Evaluation and Enhancement of Carbon Dioxide Flooding Through Sweep Improvement

DE-FC26-04NT15536

Program

This project was selected in response to DOE's Office of Fossil Energy Research and Development solicitation DE-PS26-04NT15450-3F.

Project Goal

This research is studying the effectiveness of carbon dioxide (CO_2) flooding in a mature reservoir to identify and develop methods and strategies to improve oil recovery in CO_2 floods. 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 CO_2 project that relates actual reservoir performance with predicted performance. Knowledge gained from this detailed analysis will yield improved operating practices that will serve as a guide to improving oil recovery in active CO_2 floods and as a strategy for implementing new CO_2 floods.

Performers

University of Oklahoma
Norman, OK

Denbury Resources, Inc.
Plano, TX

Project Results

This project commenced on October 1, 2004, and has focused on tasks associated with the historical evaluation of the sweep efficiency in Little Creek field. In addition, the laboratory work is being set up, and a logging suite is being developed.

Benefits

Martin and Taber (1992) have estimated that an incremental 5-30 billion barrels of oil could be recovered from CO_2 flooding in the United States, depending on the oil price and economic incentives. Taber et al. (1997) projected that about 80% of the world's reservoirs could recover some incremental oil from CO_2 flooding. With this much potential for economic benefit, the question becomes: Why have more CO_2 floods not been initiated? The answer is primarily the cost of the CO_2. Floods that are near CO_2 infrastructure are recovering significant amounts of incremental oil, while those that are a distance from the infrastructure are debating the economics of extending pipelines and compression facilities to outlying areas. Minimizing the utilization rate through intelligent application of mobility and conformance-control measures would greatly improve the economics of extending the infrastructure to these outlying areas by ensuring that the CO_2 contacts more of the reservoir.

Slim-tube miscibility-testing equipment.

Background

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.

The University of Oklahoma, through the Mewbourne School of Petroleum and Geological Engineering, has partnered with Denbury Resources, Inc. to evaluate CO_2 displacement efficiency in a mature oil reservoir. 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.

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 CO_2 injection projects, in progress or planned, and ultimately yield improved oil recoveries due to CO_2 flooding and reduce CO_2 utilization rates.

Project Summary

The following information summarizes the research tasks as originally proposed. The research team has begun to address Task 1 during the first nine months of the project and will continue to complete these tasks during the upcoming project year. It is anticipated that most items in Task 1 should be complete at the end of Project Year 2. During the later half of the year efforts will be shifted to Task 2 with the extension of the findings from Task 1 to other reservoirs.

The project tasks break out as follows:

- Task 1, historical evaluation of sweep efficiency in a mature CO_2 flood. This task is devoted to analyzing the historical per-

formance of Little Creek field to evaluate the effectiveness of injection and production operations during the active CO_2 flooding process. This task focuses on comparing performance predictions with actual historical performance data, including displacement studies, conformance issues, and sweep efficiency. Laboratory displacement studies provide a means to correlate actual reservoir performance to simulation studies and to laboratory studies for CO_2 flooding. Historical reservoir, production, and well data are to be used to evaluate the effectiveness of CO_2 injection and sweep in Little Creek field. This study incorporates an active production logging program to evaluate injection profiles in individual wells to identify vertical injection conformance or isolate injection issues. Cased-hole logs also are run in selected wells to estimate oil saturation through the Little Creek reservoir to verify sweep efficiency or identify potential unswept segments of the reservoir. The simulation study is used to match historical reservoir performance prior to the initiation of the CO_2 flood in order to develop a dynamic reservoir model for use in predicting performance based on actual reservoir conditions. The emphasis is 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.

• Task 2: extension of sweep efficiency findings to target reservoirs for CO_2 flooding. 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 (10-20o API gravity) 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 could serve as candidate reservoirs for this task and has agreed to consider implementing ideas developed to improve oil recovery. Work in this task also focuses 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 are expected to 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.

Current Status (August 2005)

The project's first annual report was due to DOE in September 2005.

CO_2 separation facilities at Little Creek field.

Publications

First annual report due to DOE in September, 2005.

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

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

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