks 1-3 have been completed and water injection began in October 1995.

In the Savonburg Project, the reservoir management portion involves performance evaluation. This work included 1) reservoir characterization and the development of a reservoir database, 2) identification of operational problems, 3) identification of near wellbore problems such as plugging caused from poor water quality, 4) identification of unrecovered mobile oil and estimation of recovery factors, and 5) preliminary identification of the most efficient and economical recovery process i.e., polymer augmented waterflooding or infill drilling (vertical or horizontal wells).

To accomplish this work the initial budget period was subdivided into four major tasks. The tasks included 1) geological and engineering analysis, 2) waterplant optimization, 3) wellbore cleanup and pattern changes, and 4) field operations. This work was completed and the project has moved into Budget Period 2.

The Budget Period 2 objectives consisted of continual optimization of this mature waterflood in an attempt to optimize secondary and tertiary oil recovery. To accomplish these objectives the second budget period is subdivided into six major tasks. The tasks were 1) waterplant development, 2) profile modification treatments, 3) pattern changes, new wells and wellbore cleanups, 4) reservoir development (polymer flooding), 5) field operations, and 6) technology transfer.
Summary of Technical Progress

Stewart Field Project

Task II.1 - Design/Construct Waterflood Plant

Summary of work in last quarter

In December, the two injection pumps were modified to increase the injection capacity from approximately 6,000 to 9,900 BWPD. This increase was to handle the additional injection requirements expected from converting three producers to injectors. While the pumps were down, some preventive maintenance was also performed.

Summary of planned work for next quarter

Based upon results of the injection expansion, will evaluate further expansion in the east part of the field.

Task II.2 - Design/Construct Injection System

Summary of work in last quarter

Following the injection pumps modifications, as the system was brought back on line, one of the two water supply wells suffered a motor short. This required the equipment be pulled and replaced. The well also required some cleaning due to chemical deposits found in the well. The total downtime for this work reached 9 days partly due to inclement weather.

In December, three additional wells were converted to injection to improve the sweep efficiency in several areas of the waterflood. These include the following wells:

<table>
<thead>
<tr>
<th>Well</th>
<th>Previous Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scott 4-5</td>
<td>Producing approximately 10 to 12 BOPD</td>
</tr>
<tr>
<td>Sherman 3-8</td>
<td>Producing less than 1 BOPD</td>
</tr>
<tr>
<td>Nelson 2-2</td>
<td>Shut-in</td>
</tr>
</tbody>
</table>

Downhole injection profiles were attempted on several injection wells. Difficulties with the plastic coated tubing prevented completion of this program. Profiles were obtained on the Sherman 3-1, Mackey #6 and Meyer 10-2 to evaluate injection distribution. The vertical injection distributions for these three injectors were good. The remaining injection wells will be modified in the future to allow these surveys to be run on all the injectors.

Summary of planned work for next quarter

Based upon results of the injection work, will evaluate additional conversions to injection including the Scott 4-8, Bulger 7-5 and 7-10, and re-entering the Haag Estate #2 as an offset injector to the Haag Estate #5.
Task II.3 - Design/Construct Battery Consolidation and Gathering System

Summary of work in last quarter

None.

Summary of planned work for next quarter

None Planned.

Task II.4 - Waterflood Operations and Reservoir Management

Summary of work in last quarter

PetroSantander, Inc. of Houston, Texas took over operations on the Stewart Field waterflood on October 11, 1997.

Several pumping units were upsized to lower producing fluid levels. New units were purchased for the Scott 4-7, Carr 2-1, and the Haag Estate #5. Two of the pumping units released from these wells was transferred to the Sherman #4 and Haag Estate #4.

Increased downtime occurred in October due to a snowstorm that shut off the power supply for 12 hours. It required several days to stabilize production. Significant downtime also occurred in November and December due to the workovers on 5 producers to upsize the pumping equipment, two rod parts, five pump changes, and work on the injection system.

Ongoing pump changes, installation of tubing anchors, stroke length changes and speeding up pumping units were performed during the quarter on several wells. These changes are made as a result of the well testing program that identifies wells with production problems, rising fluid levels, abnormal production trends and low pump efficiencies. The changes that were made are a continued effort to maximize oil production and keep all the wells near a pumped off condition.

Continued to monitor production and injection rates, water supply volumes, and injection pressures. Continued the ongoing testing of producing wells with test trailers and fluid level instruments. An increase in the water/oil ratio of several of the earlier responding wells occurred during the quarter, plus the significant downtime has resulted in a slight decrease in the total field oil production. It is anticipated that the conversions to injection will offset this in the near future. Ongoing allocation of the injection volumes in the injection wells were performed based on response in producers and injectors. Cumulative water injection through December is 4,383,555 bbls or approximately 0.15 pore volumes. Average daily production and injection rates for the field are displayed on the attached plot.

