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Injection Into Coal Seams for Simultaneous CO_2 Mitigation and Enhanced Recovery of Coalbed Methane

Topical Report
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Disclaimer

ACKNOWLEDGEMENTS AND DISCLAIMER

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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 which 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.

This project was undertaken to test the viability of recovering coalbed methane by the process of displacing it with CO_2 and to examine the process in a field-pilot setting. To evaluate this technical viability, the results of a field test are being interpreted using data measured in the laboratory at Western Research Institute (WRI), as well as using Amoco's state-of-the art coalbed methane simulator. The laboratory setup has been modified to include a reference cell in the constant-temperature oven to permit more accurate measurements of isotherms. The isotherm measurement process has been automated so that minimal training is required for a technician to be able to perform it. Displacement tests have been conducted. The setup and measurements are described in a document, subject to the confidentiality agreement discussed above, which is being finalized.

The two-well pilot test has been interpreted, and draft documents are being prepared that consolidate the data taken on the pilot, the pressure transient analyses conducted, and the modeling study undertaken. The DOE Morgantown Energy Technology Center (METC) has approved replacing the Phase II design study with a modeling study of another CO_2 pilot being conducted in the area. That study is underway.

OBJECTIVE

The overall objective of this task is to test the technical viability of injecting CO_2 into the Fruitland Coal to displace methane from the coal and to mitigate CO_2 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 data measured in WRI's laboratory, as well as using Amoco's state-of-the art coalbed methane simulator. 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 as a result of methane-related explosions connected with coal mines in the last century (Amyotte and Pegg 1993).

Over the past 15 years, however, CBM has been increasingly recognized as a precious commodity because of, first, an encouraging Internal Revenue Code, Section 29, provides tax incentives and subsequently, advances in the technology of CBM 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 high potential to meet a part of the energy needs of the greatly increasing demand from existing and developing countries. From Europe to Zimbabwe to Australia, CBM is a burgeoning industry (Chadwick 1991).

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 CO_2. Because CO_2 is a particularly troublesome greenhouse gas (Greenberger 1991), using it to displace methane from the coal could help to alleviate CO_2 emissions. Also, the coal readily adsorbs CO_2 and this adsorption can, under certain circumstances, lead to increased displacement efficiency. Offsetting these positive effects is the fact that relatively large quantities of CO_2 are needed to displace the methane, which increases the cost of the process. Another potentially negative factor is that CO_2 can have an adverse effect on the coal, causing it to swell and ultimately to plug off what is characteristically a paucity of permeability in coalbeds under the best of circumstances.

Consequently, this project was undertaken to test the viability of recovering coalbed methane by the process of displacing it with CO_2 and to examine the process in a field-pilot setting. Because of 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 CO_2 Injection; 6.2, CO_2/N_2 Laboratory Tests in the Fruitland Coal; 6.3, Modeling of Two-Well Pilot Test; 6.4, Allison Unit CO_2 Pilot Study; and 6.5, CO_2/N_2 Laboratory Tests in Wyoming Coals.

Subtask 6.1, Two-Well Pilot Test of CO_2 Injection

This subtask is essentially complete with no significant work performed during this reporting period.

Subtask 6.2, CO_2/N_2 Laboratory Tests in the Fruitland Coal

Several nitrogen displacement tests were conducted on glass beads to check out the complete displacement system. Material balance calculations indicate that recoveries can be obtained from the tests with very little error. Consistent isotherms were still not being obtained with enough precision, so it was decided to add a reference cell to the system and to place it within the oven. Previously, very accurate measurements of displacement were required on a Ruska pump. This reference cell eliminates the need to make such measurements. Also, the Ruska pump was subject to oscillations in room temperature and required long and uncertain waiting periods to reach equilibrium. Now, with the reference cell in the oven, the temperature of the cell is better controlled. The reference cell was added, and the results are now replicable to within a couple of percent, which is well within the 5% target set by Amoco.

After placing the reference cell in the oven and checking out the operation of the cell, it was found that automating the system for determination of isotherms could be accomplished quite easily and within the equipment budget for this task. Therefore, it was decided to proceed with automating it. Such automation reduces the labor of measuring an isotherm to only sample preparation and water content determination. This cuts the cost of personnel to perform an isotherm measurement and makes the measurement more precise. These two factors should make the procedure much more competitive when compared with such a service provided by other laboratories. In initial tests of the automation system, helium void volumes have been very accurately determined. After automation of the isotherm measurement apparatus was completed, some of the isotherm measurements that were previously hard to control were repeated on coal. The automated system worked extremely well and replicates of the isotherms were obtained with excellent reproducibility. The biggest problem remaining is leaks that develop in the system during tests. These leaks seem to be localized around the valve seats, particularly during helium void volume determinations. The automation system helps, however, to identify the leaks. When leaks are present, equilibrium cannot be achieved, and the system program does not allow the test to move forward until such leaks are sealed.

