Quarterly Technical Progress Report - West Hackberry Tertiary Project

**Quarterly Report
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**By:
Travis Gillham; Bruce Cerveney; Tor Kragas**

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For
U.S. Department of Energy
Office of Fossil Energy
Federal Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880

By
Amoco Energy Group North America
150 West Warrenville Road
Naperville, Illinois 60566

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QUARTERLY TECHNICAL PROGRESS REPORT
4/1/97-6/30/97

WEST HACKBERRY TERTIARY PROJECT

Cooperative Agreement No. DE-FC22-93BC14963--15

Amoco Energy Group North America

Date of Report: 7/10/97

Award Date: 9/3/93

Anticipated Completion Date: 9/2/99 (Budget Period 1)

Government Award: \$6,017,500 (Budget Period 1)

Program Manager: Travis Gillham

Principal Investigators: Travis Gillham, Bruce Cervený (facilities), Tor Kragas (research)

Technical Project Officer: Jerry Casteel

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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 (300 to 700 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 June of 1997, air injection has increased oil production by a total of 190 barrels of oil per day (BOPD) above the normal decline in six north flank producing wells located in two low pressure fault blocks. In the high pressure reservoir on the west flank of the field, air injection is continuing while production response has yet to occur.

The following second quarter activities are discussed herein: 1)west flank performance, 2)north flank performance, 3)economics of low pressure air injection, 4)workover operations, 5)operation of air injection and production surface facilities and 6)technology transfer activities.

1)West Flank Performance

During normal injection operations, about two million standard cubic feet per day (MMSCFD) of injection air was injected into Fault Block IV in the Cam C-1,2,3 sand on the west flank. The air injector for Fault Block IV is the Gulf Land D No.51. Through June, a total of almost 1.5 billion standard cubic feet of air (BSCF) had been injected into the Gulf Land D No.51. A plot of cumulative air injected versus time is included as Figure 1. As of March, air injection had increased reservoir pressure by 500 pounds per square inch (psi) to about 3000 psi. A plot of west flank bottom hole pressure versus time can be found as Figure 2. The producing well that is located highest on structure and nearest to the air injector is the Gulf Land D No.44. The Gulf Land D No.44 is tested twice a month and still produces all water. Although air injection continues in Fault Block IV, oil production will not occur until air injection has expanded the gas cap sufficiently to push the oil rim down to the Gulf Land D No.44.

2)North Flank Performance

On the north flank of West Hackberry, air is injected in two low pressure reservoirs (300-700 psi). The two low pressure reservoirs are the Cam C-1,2,3 sands in the central area (Reservoir A) and the Cam D/Bol 3 sands in the northwest area (Reservoir B). Reservoirs A and B are characterized by low reservoir pressure, steep bed dip, large low pressure gas caps, slow water encroachment and thin oil rims. A schematic cross-section of Reservoir A is included as Figure 3.

Air injection began in the Reservoirs A and B in July and December (of 1996), respectively. As of June of 1997, oil production has increased in six wells by a total of 190 BOPD above the normal decline. A composite production plot is included as Figure 4. Through June, air injection has generated 53,740 barrels of incremental oil production. Air injection has also increased reservoir pressure and decreased producing water cut.

3)Economics of Low Pressure Air Injection

To demonstrate the economic promise of low pressure air injection for a typical domestic operator, air injection in the north flank reservoirs (from July of 1997 to June of 1997) can serve as a case study. Although the high pressure air compressors at West Hackberry supply air to both the high and low pressure floods, operating costs and initial investments for a strictly low pressure project would be much less than for a high pressure project. Rather than attempting to split out the cost of low pressure operations at West Hackberry, a compressor operating company was asked to provide a quote of the cost to supply 2 MMSCFD of air at 1000 psi at West Hackberry. For the purposes of this exercise, the price quoted is based upon the assumption that the compressor operating company would purchase and install the required air compression capacity at the West Hackberry central production facility. The price quoted was \$20,000 per month plus fuel or about \$0.49/MSCF of air assuming a cost for fuel (natural gas) of \$2 per million British Thermal Units (MMBTU).

In order to implement a low pressure flood at West Hackberry, Amoco would have been required to spend \$280,000 for downstream flowlines and control equipment along with \$40,000 to convert to shut-in wells to injectors and \$28,000 for repair well expenses. The cost to purchase the 380.5 MMSCF of air injected to date at \$0.49/MSCF would have been \$186,000. Amoco's total of before tax capital investments and operating costs for the low pressure injection would have been \$534,000. No operating costs were included for the six producing wells as those wells would have been producing with or without the air injection project.

Assuming an average oil price of \$20 per barrel, a one sixth royalty and a one eighth severance tax, the 53,740 barrels of incremental oil would have generated \$783,000 of net cash receipts before tax, capital investments and operating expenses. Subtracting \$534,000 of investments and operating costs from the \$783,000 generates an incremental \$249,000 of before tax net cash flow. The \$249,000 represents the positive incremental before tax net cash flow that could have been generated by air injection (without DOE support) in the low pressure reservoirs from July of 1996 to June of 1997.

