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
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
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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
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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 (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 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 perfs 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 (CO₂) 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:

<table>
<thead>
<tr>
<th>Well</th>
<th>BOPD</th>
<th>BWPD</th>
<th>MCFD</th>
<th>BOPD</th>
<th>BWPD</th>
<th>MCFD</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCU 7-01</td>
<td>24</td>
<td>116</td>
<td>116</td>
<td>31</td>
<td>170</td>
<td>100</td>
<td>May, 1997</td>
</tr>
<tr>
<td>SCU 7-05</td>
<td>4</td>
<td>212</td>
<td>1</td>
<td>5</td>
<td>385</td>
<td>1</td>
<td>May, 1997</td>
</tr>
<tr>
<td>SCU 7-10</td>
<td>3</td>
<td>62</td>
<td>6</td>
<td>17</td>
<td>116</td>
<td>26</td>
<td>April, 1997</td>
</tr>
</tbody>
</table>

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 CO₂ and Operation of Recycle Compression Facilities

The CO₂ recycle compression facilities have been in continuous operation during second quarter.

The CO₂ 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 leaseline injection wells for the first quarter along with second quarter volumes are reported below:

GAS INJECTION - MCF

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

No tertiary response was anticipated until mid-1997. However, incremental oil production resulting from CO₂ 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:

<table>
<thead>
<tr>
<th>Qtr</th>
<th>BOPD</th>
<th>BWPD</th>
<th>MCFD</th>
<th>BWIPD</th>
<th>MSCFPD</th>
<th>CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st 1996</td>
<td>375</td>
<td>3861</td>
<td>88</td>
<td>4520</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2nd 1996</td>
<td>356</td>
<td>3526</td>
<td>89</td>
<td>4208</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3rd 1996</td>
<td>337</td>
<td>4301</td>
<td>91</td>
<td>4144</td>
<td>3623</td>
<td></td>
</tr>
<tr>
<td>4th 1996</td>
<td>375</td>
<td>4907</td>
<td>105</td>
<td>4900</td>
<td>8674</td>
<td></td>
</tr>
<tr>
<td>1st 1997</td>
<td>442</td>
<td>5837</td>
<td>611</td>
<td>5837</td>
<td>8111</td>
<td></td>
</tr>
<tr>
<td>2nd 1997</td>
<td>425</td>
<td>6462</td>
<td>929</td>
<td>5710</td>
<td>8293</td>
<td></td>
</tr>
</tbody>
</table>

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 CO₂ injection wells, including the SCU 7C-11H horizontal well.

TASK VI  TECHNOLOGY TRANSFER, REPORTING, AND PROJECT MANAGEMENT

Technology Transfer


James C. Shoumaker also prepared and presented a poster session entitled “Drilling and Completions
Considerations of Horizontal CO₂ Injection Wells - South Cowden Unit”, at the PPCO E&P Technical Symposium on April 2-4, 1997, in Bartlesville, Oklahoma.