Summary of planned work for next quarter

Continue to monitor for response at producing wells with well tests and fluid levels. Update the reservoir computer model and simulate when applicable. Upgrade pumping equipment as necessary.
Task II.5 - Technology Transfer

Summary of work in last quarter

Continued to publicize information on the Stewart Field’s oil production. A presentation titled, “Waterflooding Using Improved Reservoir Management: Stewart Field Case Study”, was presented at a symposium sponsored by the University of Wyoming Enhanced Oil Recovery Institute on October 29-30 in Casper, WY.

Operators throughout the region continue to visit the field to view the state-of-the-art waterflood installation and computerized monitoring system.

Summary of planned work for next quarter

- Continue to publicize information on the Stewart Field’s increased oil production.
Summary of Technical Progress

Savonburg Field Project

Task II.1 - Water Plant Development

Summary of work in last quarter

In October the air flotation unit was reconfigured with the addition of a new fluid spreader and slop tray. Consequently, we experienced a reduction in filter plugging.

The piping has been winterized.

The use of FLW-162 (a flotation aid chemical) has been implemented and with the other chemicals being used should significantly improve the quality of the injection water.

Summary of work planned for next quarter

A sixty-day program of intensive attention to operational details, with daily monitoring and reporting of operations is being instituted at the water plant.

Task II.2 - Profile Modification Treatments

Summary of work in last quarter

Channel-block treatments were performed on well RW-8. A 62-bbl treatment in October followed by two 32-bbl treatments in November. A test in December indicated the treatments did not hold.

Pressure fall-off tests were performed on H-14, H-12, RW-20 and KW-51. An associated tracer test in well H-14 indicated communication with wells H-15 and H-16 in less than 24 hours.

Temperature surveys were performed on wells KW-6 (twice), KW-11, KW-10, RW-13 and RW-20.

Summary of work planned for next quarter

As soon as weather conditions allow wells RW-1, RW-3, RW-6 and RW-7 will have temperature surveys.

Pulse tests will be performed on wells H-12, O-1, RW-20, and perhaps on other wells at the south end of the field.

An attempt will be made to isolate the B3 zone in injection well HW-18.
Task II.3 - Pattern Changes and Wellbore Cleanup

Summary of work in last quarter

KW-11 was cleaned out as fill-up was indicated from the temperature survey.

RW-3, RW-9, RW-12, RW-13 and KW-6 were each jetted with an acid/chemical treatment.

The following wells were serviced during the last quarter; H-16 (six times), H-17 (twice), K-42 (twice), H-26 (twice), H-30 (twice), O-1 (twice), H-21, H-22, K-43 and K-45. Service was required to repair pumps or replace joints of 1” pump string that developed leaks.

A fishing job on H-27 recovered a joint of pipe but was unable to recover the pump.

Summary of planned work for next quarter

Wells will be tested, cleaned and worked on as needed. Another attempt will be made to recover the old pump in H-27 and reactivate the well.

As soon as the ground dries sufficiently, wells H-9 and KW-51 will be plugged.

Task II.4 - Reservoir Development (Polymer Flooding)

Summary of work in last quarter

Waiting on a decision to implement polymer flooding.

Summary of work for next quarter

Waiting on a decision to implement polymer flooding.

Task II.5 - Field Operations

Summary of work in last quarter

Normal field operations have included: 1) monitoring wells on a daily basis, 2) repairing waterplant, piping, and wells as required, 3) collecting daily rate and pressure data, and 4) solving any other daily field operational problem that might occur.

<table>
<thead>
<tr>
<th>Month</th>
<th>Oil Production</th>
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<tbody>
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<td>October 1993</td>
<td>26.4 B/D</td>
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<tr>
<td>November 1993</td>
<td>30.7 B/D</td>
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<td>32.0 B/D</td>
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<td>January 1994</td>
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<td>March 1994</td>
<td>30.3 B/D</td>
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<td>29.1 B/D</td>
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<td>May 1994</td>
<td>28.5 B/D</td>
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<tr>
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**Summary of planned work for next quarter**

Field operations will be continued.
Task II.6 - Technology Transfer

Summary of work in last quarter

A plant tour was conducted for Mike Madden of BDM/Oklahoma in June.

Summary of planned work for next quarter

The field will be visited by other operators from the area.