4)Workover Operations

With the positive production response noted in the first two low pressure reservoirs, efforts are ongoing to expand the product to a third north flank low pressure reservoir, the Cam D-1 sand. The Cam D-1 is similar in all respects to the first two low pressure reservoirs with the exception that it is much larger. Amoco attempted to convert two wells, the Cameron Parish School Board Nos.56 and 59, to air injectors. The conversion attempts were abandoned after collapsed casing was discovered in both wells. A third well, the Cameron Parish School Board No.58 will be converted to air injection. Currently, Amoco is awaiting approval from the appropriate agencies before converting the well and initiating air injection.

In Reservoir A, the SL 42 No.165 had watered out and sanded up several years ago. Workover operations to clean out the well and to return it to production have been unsuccessful. To further increase Reservoir A's production, the SL 42 No.165 will be sidetracked during the third quarter and the sidetrack will twin the existing wellbore for a completion in Reservoir A.

5)Operation of Air Injection and Production Surface Facilities

Last quarter 188,381 MSCFD of air was injected which equates to an average daily rate of 2,070 MSCFD. The primary causes of the lower air injection rate were: 1)compressor down time associated with nitrogen contaminated compressor fuel gas and 2)high injection well pressures. Preventative maintenance on the compressors and repair and modifications to the wellsite surface equipment also caused some downtime.

The gas produced from the north flank producing wells responding to air injection is increasing in nitrogen and carbon dioxide content. This is causing a problem in running the air compressor engines because the Btu content of the fuel gas is decreasing due to the increase in nitrogen and carbon dioxide. The low emission engines cannot be fully loaded on the lower Btu fuel gas. When the engines started shutting down under load, the fuel gas was sampled and determined to be the problem. North flank producing wells were tested to determine which wells were producing the high nitrogen gas. The high nitrogen producers were shut in until the gas system cleaned up. The compressor fuel systems were then adjusted to run on the lower Btu fuel gas at a reduced load. Simultaneously, increasing injection well pressures also contributed lowering the injection rates. The gas produced from SL 42 No.220 well, which was highest oil producer at 120 bopd, contained the highest amounts of nitrogen and carbon dioxide. The SL 42 No.220 was the highest contributor of the nitrogen causing the low Btu gas. The gas from the SL 42 No.220 was analyzed to be 187 Btu/cu. ft. which is lower than the content for combustion without supplementing with rich gas. Therefore, an exception to flare and permission to vent was applied for. A separator was installed at the wellsite so that the gas could be vented off the casing. This allowed the well to be produced at 120 bopd while the flare stack is being installed. The remaining oil wells which are capable of producing at economical oil rates with lower nitrogen content are being produced while the gas system is being tested and monitored to ensure that the gas system is not being contaminated with nitrogen.

Current plans are to install a flare stack to combust the non-commercial gas produced from the north flank wells producing to the satellite Separate, Test and Boost Facilities (STAB's) 9 and 10 which will enable oil production without contaminating the gas system with nitrogen and carbon dioxide. The flare system has been designed and purchased and air emissions and construction permits have been submitted to the regulatory authorities. Installation should take place next quarter.

6)Technology Transfer Activities

The following technology transfer activities took place during the second quarter:

- 1)Amoco personnel made corrections and submitted a revised paper for presentation at the annual convention of the Gulf Coast Association of Geological Societies (GCAGS) in New Orleans in during the second week of October, 1997.
- 2)Amoco and Louisiana State University (LSU) continued planning for the technology transfer workshop scheduled for September 16, 1997, in Baton Rouge, Louisiana.
- 3)Amoco personnel submitted a paper for review to the Society of Petroleum Engineers (SPE) entitled “Keys to Increasing Production Via Air Injection in Gulf Coast Light Oil Reservoirs” for presentation at the SPE Annual Technical Conference and Exhibition to be held in October, 1997, in San Antonio, Texas.
- 4)Amoco and LSU personnel submitted an article to “World Oil” entitled “A New and Economically Viable EOR Process for the U. S. Gulf Coast” that will be included in “World Oil’s” November issue.
- 5)On June 18, 1997, Amoco personnel presented the West Hackberry project to the DOE’s contractor review in Houston, Texas.

During the third quarter of 1997, Amoco and LSU personnel will conduct a technology transfer workshop at LSU on September 16, 1997. In addition, Amoco personnel will present a talk on the West Hackberry project to SPE’s South Louisiana Study Group in Houston, Texas, on September 23, 1997.

Figures:

- 1) Cumulative Air Injected versus Time
- 2) Plot of West Flank Bottom Hole Pressure versus Time
- 3) Schematic Cross-Section of Reservoir A
- 4) Composite Production Plot of Six North Flank Producing Wells

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 3

Figure 4