Report Title:

Application of Reservoir Characterization and Advanced Technology to
Improve Recovery and Economics in a Lower quality Shallow Shelf
SanAndres Reservoir

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OBJECTIVES

The Class 2 Project at West Welch was designed to demonstrate the use of advanced technologies to enhance the economics of improved oil recovery (IOR) projects in lower quality Shallow Shelf Carbonate (SSC) reservoirs, resulting in recovery of additional oil that would otherwise be left in the reservoir at project abandonment. Accurate reservoir description is critical to the effective evaluation and efficient design of IOR projects in the heterogeneous SSC reservoirs. Therefore, the majority of Budget Period 1 was devoted to reservoir characterization. Technologies being demonstrated include:

1. Advanced petrophysics
2. Three-dimensional (3-D) seismic
3. Crosswell bore tomography
4. Advanced reservoir simulation
5. Carbon dioxide (CO₂) stimulation treatments
6. Hydraulic fracturing design and monitoring
7. Mobility control agents

SUMMARY OF TECHNICAL PROGRESS

West Welch Unit is one of four large waterflood units in the Welch Field in the northwestern portion of Dawson County, Texas. The Welch Field was discovered in the early 1940's and produces oil under a solution gas drive mechanism from the San Andres formation at approximately 4800 ft. The field has been under waterflood for 30 years and a significant portion has been infill-drilled on 20-ac density. A 1982-86 pilot CO₂ injection project in the offsetting South Welch Unit yielded positive results. Recent installation of a CO₂ pipeline near the field allowed the phased development of a miscible CO₂ injection project at the South Welch Unit.

The reservoir quality at the West Welch Unit is poorer than other San Andres reservoirs due to its relative position to sea level during deposition. Because of the proximity of a CO₂ source and the CO₂ operating experience that would be available from the South Welch Unit, West Welch Unit is an ideal location for demonstrating methods for enhancing economics of IOR projects in lower quality SSC reservoirs. This Class 2 project concentrates on the efficient design of a miscible CO₂ project based on detailed reservoir characterization from advanced petrophysics, 3-D seismic interpretations and crosswell tomography interpretations.

During the first quarter of 2002 all the Federal funding was expended and the decision was made to terminate the CO₂ injection. The observation well was relogged allowing the current CO₂ saturation around the well to be determined qualitatively.

INTERWELL SEISMIC

All tasks involving the gathering, processing and interpretation of interwell seismic data were completed in 2001 so no work was undertaken in this quarter. Consideration is being given to incorporating the interwell seismic 3D realizations of porosity and permeability into the geologic model as discussed under NUMERICAL SIMULATION.

3-D SEISMIC INTEGRATION

No activities involving 3-D seismic were undertaken during the quarter.

NUMERICAL SIMULATION

Simulation performance predictions using the current geologic model are not matching actual performance too closely as shown by Figures 1 and 2. One of the OXY Permian simulation experts thinks it would be feasible to import the interwell seismic 3D realizations of porosity and permeability into the current geologic model and use the MORE simulator to compare the changes that occur. The practicality of this would depend on getting the input data from ART in a form that could be read into PETREL.

FIELD DEMONSTRATION PHASE

A total of 219 MMCF (2.43 MMCFD) of CO₂ was injected into the six injectors in the CO₂ focus area during the first quarter of 2002. The total volume of CO₂ injected through March 2002 is 4.4 BCF in the focus area and 5.4 BCF in the total project area since initiation of injection in October 1997. The focus area's hydrocarbon pore volume (HCPV) was processed this quarter at a rate of 0.2% per month. A total of 14.7% of the HCPV within the focus area has been processed through December 2001. One injector was switched from water injection to CO₂ during January 2002. The focus area injection and production performance for the first quarter of 2002 is shown on Table 1.

Approximately 2/3 of the 4853 horizontal lateral was plugged back leaving only 1100 feet of horizontal wellbore. This reduced the gas and water volumes enough to allow the well to be operated with existing equipment capacity. The only other remedial operations during the quarter were the cleaning out of injectors 4810 and 4811.

