**Design and Implementation of a CO₂ Flood Utilizing
Advanced Reservoir Characterization and Horizontal
Injection Wells in a Shallow Shelf Carbonate Approaching
Waterflood Depletion**

**Quarterly Report
January 1 - March 31, 1998**

**By
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RESERVOIR CHARACTERIZATION AND HORIZONTAL INJECTION WELLS IN A
SHALLOW SHELF CARBONATE APPROACHING WATERFLOOD DEPLETION**

Cooperative Agreement Number:	DE-FC22-94BC14991
Contractor Name and Address:	Phillips Petroleum Company 4001 Penbrook Street Odessa, Texas 79762
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Award Date:	June 3, 1994
Anticipated Completion Date:	January 2, 2001
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Project Director:	Kirk Czirr
DOE Project Officer:	Jerry F. Casteel
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OBJECTIVE

The first project objective is to utilize reservoir characterization and advanced technologies to optimize the design of a carbon dioxide (CO₂) project for the South Cowden Unit (SCU) located in Ector County, Texas. The SCU is a mature, relatively small, shallow shelf carbonate unit nearing waterflood depletion. The second project objective is to demonstrate the performance and economic viability of the project in the field. All work during the fourth quarter falls within the demonstration project.

SUMMARY OF TECHNICAL PROGRESS

BUDGET PHASE II

TASK V FIELD DEMONSTRATION

Reduce Reservoir Pressure (not included in DOE funding)

Subtask V.1.9 of the Revised Statement of Work included funds for the deepening of water injection wells inside the Unit boundary as necessary to handle the increased water injection capacity. However, this Subtask was specifically excluded from funding by the DOE.

During March, 1997, the project team requested funds to deepen, complete and equip South Cowden Unit (SCU) Well No. 2-18 for use as a water disposal well for the South Cowden Unit CO₂ project. Recent shut-in bottomhole pressure data in the DOE Project Area indicate the reservoir pressure to be approximately 2300 psig in the SCU, increasing to approximately 2600 psig in the Emmons Unit to the immediate north. Bottom-hole pressure surveys run on the horizontal injection Wells Nos. 6C-25H and 7C-11H, on February 3, 1998, indicated 2614 psig and 2632 psig @ reservoir datum of -1700 (4651 TVD). The minimum miscibility pressure (MMP) for the CO₂ project is only 1200 psig; therefore, significant margin exists above the MMP in which to work. In fact, the optimum reservoir pressure for CO₂ flooding is estimated at closer to 1800 psig, as lower pressures would allow the injected CO₂ to occupy more reservoir volume and contact more recoverable oil. The Project team is in unanimous agreement that disposal of water in a lower San Andres interval would ultimately increase the overall San Andres system pressure, thus further contributing to the problem. Thus, the above-mentioned project was recommended as an alternative to Subtask V.1.9 of Phase II of the South Cowden Unit DOE Project.

Approximately 8000 BWPD are currently being produced in the Unit, and are being reinjected. As CO₂ injection continues, the reservoir will necessarily continue to pressure-up, further decreasing the efficiency of the CO₂ in the reservoir. Funds were requested to deepen the plugged and abandoned SCU Well No. 2-18 to the Canyon at 9880', for disposal of up to 5000 BWPD outside the San Andres CO₂ target interval. This would allow for the reduction of reservoir pressure within the Project Area, thus increasing the efficiency of the CO₂ in the reservoir and perhaps increasing the narrow pressure margin between the fracture gradient and

reservoir pressure. The identified out-of-zone injection problems are recognized to be primarily the result of injection at or above the reservoir parting pressure.

This work is premised to commence in July, 1998, with initial injection during August, 1998.

Increase Throughput

A new chemical treatment was tested on SCU Well No. 7-08 on March 5, 1998. The system was designed to address paraffin/asphaltenes, calcium carbonate, and calcium sulfate in a single application. The expense work included a paraffin/asphaltene solvent, sulfate and carbonate remover, antisludge chemicals, and an iron reducing agent. The job was applied via the casing-tubing annulus.

The well showed no increase in oil production following the treatment, but daily water production increased by over 100 BWPD.

Purchase CO₂ and Operation of Recycle Compression Facilities

The CO₂ recycle compression facilities have been in continuous operation during first quarter, 1998.

Gas injection volumes for the four SCU injection well and the three cooperative lease line injection wells for the last 12-month period are reported below. These volumes have been updated and corrected from previous reports,

GAS INJECTION

	Apr 97	May 97	Jun 97	Jul 97	Aug 97	Sep 97
Monthly -mcf	246,126	243,854	290,464	309,884	255,958	157,118
Daily Average-mcfpd	8,204	7,866	9,682	9,995	8,257	5,237
Cumulative-mcf	2,098,967	2,342,821	2,633,285	2,943,129	3,199,087	3,356,205
	Oct 97	Nov 97	Dec 97	Jan 98	Feb 98	Mar 98
Monthly -mcf	295,130	312,344	181,053	174,565	148,969	152,456
Daily Average-mcfpd	9,520	10,411	5,840	5,631	5,320	4,918
Cumulative-mcf	3,651,335	3,963,679	4,144,732	4,319,297	4,468,266	4,620,722

