Quarterly Technical Progress Report (3/3/95-6/2/95)

West Hackberry Tertiary Project

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Amoco Production Company

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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 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

Air injection was initiated on November 17, 1994. During this quarter, the West Hackberry Tertiary Project completed the first six months of air injection operations. The following events are reviewed in this quarter's technical progress report: 1) early nitrogen breakthrough seen in the Gulf Land D No.56, 2) corrosion downhole in the air injectors and at the wellsite injection skid, 3) fill in the Watkins No.16 air injection well, 4) temperature logs run in air injectors (after 24 hours of shut-in), 5) substantial air compressor down time, 6) official startup ceremony and technology transfer activities.

1) Early Nitrogen Breakthrough seen in the Gulf Land D No.56

On February 9, 1995, a shut-in bottom hole pressure survey was run in the Gulf Land D No.56. Despite the fact that no gas had been injected into the Gulf Land D No.56, the tubing was found to be filled with a gas. Upstructure to the Gulf Land D No.56, a total of only 31 MMSCF of air had been injected into the Watkins No.16 as of February 9, 1995. The Gulf Land D No.56 was flowed and three gas analyses were performed on the produced gas. The three gas analyses produced similar results with an average composition of 67.9% methane, 26.5% nitrogen, 1.6% carbon dioxide, 0.35% oxygen and 3.65% hydrocarbon gasses heavier than methane. The high nitrogen content in the produced gas indicated that nitrogen had prematurely broken through to the Gulf Land D No.56. Based upon the available reservoir and geologic data, the source of the nitrogen found in the Gulf Land D No.56 is believed to be the air injected into the Watkins No.16.

The Gulf Land D No.56 is about 800' west of the Watkins No.16 and 400' downstructure. Even though the Watkins No.18 is 100' downstructure to the Watkins No.16 and only 400' north, the Watkins No.18 has seen no evidence of nitrogen production thus far. On April 6, 1995, a pulsed neutron log was run in the Watkins No.18 that showed no evidence of gas presence in the vicinity of the wellbore. An attachment which shows the Watkins No.18 pulsed neutron log overlaid onto the electric log is included in this report. The lack of nitrogen presence in the Watkins No.18 would seem to prove fault separation.
between the Watkins No. 18 and the Watkins No. 16. A revised structure map for the top of the Cam C-1 sand (which displays the newly interpreted fault) is included as an attachment.

Assuming a 50% gas saturation and a 6 acre area from the Watkins No. 16 downstructure to the Gulf Land D No. 56, the air would have flooded an average of only five feet to have reached the Gulf Land D No. 56. After just a few days of flowing gas at low rates during daylight hours from the Gulf Land D No. 56, the well loaded up with salt water. The Gulf Land D No. 56 was subsequently placed on gas lift and has averaged 300-400 BWPD with a 1% oil cut and no further evidence of nitrogen production. Ed Turek, research engineer at Amoco’s Tulsa Research Center, will history match the performance thus far of the Watkins No. 16 and Gulf Land D No. 56 to determine what magnitude of permeability difference is necessary to cause the early nitrogen breakthrough. Utilizing this information, Ed Turek will plug in the permeability difference into the prediction of future performance for the area surrounding the Gulf Land D No. 51 (air injector) in Fault Block IV.

Although no conventional cores exist in this area of the field, sidewall cores were taken in many of the wells during the 1950’s. No permeability measurements were run on these 1950’s vintage sidewall cores. A review of the sand description indicates that while much of the Cam C-1,2,3 Sand is fine to very fine grain, the upper portion of the Cam C-1 Sand possesses some medium to coarse grain sand. A log section for the Watkins No. 16 with sidewall core descriptions is included as an attachment. Differences in grain size can account for permeability variations, with larger grain sand usually possessing greater permeability. The medium to coarse grain sand found in the upper portion of the Cam C-1 Sand is suspected of being the source of the premature nitrogen breakthrough in the Gulf Land D No. 56.

Current plans are to pull the Watkins No. 16, isolate the upper portion of the Cam C-1 Sand with isolation packers and resume injection into the remainder of the Cam C-1,2,3 Sand. In addition, recompleting the Watkins No. 3 (upstructure to the Watkins No. 16) from the Bol-3 Sand to the Cam C-1 Sand is being evaluated. The purpose of recompleting and testing the Watkins No. 3 in the Cam C-1 would be to confirm the revised geologic picture.

2) Corrosion Downhole in the Air Injectors and at the Wellsite Injection Skid

On March 27, 1995, the Watkins No. 16 (air injector) developed pressure communication between the tubing and the tubing/casing annulus. Air injection into the Watkins No. 16 was immediately stopped due to concerns regarding corrosion and casing integrity. While the Watkins No. 16 was shut in, the entirety of the compressed air stream was injected into the Gulf Land D No. 51 until the Gulf Land D No. 51 also developed pressure communication between the tubing and the tubing/casing annulus and it was also shut in. The suspected cause of the communication in both air injectors is corrosion resulting
from the combination of oxygen or carbon dioxide with KCl purge water. A workover rig was moved on the Gulf Land D No.51 and the tubing was pulled. An examination of tubing indicated several leaks due to corrosion. At this time, the tubing string in the Gulf Land D No.51 is being replaced with a new string of coated tubing. As a cost savings measure, the tubing string in the Watkins No.16 will replaced with the tubing string from the Watkins No.5. During 1991, a nitrogen injection test was run in the Watkins No.5 and new tubing with premium connections was installed at that time. The Watkins No.5 will be temporarily abandoned in order to supply tubing for the Watkins No.16. By installing coated tubing in the Gulf Land D No.51 and uncoated tubing in the Watkins No.16, a valuable comparison of tubing life will be obtained.

