QUARTERLY TECHNICAL PROGRESS REPORT
1/1/97-3/31/97

WEST HACKBERRY TERTIARY PROJECT

Cooperative Agreement No. DE-FC22-93BC14963

Amoco Energy Group North America

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Abstract

The West Hackberry Tertiary Project is a field test of the concept that air injection can generate tertiary oil recovery through the Double Displacement Process. The Double Displacement Process is the gas displacement of a water invaded oil column for the purpose of recovering tertiary oil through gravity drainage. The novel aspect of this project is the use of air as the injection fluid. In Gulf Coast oil reservoirs with pronounced bed dip, reservoir performance has shown that gravity drainage recoveries average 80% to 90% of the original oil in place while water drive recoveries average 50% to 60% of the original oil in place. The target for tertiary oil recovery with the Double Displacement Process is the incremental oil between the 50% to 60% water drive recoveries and the 80% to 90% gravity drainage recoveries. The use of air injection in this process combines the benefits of air's low cost and universal accessibility with the potential for improved oil recovery resulting from spontaneous in situ combustion. If successful, this project will demonstrate that utilizing air injection in the Double Displacement Process will result in an economically viable tertiary process in many Gulf Coast oil reservoirs where other tertiary processes are presently uneconomic. The West Hackberry Tertiary Project receives matching funds from the United States Department of Energy (DOE) as part of the DOE's Class 1 Program for the development of advance recovery technologies in fluvial dominated deltaic reservoirs.

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 concept is being field tested in low pressure (350 to 800 pounds per square inch (psi)) reservoirs on the north flank of the field and high pressure reservoirs (2500 to 3300 psi) on the west flank of the field.

The low pressure reservoirs on the north flank of the field are characterized by steep bed dips, large low pressure gas caps, slow water encroachment and thin oil rims. A thin oil rim on a steeply dipping structure occupies a small area. As water encroaches, a producing well will water out while upstructure wells will still reside in the gas cap. Draining the oil rim represents a considerable challenge. Air injection in this situation can increase oil recovery by: 1)repressurizing the reservoir, 2)pushing the oil rim down to downstructure producing wells and 3)effective use of the Double Displacement Process.

The high pressure reservoirs on the west flank are under active water drive and all producing wells have watered out. Air injection in the high pressure reservoirs is expected to generate tertiary oil recovery through the Double Displacement Process.

Summary of Technical Progress

As of March, air injection has increased oil production by a total of 150 barrels of oil per day (BOPD) above the normal decline in two low pressure reservoirs on the north flank. Figure 1 is a composite production plot for the five north flank producing wells that are responding to air injection. Low pressure air injection in future projects will require much lower capital investment and operating costs than high pressure air injection. With the increase in north flank oil production noted herein, the West Hackberry Tertiary Project is proving that air injection can be an economically viable enhanced recovery process in low pressure Gulf Coast salt dome oil reservoirs.

During the first quarter of 1997, the project moved forward with significant accomplishments noted on several fronts. The following topics are discussed herein: 1)extension of Budget Period 1, 2)west flank performance, 3)north flank performance, 4)operation and maintenance of the air injection system, 5)technology transfer activities and 6)plans for the upcoming quarter.

1)Extension of Budget Period 1

Although the north flank has exhibited increased oil production from air injection, the west flank has not. The original project proposal envisioned achieving increased oil production on the west flank before the end of Budget Period 1. To allow the project sufficient time to yield west flank production response during Budget Period 1, Amoco and the DOE agreed to a 24 month extension of Budget Period 1 at no increase in cost for the DOE above the original authorized cost for Budget Period 1. The end of Budget Period 1 has been extended from April 2, 1997, to April 2, 1999.

2)West Flank Performance

Of the project's 4 million standard cubic feet per day (MMSCFD) of injection capacity, roughly half is injected on the west flank and half on the north flank. On the west flank, air has been injected into two fault blocks, Fault Block II and IV.

During normal compressor operations in the first quarter of 1997, an average of 2 MMSCFD was injected into the Gulf Land D No. 51 in Fault Block IV. The vast majority of air injected in the project has been injected into the Gulf Land D No. 51. A plot of cumulative air injected versus time is included as Figure 2. During January of 1997, an increase in surface injection pressure was successfully treated with injection of a mutual solvent and hydrochloric acid. The success of the acid treatment suggests that the source of plugging in the injection well is rust (iron oxide) from the tubing and injection lines. The hydrochloric acid treatment was repeated with similar success in both north flank air injectors.

Through the middle of March, the highest producing well on structure in Fault Block IV, the Gulf Land D No. 44, was gas lifted at an average rate of 200 to 250 barrels of water per day (BWPD) with no oil and no measurable gas. A sample of produced gas taken from the Gulf Land D No. 44 on March 17, 1997, showed a 10 percent nitrogen concentration. Gas production gradually increased from 0 to 0.1 MMSCFD over the last two weeks of March. Additional gas analyses will be required to determine if the presence of nitrogen is sourced by formation gas rather than gas lift gas. If the presence of nitrogen is due to formation gas, this would be the first evidence of nitrogen breakthrough in Fault Block IV. While nitrogen breakthrough would confirm that the injector and the producer share the same reservoir, more production performance will be needed to determine if the nitrogen will be followed by oil production.

Fault Block II has seen limited air injection due to premature nitrogen breakthrough and no production response. Current operating strategy is to inject into Fault Block II only when the other three injection wells are unable to take the full 4 MMSCFD of injection capacity. No air was injected into Fault Block II during the first quarter of 1997.

3)North Flank Performance

Air injection continued in two low pressure reservoirs on the north flank throughout the first quarter. The two low pressure reservoirs are the Cam C-1,2,3 sands in the central area and the Cam D/Bol 3 sands in the northwest area.

