QUARTERLY TECHNICAL PROGRESS REPORT
7/1/96-9/30/96

WEST HACKBERRY TERTIARY PROJECT

Cooperative Agreement No. DE-FC22-93BC14963

Amoco Exploration and Production Sector

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Reporting Period: 7/1/96-9/30/96 (12th Quarter of Budget Period 1)

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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 reservoirs for the project are the Camerina sands located on the west and north flanks 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

During the third quarter of 1996, air injection continued on the west flank and was initiated on the north flank. In addition, the first oil production from air injection occurred and the air injection flowline to the north flank neared completion. The following topics are discussed herein: 1) summary of west flank activities, 2) first oil production occurs on the north flank, 3) operation and maintenance of air injection system, 4) installation of equipment for north flank air injection and 5) plans for the upcoming quarter.

1) Summary of West Flank Activities

On the west flank, air is injected into two fault blocks, Fault Block II and IV. A structure map of the top of the Cam C-1 depicting the location of the fault blocks on the west flank is included as Figure No.1. Fault Block II has seen limited air injection due to premature nitrogen breakthrough and no production response. No production response has been noted in Fault Block IV even though Fault Block IV has seen the vast majority of the air injected to date. Reservoir pressure has increased in Fault Block IV by 350 pounds per square inch (psi) since the start of air injection. Production response is expected in Fault Block IV after sufficient air has been injected to expand the gas cap and thereby push the oil rim down to the location of the highest producing well on structure, the Gulf Land D No.44 (GLD No.44).

The GLD No.51 serves as the air injector for Fault Block IV on the west flank of West Hackberry Field. In July of 1996, the GLD No.51 became plugged with iron oxide and sand fill when the air injection compressors went down. In August, a workover was initiated to wash fill out of the wellbore. Several pieces of casing were recovered during the workover. Drilling mud was used during the workover to keep the formation sand from sloughing in while tripping in and out of the wellbore. To prevent sand fill in the future, the well will be gravel packed. After cleaning the fill out of the wellbore, the
workover was discontinued while a gravel pack screen was being manufactured. Completing the GLD No.51 with a gravel pack was deferred in order to gain operating experience with air injection through the gravel packs in the other two air injectors. To date, the only problem experienced with air injection through a gravel pack has been some iron oxide fill inside of the screen. The GLD No.51 will be gravel packed and returned to injection during the middle of October.

During the workover on the GLD No.51, air injection was discontinued throughout the field due to safety concerns relating to the proximity of the high pressure air injection line to the workover operations. While the GLD No.51 has been shut in awaiting the gravel pack, injection was initiated on the north flank in the SL 42 No.155 and was restarted on the west flank in Fault Block II in the Watkins No.18.

Approximately 0.4 million standard cubic feet per day (MMSCFD) of air is currently being injected into the Watkins No.18. Once the GLD No.51 is gravel packed, air injection will be split between the GLD No.51 on the west flank and the SL 42 No.155 on the north flank. A plot of west flank air injection rates and pressure versus time is included as Figure No.2. A plot of cumulative air injected versus time is included as Figure No.3.

2) First Oil Production Occurs on the North Flank

Air injection began on the north flank in a low pressure Cam C-1,2,3 oil reservoir, the WH Cam C RB SU, during July of 1996. This north flank reservoir had previously undergone gas injection which improved the rate for the nearest downstructure producing well, the SL 42 No.220, from 21 barrels of oil per day (BOPD) and 89 barrels of water per day (BWPD) in December of 1991 to 43 BOPD and 88 BWPD in April of 1993. The production rate achieved in April of 1993 remained at about that same level for the next three years. After air injection began in the WH Cam C RB SU in July of 1996, the SL 42 No.220 was tested on August 11, 1996, producing at a rate of 177 BOPD and 145 BWPD. This is the first increase in oil production as a result of air injection in the West Hackberry Tertiary Project.

The air injector for the Cam C RB SU is the SL 42 No.155. A structure map depicting the location of the various wells in the WH Cam C RB SU is included as Figure No.4. Although the SL 42 No.98 was originally the gas injector for this reservoir, an attempt to convert the well to air injection was unsuccessful due to collapsed casing. After the failure of the SL 42 No.98, the SL 42 No.155 was converted into an air injector and continues to serve as the air injector for the WH Cam C RB SU. Currently, 3.3 to 3.4 MMSCFD is injected into the SL 42 No.155. A plot of injection rates and pressures versus time for the SL 42 No.155 is included as Figure No.5.

The area depicted on the north flank structure map in Figure No.4 is highly faulted with low pressure fault blocks that typically exhibit reservoir pressures in the range of 330 to
500 psi. Many of the faults in the structure map were included to explain differences in gas/oil and oil/water contacts between wells. Although the SL 42 No.220 was the first well to exhibit increased production, as many as four additional wells in several fault blocks in the immediate area have seen some increase in production (and or nitrogen production) since the start of north flank air injection. A composite production plot for all five wells is included as Figure No.6.

Several of the five wells that have seen an increase in production have also exhibited an increase in nitrogen content in the produced gas. The presence of increased nitrogen in the produced gas of several wells in several fault blocks has proven that air injection is influencing more than the single fault block in which the air injector is located. The table on Figure No.7 shows the composition of samples of recently collected produced gas from nearby wells and the field overall.

