Evaluation and Enhancement of Carbon Dioxide Flooding Through Sweep Improvement

DE-FC26-04NT15536

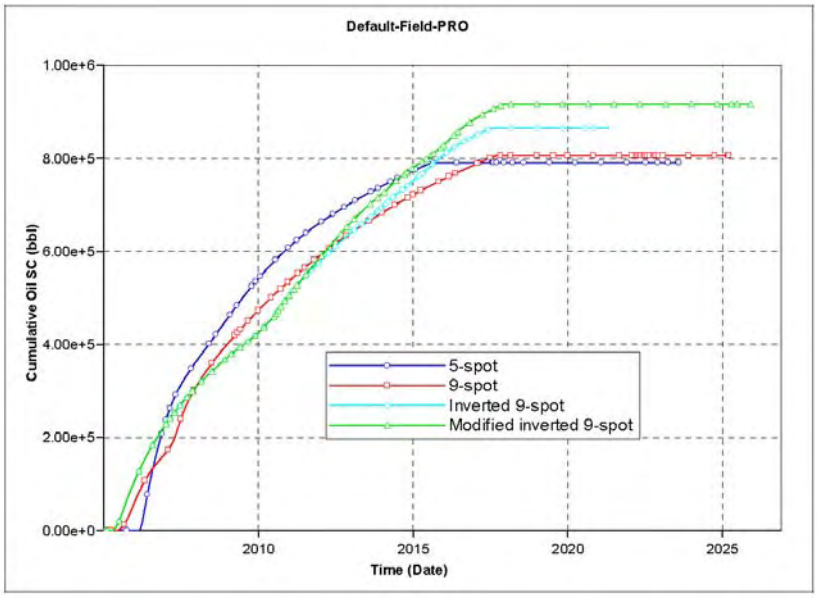
Goal

The objective of the project is to develop a methodology for improving sweep efficiency and reducing CO_2 utilization rates by performing a detailed post-mortem on a mature carbon dioxide project that relates actual reservoir performance to predicted performance.

Performers

Louisiana State University
Baton Rouge, LA

Denbury Resources, Inc.
Plano, TX



Comparison of simulated oil recovery for different well patterns indicating a modified inverted nine-spot pattern yields greatest ultimate recovery for Little Creek reservoir properties.

Results

Efforts have focused on tasks associated with the historical evaluation of the sweep efficiency in Little Creek field, operated by Denbury Resources Inc. The historical performance of Little Creek field has been analyzed to evaluate the effectiveness of injection and production operations during the active CO_2 flooding process. A simulation study has been performed that provided insight into a preferred operating strategy for CO_2 flooding. Production logging has begun, and the results of the logs run are being incorporated into a simulation study being conducted on a pattern-by-pattern basis. Reservoir performance is also being compared with the original flood design found in the records Shell Oil Company provided to Denbury Resources.

Researchers have:

- Completed a parametric study of factors affecting the miscible Completed parametric study of factors effecting miscible carbon dioxide flooding process and their effect on sweep efficiency.
- Proposed an operating strategy, based on the parametric study and simulation results, to maximize oil recovery in Completed parametric study of factors effecting miscible carbon dioxide flooding process and their effect on sweep efficiency.
- Based on the parametric study and simulation results, an operating strategy was proposed to maximize oil recovery in carbon dioxide floods.
- Initiated a production logging program and are incorporating results into pattern-by-pattern simulation studies.

Benefits

CO_2 displacement is a common improved recovery method applied to light oil reservoirs. The economic and technical success of CO_2 floods is often limited by poor sweep efficiency or large CO_2 utilization rates. Little Creek field in Mississippi is being studied to relate laboratory displacement results and simulated performance predictions to the historical reservoir performance to determine sweep efficiency, improve the understanding of the reservoir response to CO_2 injection, and develop scaling methodologies to relate laboratory data and simulation results to predicted reservoir behavior.

Background

This project is studying the effectiveness of CO_2 flooding in a mature reservoir to identify and develop methods and strategies to improve oil recovery in CO_2 floods. The study of Little Creek field will identify strategies to improve recovery from the reservoir through understanding conformance control and sweep in the current operations. Based on the knowledge gained during this study, methods will be developed for predicting conformance control and sweep efficiency that can be extended to other CO2 injection projects, in progress or planned, and ultimately yield improved oil recoveries due to CO2 flooding and reduce CO_2 utilization rates.

Summary

The project was designed to be conducted in two primary tasks:

- Task 1: Historical evaluation of sweep efficiency in a mature CO_2 flood.
- Task 2: Extension of sweep efficiency findings to target reservoirs for CO_2 flooding.