Surface corrosion has also been noted in the valves at the wellsite injection skids. This is believed to be the result of the back pressure valves leaking and allowing KCl water back into the air injection lines. No evidence of corrosion has been found in the equipment immediately downstream of the air compressors. Based upon the experiences of other air injection projects, corrosion from downstream of the air compressors to the wellsite injection skids is not believed to be a significant problem.

After a meeting between corrosion experts, field personnel and the facilities engineer, a consensus was reached that the primary source of corrosion at both the wellsite injection skid and downhole was the combination of KCl purge water with oxygen and or carbon dioxide. The water purge system has served two purposes:
1) The first purpose was to prevent the wellbore from overheating due to the backflow of burning hydrocarbons. With the volume of air injected into the Gulf Land D No.51 and the Watkins No.16 thus far, much of the near-wellbore hydrocarbons should have been burned off and purging with KCl water is no longer believed to be necessary.
2) The second purpose for purge water was to prevent explosions resulting from the mixture of oxygen and hydrocarbons in the wellbore. A recent gas analysis from gas flowed back from the Watkins No.16 indicated that the produced gas was 98.3% nitrogen, 1.5% oxygen and a trace of hydrocarbon gasses. The gas flowed back from the Gulf Land D No.51 was 97.4% nitrogen, 2.3% oxygen and a trace of hydrocarbon gasses. The gas mixture flowed back from the air injectors has so little hydrocarbon fraction that the potential for explosion in the tubulars in the well is non-existent.

In the original project design, the water purge system was expected to be in service for a limited time period(six months to a year), until the system was no longer necessary. The water purge system appears to have outlived its usefulness and will be discontinued from this point forward in order to minimize future corrosion problems.

3) The Presence of Fill in the Watkins No.16 (air injector)

During March of 1995, field personnel checked for fill in the Watkins No.16 air injection well. The bottom in the Watkins No.16 was tagged at 8944', about 28' above the base of the perforations at 8972' and covering the Cam C-3 Sand. A bailer run on slickline
recovered iron oxide scale from the well. The bottom at 8944’ represents 180’ of fill in 5-1/2” casing above the previous clean out depth of 9124’. Slickline measurements are often questionable and the location of the top of the fill will be confirmed when the well is pulled and cleaned out to bottom. When the Watkins No.16 is pulled to repair the tubing leak, the fill will be washed out, sampled and analyzed.

4) Temperature Logs Run in Air Injectors after 24 Hours of Shut-in Time

On March 28, 1995, a tool was run on slickline into each of the air injection wells to measure the temperature about 24 hours after the wells had stopped injection and purge water had been pumped. The temperature of the Watkins No.16 was 298 degrees Fahrenheit at a depth of 8888’, near the middle of the perforations. Up inside the tubing at a depth of 8680’, the temperature was 202 degrees Fahrenheit. Prior to air injection in the Watkins No.16, the reservoir temperature in the Cam C-1,2,3 was 204 degrees Fahrenheit. The higher temperature seen after 24 hours of shut-in and injection of purge water is attributed to high temperature combustion in the reservoir.

The temperature tool run in the Gulf Land D No.51 recorded the following temperatures:

- 7328’ 176 degrees F
- 7367’ 190 degrees F
- 7383’ 218 degrees F
- 7390’ 228 degrees F
- 7417’ 202 degrees F
- 7446’ 190 degrees F

A log section is included which shows the location of the temperature measurements in the Gulf Land D No.51. Prior to air injection, the reservoir temperature in the Cam C-1,2,3 in the Gulf Land D No.51 was 186 degrees Fahrenheit.

A basic principle of air injection is that oxygen burns the near wellbore oil first and thereafter farther and farther from the wellbore. A much greater volume of air has been injected into the Gulf Land D No.51(325 MMSCF) than into the Watkins No.16(46 MMSCF), theoretically burning a much greater volume surrounding the Gulf Land D No.51 wellbore. The greater injection volume in the Gulf Land D No.51 should now result in the burn taking place at a greater distance from the wellbore than the burn surrounding the Watkins No.16. An indicator that this is indeed occurring is the lower maximum temperature(228 degrees F) found in the Gulf Land D No.51 as compared to the maximum temperature(298 degrees F) found in the Watkins No.16.

When comparing temperature with depth on the log in the Gulf Land D No.51, the Cam C-1 temperature(190 degrees) is lower than the Cam C-2,3 temperature(228 degrees F). The lower temperature found in the Cam C-1 would seem to indicate that more air has been injected into the Cam C-1 than into the Cam C-2,3.
5) Substantial Air Compressor Down Time

During the past quarter, the air injection compressors suffered significant down time due to mechanical failures. Plots representing daily injection rates (and pressures) and cumulative injection are included as attachments. The following is a summary of the problems encountered and the solutions implemented.