Although a basic gas compositional analysis measures nitrogen, the oxygen portion is hidden in the nitrogen content. Running a gas sample through a second gas chromatograph column is necessary to determine the amount of oxygen in a sample of produced gas. The current operating practice in West Hackberry is to measure a gas sample for oxygen content if the sample exhibits greater than 5 mole percent (%) nitrogen content. As noted on Figure No.7, the gas sample with the highest nitrogen content showed almost no oxygen content. The oxygen monitors at the production facilities have also measured almost no oxygen content in the produced gas. The lack of oxygen content in the produced gas proves that the oxygen is being consumed through combustion with the oil in the reservoir. The lack of combustion-generated carbon dioxide in the produced gas is due to the carbon dioxide dissolving into the reservoir oil.

Injecting air into low pressure oil reservoirs can increase oil recovery by: 1) pushing the oil rim downstructure to the structural location of existing wellbores, 2) repressurizing the reservoir and 3) obtaining tertiary oil recovery through the double displacement process. Although nitrogen, carbon dioxide and natural gas have been utilized to increase oil recovery in Gulf Coast reservoirs in the past, this project is unique in the use of air as the injection gas. For Gulf Coast projects such as the West Hackberry Tertiary Project, air injection combines the benefits of low cost with universal accessibility.

3) Operation and Maintenance of Air Injection System

Relatively little downtime occurred last quarter due to mechanical failures of the surface equipment. In July, broken drive belts on the reciprocating compressor auxiliary water pump did cause approximately 12 hours of downtime. The remainder of the downtime was caused by injection well repairs as discussed under the summary of West Flank activities. While the injection well repairs were being performed, the downtime was utilized to simultaneously perform preventative maintenance on the compressors and a screw compressor repair. A problem with contamination of the screw compressor lubricant with coolant was being monitored prior to the injection well problems. This
problem occurred before and was thought to be caused by communication in the oil cooler, however, replacing the oil cooler did not solve the problem. Based on new information, Atlas-Copco diagnosed the oil-coolant communication to be most likely occurring across a leaking plug in a machined port in either the low pressure or high pressure compressor assembly. Both the low and high pressure screw compressor assemblies were removed, disassembled and inspected. The high pressure assembly was found to have the leaking plugs. Atlas-Copco installed a new high pressure screw compressor assembly under warranty and no oil contamination has been noted to date.

4) Installation of Equipment for North Flank Air Injection

Last quarter, most of the north flank injection equipment was completed and in July air injection commenced in the SL 42 Well No.155. The air injection line across Black Lake to serve the other north flank injection wells is approximately 90% complete as of this date and will be completed in the upcoming quarter. In addition, oxygen monitors were installed in the producing well equipment serving the north flank to monitor the produced gas for oxygen content which could cause an explosive mixture. Although nitrogen content in the produced gas has increased, only trace amounts of oxygen have been detected indicating that combustion is occurring in the reservoir and the oxygen is being consumed in the combustion process.

5) Plans for the Upcoming Quarter

Operating strategy in the upcoming months will be to continue to split air injection between the west flank and the north flank. The plan for air injection on the west flank will be to continue to expand the gas cap until the oil rim reaches the producers and production can begin. The plan for air injection on the north flank will be to expand the project to additional low pressure reservoirs in order to maximize production response. During the fourth quarter of 1996 the following activities are planned:
1) Completion of the repair on the GLD No.51 including gravel packing the well and returning the well to air injection.
2) After the GLD No.51 is repaired, divide the air injection between the north flank and the west flank with each area receiving about 2 MMSCFD.
3) Continued monitoring both the west flank for production response and the north flank for additional production response.
4) After proper unitization and permitting approvals have been obtained, initiate air injection into additional low pressure reservoirs on the north flank.
5) Repair the SL 42 No.165 in the WH Cam C RB SU to take advantage of the oil rim being pushed downstructure.
6) Recomplete the CPSB No.56 to the Cam D-1 in the WH NF Cam D SU and convert the well into an air injector.
Figures:

1) Structure Map for the Cam C-1 Sand (west flank)
2) Plot of West Flank Air Injection Rate and Air Injection Wellhead Pressure vs. Time
3) Plot of Cumulative Air Injected vs. Time (north and west flanks)
4) Structure Map for the Cam C-1 Sand (north flank)
5) Plot of North Flank Air Injection Rate and Air Injection Wellhead Pressure vs. Time
6) Combined Production Plot for 5 Wells on the North Flank
7) Table of Recent Gas Compositional Analyses
Air Injection Rate & Wellhead Pressure (FB II-west flank)
Watkins No.16 (11/94-3/95) + Watkins No.18 (12/95 to present)

Air Injection Rate & Wellhead Pressure
Gulf Land D No.51 (FB IV-west flank)

Figure No.2
Top of Cam C-1 Sand

W. Hackberry Tertiary Project

West Hackberry Field (north flank)

Cameron Parish, La.
SL 42 No.155(WH Cam C RB SU-north flank)

Air Injection Rate and Wellhead Pressure

Figure No.5
Wells Influenced by North Flank Air Injection

Combined Plot for SL 42 Nos. 197, 205, 220, 221, 222 (north flank)

West Hackberry Field, Cameron Parish, La.

Water Rate (Calendar Day) (bbls)

Oil Rate (Calendar Day) (bbls)

Gas Rate (Calendar Day) (Mscf)
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<tr>
<th>Field Gas Sales</th>
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<th>SL 42 No.197</th>
<th>SL 42 No.221</th>
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<td></td>
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<td></td>
</tr>
<tr>
<td>N2</td>
<td>0.29%</td>
<td>3.61%</td>
<td>4.16%</td>
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<td>N/A*</td>
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<td>0.91%</td>
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N/A* (oxygen not measured in this sample)

Figure No.7