CO_2 Sequestration Potential of Texas Low-Rank Coals

Quarterly Technical Progress Report

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ABSTRACT

The objectives of this project are to evaluate the feasibility of carbon dioxide (CO_2) sequestration in Texas low-rank coals and to determine the potential for enhanced coalbed methane (CBM) recovery as an added benefit of sequestration. The main objective for this reporting period was to perform pressure transient testing to determine permeability of deep Wilcox coal to use as additional, necessary data for modeling performance of CO_2 sequestration and enhanced coalbed methane recovery.

To perform permeability testing of the Wilcox coal, we worked with Anadarko Petroleum Corporation in selecting the well and intervals to test and in designing the pressure transient test. Anadarko agreed to allow us to perform permeability tests in coal beds in an existing shut-in well (Well APCT2). This well is located in the region of the Sam K. Seymour power station, a site that we earlier identified as a major point source of CO_2 emissions. A service company, Pinnacle Technologies Inc. (Pinnacle) was contracted to conduct the tests in the field. Intervals tested were 2 coal beds with thicknesses of 3 and 7 feet, respectively, at approximately 4,100 ft depth in the Lower Calvert Bluff Formation of the Wilcox Group in east-central Texas. Analyses of pressure transient test data indicate that average values for coalbed methane reservoir permeability in the tested coals are between 1.9 and 4.2 mD. These values are in the lower end of the range of permeability used in the preliminary simulation modeling. These new coal fracture permeability data from the APCT2 well, along with the acquired gas compositional analyses and sorption capacities of CO_2, CH_4, and N_2, complete the reservoir description phase of the project.

During this quarter we also continued work on reservoir and economic modeling to evaluate performance of CO_2 sequestration and enhanced coalbed methane recovery.

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INTRODUCTION

The objectives of this project are to evaluate the feasibility of carbon dioxide (CO_2) sequestration in Texas low-rank coals and to determine the potential for enhanced coalbed methane (ECBM) recovery as an added benefit of sequestration. During this reporting period, we acquired pressure transient test data and interpreted coalbed reservoir fracture permeability of deep Wilcox coals from an Anadarko Petroleum Corporation well (Well APCT2). The actual well location is confidential. Also, we continued work on reservoir and economic modeling to evaluate performance of CO_2 sequestration and enhanced coalbed methane recovery.

EXPERIMENTAL

During this quarter, we completed a primary task necessary to characterize Wilcox coalbed reservoirs – determining coal permeability. Permeability, as well as skin factor and reservoir pressure, is a critical parameter for the extraction of gas from coal beds (Seidle *et al*., 1991). Our characterization included determination of absolute coal fracture permeability from two Wilcox coals perforated in the Anadarko APCT2 well.

As discussed in the first quarterly report of 2004, water injection/fall-off pressure transient tests are the tests recommended to best determine permeability in coalbed reservoirs (Zuber *et al*., 1990), as opposed to withdrawing fluids from the formation, which may result in methane desorption. Well test analysis becomes difficult in the presence of two-phase flow conditions and the combined mechanisms of diffusion and gas flow in porous media.

Pinnacle Technologies conducted two injection/falloff tests in the APCT2 well for Anadarko Petroleum Corporation, with the purpose to determine in situ permeability to water in multiple perforated intervals. Pinnacle used its Denver-based injection/falloff PermPT equipment, which is specially designed for coalbed methane reservoirs, to conduct the injection/falloff tests. Bottom-hole pressure measurement was used for both tests performed, with surface injection rates measured at the injection unit. Maximum fracture gradients based on breakdowns pumped prior to the PermPT injection tests were used to determine maximum surface injection pressure (Pinnacle, 2005).

A bottom-hole assembly consisting of a retrievable bridge plug, retrievable head, perforated sub containing Pinnacle's bottom hole pressure gauges, packer, in-line mechanical ball valve, and tubing to surface was run to isolate between packers the coal seams we wanted to test.

The first injection/falloff test was conducted in one coal seam with perforated thickness of 7 ft at approximately 4,200-ft depth. For the permeability test, fresh water was injected for 4.0 hours at an average rate of 1.84 gallons per minute and average surface injection pressure of 727 psi. The well was shut in downhole by closing the mechanical ball valve, allowing pressure to fall off for 15.9 hours following the injection period.

The second injection/falloff test was conducted in one coal seam with perforated thickness of 3 ft at approximately 4,000 ft depth. For the permeability test, fresh water was injected for 4.0 hours at an average rate of 1.00 gallons per minute and average surface injection pressure of 938 psi. The well was shut in downhole by closing the mechanical ball valve, allowing pressure to falloff for 16.0 hours following the injection period.

Digital pressure and temperature data were recorded to permit analysis of the transient data. Tests were supervised by Anadarko and Texas A&M University personnel and were conducted with no complications.

RESULTS AND DISCUSSION

Pressure injection/falloff tests (PFOT's)

Data from both injection/falloff tests were of good quality. For the first test, semi-log analysis of the pressure falloff data resulted in coal seam permeability to water of 1.9 mD, a skin factor of -4.9, and an average reservoir pressure of 1,851 psi (Fig. 1). Average reservoir pressure is equivalent to a gradient of 0.44 psi/ft. The reservoir temperature was estimated to be 145 ^{o}F.

For the second test, semi-log analysis of the pressure falloff data resulted in coal seam permeability to water of 4.2 mD, a skin factor of -1.9, and an average reservoir pressure of 1,687 psi (Fig. 2). Average reservoir pressure is equivalent to a gradient of 0.43 psi/ft. The reservoir temperature was estimated to be 140 ^{o}F. In both tests, negative skin factors indicate that the tested zones are stimulated, as a combined result of open cleats, perforating activities, and the injection tests creating microfractures near wellbore.