In March of 1995 a mechanical failure of the piston rod packing, rings and rider bands occurred to the reciprocating compressor. Inspection revealed damage to the piston rod packing on all four throws, rings on the third and fifth stage cylinders and rider bands on the third stage cylinder due to insufficient lubrication. Most fires and explosions in air compressors systems can be traced to deposits of carbon and excess lubricant that result from over-lubrication. Proper lubrication rates are often achieved by experimentation. Insufficient lubrication will cause packing and ring failures while too much lubrication can cause the more catastrophic fire or explosion. After the repair, the lubrication rate was increased from 1.5 to 3 gallons per day to prevent future packing and ring failures. The compressor piping will be disassembled to check for over-lubrication and deposits within the next six months. Total downtime for this failure was 11 days. This repair was covered under warranty by the compressor manufacturer.

On April 1, 1995, the reciprocating compressor went down due to a malfunctioning shuttle valve in the fuel system of the engine. Total time to have a manufacturer’s representative on location to diagnose and repair the problem was three days. This repair was covered under the engine manufacturer’s warranty.

The screw compressor would no longer load on April 11, 1995. Some prior problems had been occurring with the compressor loading. The problem was thought to be caused by the control valve being placed too far from the loading valve causing the oil pressure to drop in the control line below what was required to operate the loading valve. The vendor’s representative for the screw compressor moved the control valve closer to the loading valve to reduce the pressure drop. This solved the loading problem. Downtime for this problem was two days. This modification was performed at the vendor’s expense.

Shortly after repair of the loading valve, the screw compressor started to shut down due to low oil pressure. On April 17, 1995, the vendor’s representative found a defective oil cooler which was allowing communication between the compressor oil and coolant. A new cooler was installed. Total downtime was seven days. This repair was covered under the screw compressor’s manufacturer’s warranty. The defective cooler was sent to the manufacturer for inspection to determine the cause of the failure. The cause of the failure is undetermined at this time.

On April 30, 1995, a mechanical failure of both turbochargers occurred on the engine of the reciprocating compressor. Two new turbochargers were installed by the manufacturer’s representative. Total downtime was 11 days. Disassembly and inspection
of the turbochargers indicated a lubrication failure. Further investigation and discussion with the manufacturer is underway to prevent subsequent turbocharger failures and to determine if this repair is covered under warranty. Repairs to the compressors were completed as of May 11, 1995. At that time pressure communication was found in the Gulf Land D No.51 and restarting air injection is currently waiting on the completion of the repair to the Gulf Land D No.51.

6) Official Start-up Ceremony and Technology Transfer Activities

On March 30, 1995, an official start-up ceremony and media event was held at West Hackberry Field for the purpose of publicizing the project. Those attending the ceremony included Gene Pauling(DOE), Tammy Borgoyne(LEU), Dr. Bill Bernard(LEU) and local television, radio and newspaper reporters. The project received favorable news reports concerning the project which appeared on local radio and television stations and in the local newspapers. Excerpts of the news release also appeared in the April 10th edition of “Improved Recovery Week”.

In the area of technology transfer, work has been ongoing with the hosting of informal field tours of the air injection project. On April 18th, Andy Houser of Kerr-McGee toured the air injection site. On April 27th, Dan Petri and three other representatives of TOTAL Minatome Corporation toured the air injection project. Both TOTAL and Kerr-McGee are currently evaluating air injection projects in the United States in the Williston Basin(North Dakota, S. Dakota and Montana).

Upcoming Workovers

The repairs on the air injectors, the Watkins No.16 and the Gulf Land D No.51 have been addressed in prior sections of this report. The recompletion of the Watkins No.3 from the Bol-3 to the Cam C-1 is under evaluation. In order to better understand the performance of the air injection project in the area surrounding the Gulf Land D No.51, a recompletion has been planned to test the Cam C-1 in the Gulf Land D No.45 to determine whether this area has already been swept by nitrogen or not. If the Cam C-1 produces nitrogen, the Gulf Land D No.45 will be recompleted down to the Cam C-2,3 and tested. A recompletion of the Gulf Land D No.44 to the Cam C-1 Sand is also under evaluation.
**Attachments:**

1) Revised 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) Pulsed Neutron Log of Watkins No.18 Overlaid on the Electric Log
5) Pulsed Neutron Log of Watkins No.16 Overlaid on the Electric Log (with sidewall core descriptions)
6) Pulsed Neutron Log of Gulf Land D No.56 Overlaid on the Electric Log
7) Log Section for the Gulf Land D No.51 (with temperature measurements)
8) Plot of Bottom Hole Pressures vs. Time
9) Table of Bottom Hole Pressures vs. Time
Evidence Of Nitrogen

Water With Residual Oil Saturation

Amoco Production Company
HACKBERRY FIELD
STRUCTURE MAP
CAM C-I SAND
CAMERON PH., LOUISIANA

graphic scale

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