INJECTION INTO COAL SEAMS FOR SIMULTANEOUS CO₂ MITIGATION AND ENHANCED RECOVERY OF COALBED METHANE

Topical Report

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EXECUTIVE SUMMARY

Because of confidentiality requirements of this task, this topical report is necessarily brief and is based on quarterly reports that have been previously approved for release by Amoco Production Company (Amoco). More detailed topical reports have been written and will continue to be written as the project proceeds. The U.S. Department of Energy (DOE) has approved that these detailed reports can be held in confidence for a period not to exceed three years from their dates of publication. When this three-year period has transpired, or earlier with Amoco's approval, the more detailed topical reports will be provided to DOE for its discretionary use.

Three detailed technical reports have been written that cover the two-well pilot test, the laboratory work, and modeling using a coal reservoir description and Amoco's coalbed methane simulator. The document covering the two-well pilot test elicited many comments from Amoco personnel and a major revision of the document is in progress. The other two documents are essentially complete.

History matching of the Allison Unit CO₂ injection project has been completed and long-term performance predictions have been made using the resulting reservoir description. Idealized predictions for a quarter of a five-spot pattern of the process have been made and economics of the process evaluated.

OBJECTIVE

The overall objective of this task is to test the technical viability of injecting CO₂ into the Fruitland Coal to displace methane from the coal and to mitigate CO₂ emissions that are a consequence of primary coalbed methane production from surrounding wells in the area. To evaluate this technical viability, a field test was conducted, and the test is being interpreted using Amoco's coalbed methane simulator and data collected in WRI's laboratory. Also, a second pilot of the process is being evaluated using the simulator. Ultimately, the technology developed will be applied to a Wyoming coal.

INTRODUCTION

Coalbed methane (CBM) is the hydrocarbon gas consisting largely of methane that is either adsorbed on the abundant surface area of the coal (McGill and Kausc 1993) or absorbed in the microporosity of the coal (*Petroleum Frontiers* 1986). Historically, CBM has generally been regarded as a nuisance and a hazard to miners. Internationally, 15,000 people have died from methane-related explosions connected with coal mines in the last century (Amyotte and Pegg 1993).

Over the past two decades, however, CBM has been increasingly recognized as a precious commodity, first because of encouraging Internal Revenue Code, Section 29 tax incentives and subsequently, because of advances in the technology of its production. The Petroleum Information Corporation (*Petroleum Frontiers* 1986) estimates that domestically at least a 50-year supply of methane is stored in the coal. This is nearly twice the amount of domestic conventional resource available (*Petroleum Frontiers* 1986). Near the end of 1990 in the United States, nearly 5% of total gas production was coming from coalbeds (Chadwick 1991). Internationally, CBM resources have a high potential to meet part of the greatly increasing energy demands of both developed and developing countries.

One of the most promising areas of technology development for the recovery of CBM is enhanced CBM recovery (ECBM). In Amoco-patented technology (Puri and Stein 1989), nitrogen has already been successful in displacing methane from coal (*Oil and Gas Journal* 1993). Other displacing agents are also being considered. One such agent is CO₂. Because CO₂ is a particularly troublesome greenhouse gas (Greenberger 1991), using it to displace methane from the coal could help to alleviate CO₂ emissions. Also, the coal readily adsorbs CO₂ and this adsorption can, under certain circumstances, lead to increased displacement efficiency. Offsetting these positive effects is the fact that relatively large quantities of CO₂ are needed to displace the methane, which increases the cost of the process. Another potentially negative factor is that CO₂ can have an adverse effect

on the coal, causing it to swell and ultimately to plug off what is even under the best of circumstances characteristically a paucity of permeability in coalbeds.

Consequently, this project was undertaken to test the viability of recovering coalbed methane by the process of displacing it with CO₂ and to examine the process in a field-pilot setting. Because of the confidentiality requirements of the project, the following description is necessarily brief and is based on quarterly reports that have been previously approved for release by Amoco. More detailed topical reports have been written, and will continue to be written, as the project proceeds. The U.S. Department of Energy (DOE) has approved that these detailed reports can be held in confidence for a period not to exceed three years from their dates of publication. When this three-year period has transpired, or earlier with Amoco's approval, the more detailed topical reports will be provided to DOE for its discretionary use.

