QUARTERLY TECHNICAL PROGRESS REPORT  
10/1/95-12/31/95

WEST HACKBERRY TERTIARY PROJECT

Cooperative Agreement No. DE-FC22-93BC14963

Amoco Exploration and Production Sector

Date of Report: 1/10/96  
Award Date: 9/3/93  
Anticipated Completion Date: 4/2/97 (Budget Period 1)  
Government Award: $6,017,500 (Budget Period 1)  
Program Manager: Travis Gillham  
Principal Investigators: Travis Gillham, Bruce Cerveny (facilities), Ed Turek (research)  
Technical Project Officer: Edith C. Allison  
Reporting Period: 10/1/95-12/31/95 (9th Quarter of Budget Period 1)
Objectives

The goal of the West Hackberry Tertiary Project is to demonstrate the technical and economic feasibility of combining air injection with the Double Displacement Process for tertiary oil recovery. The Double Displacement Process is the gas displacement of a water invaded oil column for the purpose of recovering oil through gravity drainage. The novel aspect of this project is the use of air as the injection fluid. The target reservoir for the project is the Camerina C-1,2,3 Sand located on the West Flank of West Hackberry Field in Cameron Parish, Louisiana. If successful, this project will demonstrate that the use of air injection in the Double Displacement Process can economically recover oil in reservoirs where tertiary oil recovery is presently uneconomic.

Summary of Technical Progress

Contained herein is a discussion of the activities of the West Hackberry Tertiary Project during the quarter from October 1, 1995, to December 31, 1995. A total of 635 MMSCF of air was injected between the start of injection operations on November 17, 1994, and December 31, 1995. The following issues are reviewed in this quarter’s technical progress report: 1) a revision of air injection strategy and reservoir modeling, 2) summary of production performance and well workovers, 3) air compressor operations and repairs, 4) updated bottom hole pressure data and 5) technology transfer activities.

1) A Revision of Air Injection Strategy and Reservoir Modeling

Mechanical problems within the air injection surface facilities have resulted in much lower volumes of air injected than originally predicted in the project design. Plots of air injection rates and pressures along with cumulative injection volumes are included in Fig. 2 and 3. Although reservoir pressure has increased as a result of air injection, no production response has been seen to date. Operating strategy for the near term will be to maximize the likelihood of seeing initial production response during Budget Period 1.

The original project design envisioned injecting air into two fault blocks at the same time. Continuing to inject air into both fault blocks simultaneously decreases the likelihood that production response will be seen in either fault block before the end of Budget Period 1 in April of 1997. To improve the likelihood of seeing timely production response, all available air will be injected into one injector, the Gulf Land D No.51 in Fault Block IV, rather than splitting the injection streams between the two injection wells. If at any time the Gulf Land D No.51 is unable to accept the entire injection stream, the remainder will be injected into the Watkins No.18 in Fault Block II.

A reservoir modeling study has been completed by Dr. Ed Turek at Amoco’s Tulsa Research Center which incorporates injection and production data since the beginning of the project. The updated reservoir model suggests that if all available air (4 MMSCFD) is
injected into the Gulf Land D No.51 from this time forward, production response will be seen in the Gulf Land D No.44 by mid-1996 and in the Gulf Land D No.45 during the first quarter of 1997.

2) Summary of Production Performance and Well Workovers

Fault Block II
In Fault Block II, air injection was deferred after early nitrogen breakthrough and mechanical problems developed in the air injector. The Watkins No.16 was the original air injector while the Watkins No.18 and the Gulf Land D No.56 were originally planned to be producing wells for Fault Block II. To reference the location of each well in Fault Block II, a structure map for the top of the Cam C-1 sand is included as Fig. 1. The early nitrogen breakthrough noted in the Watkins No.18 and Gulf Land D No.56 was attributed to a high permeability interval of coarse grain sand found in the upper portion of the Cam C-1 sand. The early nitrogen production detected in Fault Block II was not accompanied by an increase in oil production.