Unit Production

By late December, sustained oil production had increased approximately 150 barrels of oil per day (BOPD) total, with 75 BOPD as a result of the CO₂ injection in the near vicinity of the horizontal injection wells, and the remaining 75 BOPD as a result of the earlier stimulation program. The

production in the following quarter has been declining primarily as a result of decreased CO₂ injection, as the reservoir pressure will begin to level-out and decline. A summary of quarterly average production and injection follows:

Qtr	-----PRODUCTION-----			-----INJECTION-----	
	BOPD	BWPD	MCFD	BWIPD	MSCFPD CO ₂
1st 1996	375	3861	88	4520	0
2nd 1996	356	3526	89	4208	0
3rd 1996	337	4301	91	4144	3623
4th 1996	375	4907	105	4900	8674
1st 1997	442	5837	611	5837	8111
2nd 1997	425	6462	929	6462	8576
3rd 1997	445	6408	1110	6834	7858
4th 1997	485	8003	1317	8003	8571
1st 1998	464	6612	829	6613	5298

* Volumes starting in October, 1997, may need to be further corrected in the future as our new production reporting system is quality-controlled and allocations reviewed.

Monitor Project Performance

As the CO₂ project progressed this year, several key problem areas were identified for resolution. These problem areas can be summarized as : (1) high reservoir pressure, (2) narrow margin between reservoir pressure and parting pressure, and (3) out-of-zone injection problems.

The reservoir pressure in the project area is estimated at 2300 pounds per square inch gauged (psig), with much higher pressures to the north in the Emmons Unit (estimated at 2600 psig), and lower pressures to the south along the project area boundary. For this reason, the CO₂ preferentially is traveling to the south of the horizontal Well No. 7C-11H, with initial oil response and CO₂ breakthrough occurring primarily in that region. The project team is currently reviewing various alternatives for moving produced water off-lease for disposal outside of the Project area, in an effort to reduce overall system pressures. The reduction of overall reservoir pressure will also increase the efficiency of the injected CO₂, as the same amount of CO₂ will occupy more space, thus contact more oil under lower pressures.

Instantaneous shut-down pressure (ISDP) data obtained from the wellwork during second and third quarters in both the Emmons Unit and South Cowden Unit indicates the frac gradient to be approximately .6 psi/ft. With this knowledge the team recommended that the surface injection pressures for the water injection wells be limited to 650 psig for any water injection within the project area, and 1150 psig for CO₂ injection. This would necessarily reduce the amount of CO₂ being purchased, as well as injected, but would better insure the purchased CO₂ was in fact being

efficiently utilized. For the time being, the water injection wells surrounding the project area would be allowed to exceed these recommended injection pressures to dispose of excess water in the lower zones.

The field personnel implemented the above recommendations, which reduced considerably the amount of purchased gas required. However, it also changed the mix of the injected CO₂ with the contaminated produced gas, thus the fluid head and resulting maximum surface injection pressures. Pressure surveys with gradient stops are planned for January in order to determine guideline pressures under current mixing conditions. As a result of the changes, the purchased CO₂ volumes were reduced to minimum contract quantities of approximately 5 MMscfd, primarily being injected in the horizontal injection Wells Nos. 6C-25H and 7C-11H.

The out-of-zone injection problem is also believed to be exacerbated by the high reservoir pressure; for this reason, further conformance control work, including foamed cement squeezes and monomer/polymer work will be delayed until after the reservoir pressure has been reduced by a couple of hundred pounds.

TASK VI TECHNOLOGY TRANSFER, REPORTING, AND PROJECT MANAGEMENT

Technology Transfer

Kimberly B. Dollens participated as a panelist and presenter in the 1997 SPE CO₂ Conference (Dec. 10-11, 1997) in Midland, Texas. The conference focused on actual case histories. The talk was entitled "Application of Horizontal Injection Wells in the South Cowden Unit CO₂ Flood". She also participated as a presenter in the 1998 Permian Basin Recovery Conference in Midland, Texas, on Thursday, March 26, 1998.

Kimberly B. Dollens submitted an abstract for a paper entitled "Field Implementation of a CO₂ Flood in a Small Waterflood-Depleted Carbonate Unit," for presentation at the 1998 Southwestern Petroleum Short Course in Lubbock, Texas, April 8-9, 1997. The proposed paper will be co-authored by Ms. Dollens, Ken J. Harpole, and Larry Hallenbeck.

An abstract was submitted by T. F. McCoy, K. J. Harpole, and K. B. Dollens to the selection committee for the SPE Sixth International Oil and Gas Conference and Exhibition in Beijing, China, on November 2-6, 1998. The abstract is entitled "Transient Test Analysis Case History for Two Horizontal Miscible Gas Injection Wells".

A poster session entitled "Reservoir Characterization of an Upper Permian Platform Carbonate in Preparation for a Horizontal-Well CO₂ Flood, South Cowden Unit, West Texas" was presented by Craig Caldwell and Kimberly B. Dollens at the Permian Basin Section of the Society of Economic Paleontologists and Mineralogists' (SEPM) Permian Basin Core Workshop in Midland, Texas, on Thursday, February 26, 1998.