DISCUSSION

This project is divided into five Subtasks:

- 6.1 Two-Well Pilot Test of CO₂ Injection
- 6.2 CO₂/N₂ Laboratory Tests in the Fruitland Coal
- 6.3 Modeling of Two-Well Pilot Test
- 6.4 Allison Unit CO₂ Pilot Study
- 6.5 CO₂/N₂ Laboratory Tests in Wyoming Coals.

Subtask 6.1, Two-Well Pilot Test of CO₂ Injection

A draft final report entitled "Two-Well Pilot Test" was completed and submitted to Amoco for review on August 30, 1996. Amoco suggested many changes to the document. Comments made by Amoco regarding the draft final report were addressed by WRI, and suggestions were made to Amoco about how the document might be changed to address Amoco's concerns. Amoco reviewed these suggestions. It was decided that where differences of technical opinion remain, both Amoco's arguments and WRI's arguments will be included in the final document.

Subtask 6.2, CO₂/N₂ Laboratory Tests in the Fruitland Coal

A draft final report entitled "Development of a Coalbed Methane Adsorption and Displacement System" was submitted to Amoco for review on August 30, 1996. After this review, the document was revised and is essentially complete.

Subtask 6.3, Modeling of Two-Well Pilot Test

A draft final report entitled "History Match Studies of the CO₂ Pilot Using a Coal Reservoir Description" was completed and submitted to Amoco on August 30, 1996, and was subsequently reviewed by Amoco. The document has been revised and is essentially complete.

Subtask 6.4, Allison Unit CO₂ Pilot Study

In the initial modeling attempts of the Allison Unit, available density well logs were reinterpreted using a different porosity cutoff, and thicknesses were determined for wells in the model study area. Where well logs were not available, values of thicknesses were determined by contouring. Initial estimates of permeability were obtained by assuming that the permeability-thickness product was proportional to the cumulative production from the well. Values for permeability between wells was determined by contouring. The model study area consists of a 42 x 46 x 1 regularly spaced grid. Four injectors and 15 producers are contained within the study area. Actual monthly rate data obtained from Dwights Energy Data, Software & Information Services for each well was specified. Estimates of initial conditions were provided. To check out the model, a rudimentary attempt to match primary performance of the wells was made with reasonable success. No attempts were made to match the water performance because the rates were so sporadic. Bottomhole pressures were allowed to float for these first attempts, but still the predicted average pressure in the reservoir was very close to the actual pressure measured in the pressure observation well and tracked very closely the movement of the pressure in the observation well in response to CO₂ injection. A meeting was held in Tulsa with personnel from Amoco's Exploration and Production Technology Group (EPTG) and Amoco's Southern Rockies Business Unit (now known as San Juan Business Unit) on May 29, 1996, to discuss the results of the modeling study at that state of progress.

Then, new data were obtained and reviewed. Bottomhole pressures were calculated from measured surface pressures using correlations for two-phase flow available in the literature. Some new techniques for data reduction that were developed during performance of the other subtasks were employed for this subtask.

History matching of the primary performance of the Allison Unit Pilot was completed using Amoco's coalbed methane simulator and a long-range prediction was made for operation under CO₂ injection. An outline of the proposed final documentation of the project was written by WRI and given to Amoco for review. On March 5, 1997, highlights of the study were presented by WRI at a meeting in Denver. Personnel from Amoco's Southern Rockies Business Unit and from Amoco's Exploration and Technology Group from Tulsa attended the meeting. WRI also presented expected economics under different operating scenarios for an idealized quarter of a five-spot pattern. These

economics were generated with a program called PEEP (Petroleum Economics Evaluation Program), lent to WRI by Amoco. In developing the grid of thickness data, WRI had very little geological control of thickness data in the model study area. Also, WRI had inadvertently used the wrong density cutoff on some logs. WRI suggested that the history matching be revised. Amoco agreed and also provided additional thickness control for the model study area. The history match has since been revised, new predictions have been made, and new five-spot economics have been prepared using more current data. A new outline of the draft document has been provided to Amoco. Meridian, Inc.'s interest in the Allison project was acquired by Burlington Resources, Inc.

Subtask 6.5, CO₂/N₂ Laboratory Tests in Wyoming Coals

No significant work was accomplished on this subtask.

CONCLUSIONS

Three detailed reports have been written covering the two-well pilot test, the laboratory work, and modeling using a coal reservoir description and Amoco's coalbed methane simulator. The first of these reports is being revised and the other two are essentially complete. Modeling of the Allison Unit is complete and a report is in progress.

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