In August of 1995, a repair was initiated to squeeze off the high permeability interval in the upper portion of the Cam C-1 sand in the Watkins No.16 (air injector). A failure downhole during the workover resulted in a tubing string being cemented in the well and the wellbore being junked and abandoned. To replace the Watkins No.16 air injector, the Watkins No.18 was converted from a producer to an air injector. The Watkins No.18 was the ideal replacement for the Watkins No.16 as the tree for the Watkins No.18 was 400 ft away and the wellbore encountered the Cam C-1 sand only 100 ft downstructure. To convert the Watkins No.18 into an air injector, the tubing and tree were replaced, the air injection flowlines were extended from the Watkins No.16 to the Watkins No.18 and the wellsite air injection skid was moved from the Watkins No.16 to the Watkins No.18. Air injection into the Watkins No.18 began during December of 1995.

Fault Block IV
In Fault Block IV, the Gulf Land D No.51 is the most upstructure well and serves as the air injector. The Gulf Land D Nos. 44 and 45 are the next highest wells completed on structure and are expected to see the earliest production response when it occurs. To reference the location of each well in Fault Block IV, a structure map for the top of the Cam C-1 sand is included as Fig. 1.

During December of 1995, sand bridges above the perforation interval in the Gulf Land D No.51 prevented the resumption of air injection into the well. A coil tubing unit was moved onto the well. The coiled tubing unit was unable to work below the upper half of the perforation interval while washing sand and scale out of the well. Even though the coiled tubing workover appears to have been successful in allowing for air injection to resume, the Gulf Land D No.51 is not capable of taking the full 4 MMSCFD of available compression capacity. The Watkins No.18 in Fault Block II is accepting some of the available air at this time. Within the next month, a workover will commence on the Gulf
Land D No.51 to acidize the current completion interval. The end result will be a completion in the Gulf Land D No.51 that will be capable of accepting the full 4 MMSCFD of available compression capacity.

The Gulf Land D No.45 had previously watered out in December of 1990. On August 17, 1995, the Gulf Land D No.45 was recompleted to the Cam C-1,2 in the identical completion interval as before and tested at a rate of 190 BOPD, 451 BWPD and 25 MSCFD while on gas lift. After one month of production, the Gulf Land D No.45 had declined to 60 BOPD and 480 BWPD.

If air injection was the source of the oil production in the Gulf Land D No.45, the oil cut should have increased when air injection was restarted in October. As indicated on the following table, the oil cut has continued to decrease since the initial production response in August:

<table>
<thead>
<tr>
<th>Year</th>
<th>BOPD</th>
<th>BWPD</th>
<th>% Water</th>
<th>MCFD</th>
</tr>
</thead>
<tbody>
<tr>
<td>August</td>
<td>183</td>
<td>415</td>
<td>69%</td>
<td>72</td>
</tr>
<tr>
<td>Sept.</td>
<td>60</td>
<td>480</td>
<td>89%</td>
<td>89</td>
</tr>
<tr>
<td>Oct.</td>
<td>55</td>
<td>480</td>
<td>90%</td>
<td>80</td>
</tr>
<tr>
<td>Nov.</td>
<td>50</td>
<td>450</td>
<td>90%</td>
<td>50</td>
</tr>
<tr>
<td>Dec.</td>
<td>45</td>
<td>450</td>
<td>91%</td>
<td>40</td>
</tr>
</tbody>
</table>

In light of the increasing water cut in the Gulf Land D No.45, the source of the new oil production in the Gulf Land D No.45 is believed to be a thin interval producing through a gravel pack that had sanded up in the previous Cam C-1,2 completion.

On October 8, 1995, the Gulf Land D No.44 was recompleted to the Cam C-1,2 and tested gas lifting at a rate of 0 BOPD, 0 MSCFD and 413 BWPD. The Gulf Land D No.44 is the next most upstructure well in Fault Block IV after the Gulf Land D No.51 and is expected to see the earliest production response in Fault Block IV when it occurs.