A report describing this subtask is being finalized.

Subtask 6.3, Modeling of Two-Well Pilot Test

The Pressure Falloff Test (PFOT) taken the second half of September 1994 on the injector was compared to the pre-CO_2 Pressure Buildup Test taken in October 1993. WRI wrote several computer programs to assist in evaluating the data. One of these programs calculates the primary pressure derivative (PPD) (Mattar and Zaoral 1992). The primary pressure derivative is used to assess the quality of the data. With the exception of the very early time data, the data appears to be of good quality. With the use of the computer programs, evaluation of the data indicates that the responses of the two tests appear to be very similar. A finite-conductivity fracture still appears to be the best explanation for the response. After the two tests were reconciled, a request was sent to Amoco to verify that there was no artificial fracture on the well. A search through the data by Amoco revealed that a rather extensive fracture job had been conducted in 1984, which had previously been overlooked.

An updated version of Amoco's coalbed methane simulator was installed on WRI's system. This version allows for the inclusion of both sandstone and coal in the same model. Refinement of the history matches continued.

The above results were presented in Tulsa, Oklahoma, on June 27, 1995, to Amoco personnel from the Exploration and Production Technology Group based in Tulsa and the Southern Rockies Business Unit based in Denver The consensus was that we should begin to wind down the pilot study, with the exception of some future predictions using the current description and attempt another history match of the data using the most recent fracture information obtained from reanalysis of the pressure transient data.

Also, based on model predictions, it was determined that more definitive diagnosis of the pilot might be possible by conducting another flowback test of the pilot injector. That flowback test was conducted September 6 through September 27, 1995. The flowback test was evaluated, and this evaluation was presented in Denver on December 13, 1995, to Amoco personnel from the Exploration and Production Technology Group and the Southern Rockies Business Unit. After discussion of this test, it was collectively decided to wrap up the study of this pilot and to concentrate our modeling work on the Allison Unit. Rather than finalizing the report, it was decided that a draft of the report, which is near completion, be reviewed by Amoco personnel, the contents of the report discussed, then the finalized version prepared. This should result in a more collective viewpoint on the interpretation of the pilot.

Subtask 6.4, Allison Unit CO_2 Pilot Study

Also at the June 27, 1995, meeting, substitution of a thorough study of a similar pilot being conducted by Meridian in place of the Phase II design was discussed. Amoco is entitled to the results of the Meridian pilot. A formal request to change the program was made to METC by WRI, and that request was evaluated, revised and resubmitted. The request was approved by METC in the third quarter, 1995.

An accounting of the available data was obtained, and data was gathered for the pilot from both Amoco's files and from commercial sources. Available digitized density logs from Amoco were evaluated and a preliminary isopach map of the model study area of the Fruitland Coal was prepared. The area seems to be extremely heterogeneous with some complete pinchouts of the coal. Previously published geological documents of the area were reviewed and confirm the heterogeneity of the coal. This information was reviewed at the meeting in Denver discussed above. On December 27th and 28th, more data was obtained from Amoco's files. Some were well logs that were not digitized that will help to define the coal in the model study area.

Subtask 6.5, CO_2/N_2 Laboratory Tests in Wyoming Coals

Although Wyoming CBM operators have yet to be contacted, a fact-finding meeting was held in Cheyenne at the state engineer's office to find out what companies are currently active in coalbed methane in the state. Only a few companies are active in Wyoming, but others are contemplating future activity. After the report is finalized on Subtask 6.2, these operators at least will be contacted to obtain samples of subbituminous coal. If necessary, other operators in the Rocky Mountain area will also be contacted.

CONCLUSIONS

The laboratory setup was modified to allow more accurate measurement of isotherms by replacing the Ruska pump with a reference cell placed in the constant-temperature oven. This in turn, permitted the system to be automated. A report discussing the laboratory setup and measurements taken using the setup is being finalized. Previously unreconcilable pre-test and post-test pressure transient tests on the injector for the two-well pilot test were reconciled, with a large finite conductivity fracture indicated. A flowback test on the injector was performed by Amoco and analyzed by WRI. The Phase II Design subtask was replaced by a modeling study of the Allison Unit CO_2 Pilot, which is currently underway.

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