

**Design and Implementation of a CO<sub>2</sub> Flood Utilizing  
Advanced Reservoir Characterization and Horizontal  
Injection Wells in a Shallow Shelf Carbonate Approaching  
Waterflood Depletion**

**Quarterly Report  
April 1 - June 30, 1997**

Work Performed Under Contract No.: DE-FC22-94BC14991

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

By  
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**DESIGN AND IMPLEMENTATION OF A CO2 FLOOD UTILIZING ADVANCED  
RESERVOIR CHARACTERIZATION AND HORIZONTAL INJECTION WELLS IN A  
SHALLOW SHELF CARBONATE APPROACHING WATERFLOOD DEPLETION**

**Cooperative Agreement Number:** DE-FC22-94BC14991--13

**Contractor Name and Address:** Phillips Petroleum Company  
4001 Penbrook Street  
Odessa, Texas 79762

**Date of Report:** August 1, 1997

**Award Date:** June 3, 1994

**Anticipated Completion Date:** January 2, 2001

**Government Award for 1997 Fiscal Year:** \$1,379,607

**Project Director:** John S. Chimahusky

**DOE Project Officer:** Jerry F. Casteel

**Reporting Period:** April 1, 1997 - June 30, 1997

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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 (CO<sub>2</sub>) 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 second quarter falls within the demonstration project.

## **SUMMARY OF TECHNICAL PROGRESS**

### **BUDGET PHASE II**

#### **TASK V FIELD DEMONSTRATION**

##### **Drill two vertical WAG injectors along South Cowden Unit boundary - approved under Amendment No. A007 to the Cooperative Agreement for inclusion in Phase II funding**

Vertical water-alternating-gas (WAG) injection Wells 6-26W and 6-27W were placed on injection during January, 1997. Injection profile surveys were run while on water injection during early February, 1997.

The injection survey on Well 6-26W indicated communication between a water sand at 4344-4355' and casing perforations 4568-4572' and 4578-4582'. During the shut-in period, the log indicated that flow from the water sand was entering the wellbore through the perforations in communication at a rate of 35 barrels per day (BPD) and was cross-flowing into the selectively perforated interval 4592-4726'.

The injection survey also suggested that the selectively perforated intervals below 4700' (4709-4711', 4716-4718', and 4724-4726') were taking approximately 15% of the injection water with evidence of downward channeling. A remedial workover was proposed to squeeze the selectively perforated interval 4709-4726' and the selectively perforated interval 4568-4582' in an effort to limit out-of-zone injection.

A workover was performed during early April, 1997, to conventionally squeeze cement the lower thief zone (4709-4726') below a retainer at 4701' and then squeeze cement the upper perms at 4568-4582'. After three attempts to squeeze the upper zone, the well pressure tested in the upper zone and the well was placed back on water injection.

A subsequent water injection profile survey was run during June which indicated that the upward channel had successfully been plugged; however, virtually one hundred percent (100%) of the injected water was going out the bottom of the well. A foamed cement job was then performed during late

June to stop the out-of-zone injection, and the well was reperforated across the E and upper F zones (4618-4638'). The job appeared to have been successful as planned, and the well was then placed on carbon dioxide (CO<sub>2</sub>) injection. A subsequent injection profile will be run in third quarter to confirm the success of the foamed cement job.

The injection log run on Well 6-27W indicated 50-60% of the injection volume was leaving the wellbore through the perforated interval 4746-4748', which was mistakenly perforated below the oil-water-contact at approximately -1800' subsea (ss). The injection survey also indicated limited water injection occurring above 4686'. A foamed cement job is planned during third quarter pending evaluation of the success of the procedure in Well 6-26W.

**Workover or Recondition Existing Wells**

During second quarter 1997, three wells were acid stimulated. The results follow:

	-----BEFORE-----			-----AFTER-----			
Well	BOPD	BWPD	MCFD	BOPD	BWPD	MCFD	Comments
SCU 7-01	24	116	116	31	170	100	May, 1997
SCU 7-05	4	212	1	5	385	1	May, 1997
SCU 7-10	3	62	6	17	116	26	April, 1997

The DOE does not share in the costs of these acid stimulation jobs, which were deemed necessary as a result of updated reservoir simulation modeling.

**Purchase CO<sub>2</sub> and Operation of Recycle Compression Facilities**

The CO<sub>2</sub> recycle compression facilities have been in continuous operation during second quarter.

The CO<sub>2</sub> injection volumes for first quarter were erroneously reported in the first quarter report due to calibration problems in the field. Therefore, revised gas injection volumes for the four SCU injection well and the three cooperative lease line injection wells for the first quarter along with second quarter volumes are reported below:

**GAS INJECTION - MCF**

	Jan 97	Feb 97	Mar 97	Apr 97	May 97	Jun 97
Monthly	236,091	230,633	263,268	246,126	243,854	264,694
Daily Average	7,616	8,237	8,493	8,204	7,866	8,823
Cumulative	1,358,248	1,588,881	1,852,149	2,098,275	2,342,129	2,606,823

## **Unit Production**

No tertiary response was anticipated until mid-1997. However, incremental oil production resulting from CO<sub>2</sub> injection has been sustained at approximately 70 BOPD during second quarter, 1997, in the near vicinity of the horizontal injection wells from production Wells 6-17, 6-22, 6-24, 7-01 and 7-08. A summary of quarterly average production and injection follows:

Qtr	-----PRODUCTION-----			-----INJECTION-----	
	BOPD	BWPD	MCFD	BWIPD	MSCFPD CO <sub>2</sub>
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	5710	8293

## **Monitor Project Performance**

The South Cowden Unit full-field simulation model was updated to incorporate the exact project implementation and operating schedule, and was adjusted to reflect additional reservoir performance data from the first 12 months of project operation. The relevant field performance data included individual well injection and production rates and pressures, results of injection profile surveys, and oil response and gas breakthrough data. The simulation forecasts were integrated with operations and geologic information to fine-tune the project operating strategy. Specific recommendations were implemented to stimulate selected wells and conduct additional conformance work to improve injection profiles in the CO<sub>2</sub> injection wells, including the SCU 7C-11H horizontal well.

## **TASK VI TECHNOLOGY TRANSFER, REPORTING, AND PROJECT MANAGEMENT**

### **Technology Transfer**

SPE Paper 37470, "The Evaluation of Two Different Methods of Obtaining Injection Profiles in CO<sub>2</sub> WAG Horizontal Injection Wells," written by Kimberly B. Dollens, Burl W. Wylie, James C. Shoumaker, Orjan Johannessen, and Phil Rice, was presented by Ms. Dollens at the 1997 Phillips Petroleum Company Exploration and Production (PPCO E&P) Technical Symposium, April 2-4, 1997, in Bartlesville, Oklahoma.

James C. Shoumaker also prepared and presented a poster session entitled "Drilling and Completions

Considerations of Horizontal CO<sub>2</sub> Injection Wells - South Cowden Unit”, at the PPCO E&P Technical Symposium on April 2-4, 1997, in Bartlesville, Oklahoma.

Kimberly B. Dollens presented the project review at the U.S. Department Of Energy, National Petroleum Technology Office, Oil Technology and Gas Environmental Review on June 16, 1997, in Houston Texas.