3) Air Compressor Operations and Repairs

While no major failures occurred last quarter, a number of smaller failures, retrofits, maintenance, inspections, and injection well problems resulted in a run time of approximately 48%.

In October, the water cooled packing case on the fourth stage of the reciprocating compressor started to leak causing the unit to go down on low coolant level. This was one of the new water cooled packing assemblies installed last quarter to solve the temperature related rod packing failures. This packing case was manufactured by C. Lee Cook for Ariel. The packing case was disassembled and inspected on location with the both Ariel and Cook’s representatives present. The leak was determined to be caused by a water passage between two adjacent cups being machined off center which prevented an o-ring from making an effective seal. Although the packing case did not leak when initially
installed, it eventually failed under running conditions. The packing case was repaired by welding the coolant passage closed and remachining the passage in the correct location by Cook's representative at their local facility.

While the fourth and fifth stages were disassembled for the above packing case repair, it was noted that the piston rings on the fourth and fifth stages were being extruded due to pressure. This was a new problem that had not occurred before. The cause was determined to be from the additional piston to cylinder clearance required to incorporate the wear bands on the new piston assemblies installed last quarter. The previously used carbon impregnated Teflon material was not adequate. New rings were machined from Peek material and installed. Subsequently, the fourth and fifth stages have been disassembled and inspected at intervals of one week and one month after installation and no extrusion has been seen. Two additional inspections are planned at three months and six months.

In November, coolant was noted in the screw compressor oil. This had occurred before and was caused by communication in the oil cooler between the coolant and the oil as documented in a previous quarterly report. This was thought to be a repeat failure of the cooler. However, after shop testing and inspection, no failure or communication could be found. The only other place where communication could occur is in the low and high pressure compressor elements. The elements were pressure tested on location and no communication was found. The only explanation offered by the screw compressor packager was that the coolant must not have been fully drained from the oil system during the previous cooler repair. The compressor oil sump pan was removed totally to ensure that all of the coolant was out of the oil system. While the screw compressor was down and the service personnel were on location, the 4000 hour service was performed.

Approximately six days of downtime also occurred because no wells were available for injection. During the time that the surface equipment from the Watkins No.16 injection well was being installed at the Watkins No.18 injection well, the Gulf Land D No.51 injection well, which had been taking 100% of the available air plugged up due to sand fill.

4) Updated Bottom Hole Pressure Data

A minimum of three bottom hole pressure surveys are taken every quarter to assess the effect of air injection on reservoir pressure. The most recent series of bottom hole pressure surveys were taken in November of 1995. A plot of bottom hole pressures versus time is included as Fig. 4. With a total of 563 MMSCF of air injected into Fault Block IV through December 31, 1995, reservoir pressure has increased an average of 210 psi since the start of injection. In Fault Block IV, the reservoir pressure in the Cam C-1 is about 240 psi higher than the pressure in the Cam C-3, but both sand intervals have seen a similar increase in reservoir pressure. In Fault Block II, pressure data indicates that
reservoir pressure has increased by 36 psi since the start of injection. A total of only 71 MMSCF of air has been injected into Fault Block II as of December 31, 1995.

5) Technology Transfer Activities

On October 16, 1995, Dr. Reza Fassihi (Amoco) gave a presentation describing the West Hackberry Tertiary Project to a group of petroleum engineering graduate students at the University of Texas in Austin, Texas. Over the life of the project, Amoco has given West Hackberry talks to petroleum engineering students at LSU, University of Kansas and University of Texas.

Figures:

1) Structure Map for the Cam C-1 Sand
2) Plot of Air Injection Rate and Air Injection Wellhead Pressure vs. Time
3) Plot of Cumulative Air Injected vs. Time
4) Plot of Bottom Hole Pressures vs. Time

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Air Injection Rate & Wellhead Pressure
Watkins No.16(11/94-3/95) + Watkins No.18(12/95)

Air Injection Rate & Wellhead Pressure
Gulf Land D No.51

Figure No.2
Cumulative Air injected vs. Time
West Hackberry Tertiary Project

Figure No. 3