At the beginning of the project in 1994, observation well 4852 was drilled and cased with fiber glass casing. The well was logged initially with LLD and neutron porosity logs and then logged in 1997 with an induction log. In 2001 the well was logged again with an induction log to determine CO₂ migration by the change in hydrocarbon saturation between the two induction logs. In 2002 the observation well was relogged with a neutron porosity log. Figure 3 shows some of the curves recorded by the various logging devices run in 4852. In comparing the 1997 and 2001 induction logs, the higher and lower resistivities recorded on the log section are in nonproductive intervals where the fluid content is not affected by water or CO₂ injection. Hence, the two induction logs should track in these intervals but they do not, which makes the induction log differences across the pay zones inconclusive as an indication of saturation changes. The 2001 induction and 1994 LLD logs curves shown on track 2 of Figure 3 have similar shapes and values, but such a comparison is not valid for two different types of logging devices with different depths of investigation and vertical resolution. Also it was assumed that R_w was the same in 2001 as in 1994, which is probably incorrect.

Track 3 shows the two neutron porosity curves recorded in 1994 and 2002. An increase in CO₂ saturation is recorded by the neutron log as a decrease in porosity. The intervals where the 2002 porosity is less than the 1994 porosity is shaded in black. The percentage difference between the two curves for these intervals is

shown in track 5. According to this comparison there has been CO2 invasion across the total M1 through M3 pay interval in addition to an indication of out of zone injection below 4966 feet.

The remainder of the DOE's portion of the project total funding was expended in February 2002. CO2 injection into the project area was terminated at the end of the quarter (officially April 2, 2002) in view of the limited response that was experienced, the elimination of Federal funding and indications of out of zone CO2 injection. However, water injection will be resumed in all six of the CO2 injectors. This will maintain the reservoir pressure in the focus area above the miscibility pressure and continue to drive any miscible banks that have been formed toward producing wells. The performance of the CO2 focus area will still be monitored and Quarterly Reports issued through the project termination date of September 30, 2002.

Each quarter individual well performance is monitored to determine the focus area's response to CO2 injection. This requires distinguishing between increased oil rates caused by a miscible solvent bank approaching an active producer and increases due to other causes. Prior to the start of CO2 injection, water injection in the demonstration area was reduced to lower the reservoir pressure, which in turn lowered the oil rate in most producers. CO2 injection partially restored the reduction in reservoir pressure, causing an increase in the oil rate in some wells. Remedial treatments, well servicing and changes in producing practices and equipment also resulted in oil rate increases. Also the frequency and accuracy of individual well tests added to the subjectivity of the performance interpretation for both oil and gas (CO2 breakthrough) as did changes in CO2 input rates and switching injectors between CO2 and water. Consequently, it was necessary to observe a well's performance over several months before being comfortable making a judgement. Even then the reevaluation of existing test data plus new test data and the occurrence of gas metering problems makes it necessary to quarterly review the past performance interpretations.

Prior to this quarter, significant oil response to the CO2 injection was judged to have occurred in five wells - 4815, 4818, 4843, 4844 and 4847. On three of these wells - 4843, 4844, 4847 - and one other producer - 4842 - the volume of gas had increased to the point that the wells were judged to have experienced serious CO2 breakthrough. Three other producers - 4815, 4850, 4854 - appear to have some gas breakthrough, but the rate has been fairly low, i.e. <100 MCFPD. During this quarter there has been no additional well response to the CO2 injection. The current response status of the producers is shown on Figure 4 .

TECHNOLOGY TRANSFER

There has been no technology transfer activity during this quarter.

Table 1

CO2 Focus Area Performance
First Quarter - 2002
West Welch Unit DOE Project
Dawson County, Texas

	Jan	Feb	Mar	1st Qtr
Injection				
Average CO2 injection rate (mcf/d)	3210	2009	2026	2428
# of Injectors on CO2	5	2	2	3.0
Average rate per injector (mcf/d)	642	1005	1013	887
% HCPV injected	0.3%	0.2%	0.2%	0.7%
Cum % HCPV injected	14.3%	14.5%	14.7%	14.7%
Average water injection rate (bwpd)	0	0	0	0
# of Injectors on water	0	0	0	0
Average rate per injector	0	0	0	0
Water+CO2 % HCPV injected	0.3%	0.2%	0.2%	0.7%
Water+CO2 Cum % HCPV injected	16.2%	16.4%	16.6%	16.6%
Production				
Base oil production (bopd)	123	122	121	122
Actual oil production (bopd)	210	217	208	212
Incremental oil production (bopd)	87	95	87	90
Gas production (mcf/d)	627	330	589	515
Gas production as % injection	20%	16%	29%	21%
Base WOR	13	13	13	
WOR	3.8	3.9	3.8	3.8

Figure 1 - Model Prediction versus Actual Performance (Production)

Figure 2 - Model Prediction versus Actual Performance (Injection)

Figure 3 - WWU 4852 Observation Well - Time Lapse Logging

Figure 4 - CO2 Performance - 1st Quarter 2002