Task 1 is devoted to analyzing the historical performance of Little Creek field to evaluate the effectiveness of injection and production operations during the active CO_2 flooding process. The research team is in the process of comparing performance predictions to actual historical performance data, including displacement studies, conformance issues, and sweep efficiency. Laboratory displacement studies are being designed and will provide a means to correlate actual reservoir performance to simulation studies and to other laboratory studies for CO_2 flooding. Historical reservoir, production, and well data are being used to evaluate the effectiveness of CO_2 injection and sweep in Little Creek field. Several production logs have been run in active areas of the field to evaluate injection profiles in individual wells to identify vertical

injection conformance or isolate injection issues. The production logging portion of the project will be ongoing throughout the remaining life of the field and is being used to aid simulation studies of several of the injection patterns in the field.

Cased-hole logs to try to evaluate behind pipe saturations have also been designed, and test case areas are being evaluated in an attempt to allow the research team to quantify the measurements as best they can. If successful, these cased-hole logs will also be run in selected wells to estimate oil saturation throughout the Little Creek reservoir to verify sweep efficiency or identify potential unswept segments of the reservoir especially in the northeast quadrant of the field, which has been shut-in for nearly 10 years and may be economically productive at current oil prices.

Simulation studies are being used to match historical reservoir performance both prior to and after initiation of the CO_2 flood in order to develop a system of dynamic reservoir models for use in predicting performance based on actual reservoir conditions. The emphasis will be on integrating the understanding developed in the various activities to improve CO_2 sweep and extend that understanding to other reservoirs by developing application guidelines and recommendations for efficient CO_2 sweep. The project is also leveraging a large quantity of geological and engineering information provided to Denbury from Shell in order to evaluate potential differences between the original flood design and current operations.

Task 2 focuses on extending the findings of Task 1 to reservoirs that may be CO_2 flooding candidates. This includes reservoirs with light oils comparable to Little Creek field and heavy oils (10-20° API) where the potential for CO_2 flooding needs additional study, especially relative to sweep effects due to the viscosity variation between the CO_2 and viscous reservoir oils. Denbury has several target reservoirs in eastern Mississippi that will serve as candidate reservoirs for this task and has agreed to consider implementing ideas developed to improve oil recovery. Work in this task will also focus on laboratory studies of CO_2 displacement of heavy oils and relating the results from this task to Task 1 to improve the confidence of recovery estimates made for this application. The activities in this area will yield an improved understanding of the feasibility of CO_2 flooding heavy oil reservoirs, obstacles that need to be overcome, and potential solutions to those obstacles. This portion of the project is currently pending Congressional action on funding.

Current Status (February 2007)

The 3-year project was initiated on October 1, 2004, and completed the first quarter of its second year with slight delays in the tasks associated with miscibility testing and saturation determination. At that time, one of the original principal investigators (PI) moved to Louisiana State University (LSU) and shortly thereafter, the other PI left academia and accepted an industrial position. A fair portion of the past year has been spent completing the transfer of the project from the University of Oklahoma (OU) to LSU with funding suspended pending the transfer. It is expected that researchers at LSU will complete most of the items in Task 1 by the end of this project year. If the project is selected for continued funding for the final year, efforts will be shifted to Task 2, with the extension of the findings from Task 1 to other reservoirs. The research team expects that the project will continue to progress in a satisfactory manner from this point forward.

History matching and simulation studies of Little Creek field performance are ongoing to improve the understanding of the sweep efficiency and performance prediction techniques. During this year, miscibility testing started at OU will commence at LSU, and displacement studies will begin. The determination of cased-hole fluid saturations is a very important parameter in a CO_2 injection project to help understand vertical conformance and sweep efficiency; however, there are a number of technical challenges in determining these saturations. The research team will continue evaluating available tools and techniques that might allow a process to be developed to determine these saturations. This work should result in a field test during the current year.

Funding

This project was selected in response to DOE's Office of Fossil Energy Research and Development solicitation DE-PS2604NT15450-3F.

Slim-tube miscibility-testing equipment.

Publications

Tran, N. "Evaluation and Enhancement of Miscible Carbon Dioxide Flooding," 2005 MS thesis, University of Oklahoma, Norman, OK.

Wiggins, M.L. and Hughes, R.G. "Evaluation and Enhancement of Carbon Dioxide Flooding Through Sweep Improvement—Annual Technical Report", December 2005.

Project Start: October 1, 2004
Project End: September 30, 2007

Anticipated DOE Contribution: $678,070
Performer Contribution: $315,316 (32 percent of total)

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