Air injection began in the Cam C-1,2,3 on the north flank began in July of 1996. Three Cam C-1,2,3 wells have exhibited increased oil production as a result of air injection. A production plot which combines the producing rates for the three Cam C-1,2,3 wells is included as Figure 3. As noted on the production plot, production increased as a result of air injection and declined when air injection was interrupted. Currently, air injection rates in the Cam C-1,2,3 average 1.3 MMSCFD.

The SL 42 No. 165 had previously watered out and sanded up in a completion in the Cam C-1 sand. In March, a workover was attempted on the SL 42 No. 165 to clean out the well and replace the gravel pack. The workover was suspended when fishing operations failed to progress in cleaning out the well.

The SL 42 No. 221 is located in the gas cap of the north flank Cam C-1,2,3 reservoir and produces on beam lift. The produced gas from the SL 42 No. 221 is contaminated with a high nitrogen content as a result of air injection in the offset well. In late March, the rods and pump were pulled and a pulsed neutron log was run across the Cam C-1 sand. The log indicated that while the lower portion of the Cam C-1 is gas productive, the upper portion is possibly oil productive. A workover to plug off the gas productive lower portion of the Cam C-1 and then test the upper portion is under evaluation. One point worthy of note is even though the produced gas in the SL 42 No. 221 contains 52% nitrogen, the oxygen content is only 0.6%. The lack of oxygen in the produced gas from

the SL 42 No. 221 indicates that sufficient residual oil saturation resides in the gas cap to consume most of the oxygen through combustion.

In December of 1996, air injection began in the Cam D/Bol 3 reservoir in the northwest area of the north flank. Both producing wells in the reservoir have shown an increase in oil production in response to air injection. A production plot which combines the rates of the two producing wells in the northwest area is included as Figure 4. The average producing rate fell dramatically for February when one of the two producers was shut in for three weeks due to parted rods. After a workover replaced the parted rods, the well returned to production at about 80 BOPD while rates before air injection averaged about 50 BOPD. Presently, air injection rates in the Cam D/Bol 3 average 0.8 MMSCFD.

4)Operation and Maintenance of the Air Injection System

No major facilities modifications were performed in the last quarter. A choke was added in the injection line to the SL 42 No. 155 in order to control the flow to each of the two north flank injectors. The system was originally designed for injection into only one north flank injection well at a time. When the injection plan was changed to inject into more than one well simultaneously, rate control became an issue. This was solved by installing the choke in the air injection line for the SL 42 No. 155. Another choke will be installed in the Gulf Land A R/A C No. 245 in the upcoming quarter to provide additional control for varying injection well pressure scenarios.

Even though no major equipment failures occurred last quarter, a number of minor problems resulted in an accumulated downtime of approximately 18 days. Of the 18 days, two were utilized for preventative maintenance. Some of the causes for the unscheduled downtime were leaking reciprocating compressor valves, a broken exhaust expansion joint on the reciprocating compressor, a malfunctioning pressure controller on the GLD No. 51 back pressure valve and leaking pressure safety relief valves in the surface injection line system. The remainder of the downtime was a result of injection well plugging.

5)Technology Transfer Activities

The increase in oil production on the north flank has facilitated a more intense program of technology transfer for 1997. The following technology transfer activities have occurred or are planned for 1997:

- 1)A brief news release documenting the project's increase in oil production appeared in the "Technology Digest" section of the February, 1997, edition of the "Journal of Petroleum Technology."
- 2)On March 10, 1997, representatives from Amoco and Louisiana State University (LSU) met to begin planning a one day technology transfer workshop. The subject matter for the workshop will be gas injection for improved oil recovery with the West Hackberry Air Injection Project designated as the case study that will occupy 75% of the day. The

workshop is scheduled for September 16, 1997, in Baton Rouge, Louisiana. The workshop will be co-sponsored by Amoco, DOE, LSU and the Petroleum Technology Transfer Council (PTTC).

3) Discussions with LSU's contact at "World Oil" have facilitated arrangements for the submission of a magazine article for the August or September edition of "World Oil."

4) Amoco personnel have submitted a West Hackberry air injection paper for presentation at the annual convention of the Gulf Coast Association of Geological Societies (GCAGS) in New Orleans in October of 1997.

5) The Society of Petroleum Engineers (SPE) has accepted an abstract for a West Hackberry air injection paper which will be presented at the 1997 Annual Technical Conference and Exhibition in San Antonio in October.

6) Plans for the Upcoming Quarter

Operating strategy in the upcoming months will be to split air injection between the west flank and the north flank. Air injection on the west flank will continue in an effort to expand the gas cap until the oil rim reaches the producers and production can begin. On the north flank, air injection will be expanded to additional low pressure reservoirs in order to maximize production response.

During the second quarter of 1996, air injection will begin in a third low pressure reservoir on the north flank when the CPSB No. 56 is recompleted to the Cam D sand and converted into an air injector. In addition, Amoco is evaluating a sidetrack of the SL 42 No. 165 to increase oil recovery from the north flank Cam C-1,2,3 air injection reservoir.

Figures:

- 1) Composite Production Plot of Five North Flank Producing Wells
- 2) Plot of Cumulative Air Injected vs. Time
- 3) Composite Production Plot of Three Cam C-1,2,3 Producers (north flank)
- 4) Composite Production Plot of Two Cam D/Bol 3 Producers (north flank)

SI Metric Conversion Factors

bbl x 1.589 873	E-01 = cubic meters
cubic feet x 2.831 685	E-02 = cubic meters
psi x 6.894 757	E+00 = kPa

Figure 1.

Figure 2.

Figure 3.

Figure 4.