The permeability values obtained from these two tests are in the lower part of the range of permeability used in the preliminary simulation model (1.0, 5.0, and 20.0 mD). The geometric mean of these permeability data is 2.8 mD. A log-normal distribution derived from the calculated permeability data will be used as input in the reservoir simulation model.

Reservoir modeling

As discussed in the third quarterly report of 2003, GEM, a numerical compositional simulator developed by Computer Modeling Group Ltd (CMG), was selected for use in the simulation phase of this project. Multiple features required for coalbed methane production and carbon dioxide sequestration modeling are available in this reservoir simulator.

To begin the simulation phase, a grid sensitivity study was performed by redefining the single-layer grid model from 11*11*1 to 20*20*1 grid cells in a 5-spot pattern with 40-acre well spacing (Fig. 3). Comparison of saturation and pressure distributions, recovery efficiency, and production and injection performances of wells indicated no negative impacts resulting from use of the coarser grid model, which means it can be used with confidence (Mattax and Dalton, 1990). Results for these two cases are shown in Fig. 4. The computer time is reduced by a factor of 6 when using the coarser-grid model. The simulation run time is important because we plan to conduct a probabilistic simulation study, consisting of thousands of simulation runs, in order of quantify the uncertainty in our forecasts of CO_2 sequestration and methane production.

Economic modeling

Given the uncertainty in future CO_2 credits and other economic parameters affecting CO_2 sequestration projects, we plan to conduct a probabilistic economic analysis of the feasibility of CO_2 sequestration and enhanced coalbed methane recovery in Texas low-rank coals. We have researched economic parameters and have developed probability distributions for parameters, such as gas price, CO_2 credits, and costs, for use in the economic modeling. We have developed an economic model for CO_2 sequestration and enhanced coalbed methane recovery using Microsoft Excel and Palisade @RISK software. Macros have been developed to extract results from simulation and run them in the economic model.

Completion of the reservoir and economic modeling tasks will be the primary objectives during the next quarter.

CONCLUSION

Pressure falloff well interpretations indicated that the absolute coal fracture permeability ranges between 1.9 and 4.2 mD in the tested coal seams from Well APCT2 in the Lower Calvert Bluff Formation of the Wilcox Group in east-central Texas. The permeability values obtained from two field tests are in the low end of the range of permeability values that we used in our preliminary reservoir modeling. A log-normal distribution of these permeability data will be used as input in the reservoir simulation modeling.

REFERENCES

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3) Seidle, J.P., Kutas, G.M., and Krase, L.D., 1991, Pressure Falloff Tests of New Coal Wells, SPE paper 21809.

4) Mattax, C.C., and Dalton, R.L., 1990, Reservoir Simulation Monograph Vol. 13, SPE Monograph series.

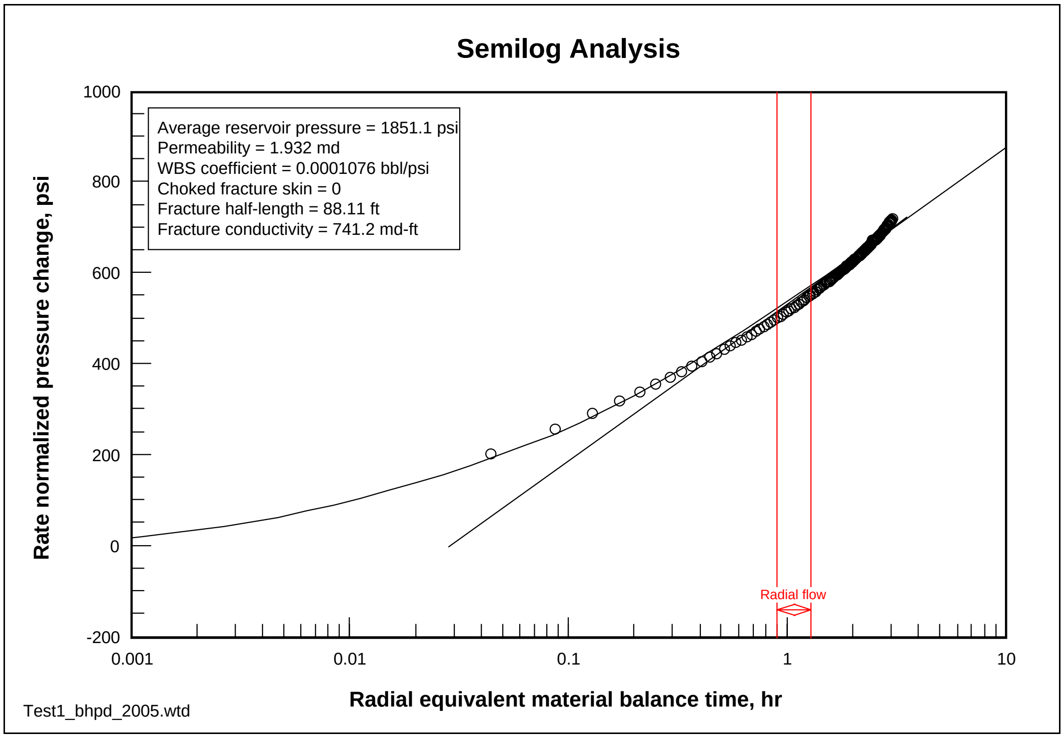

Fig. 1- Pressure falloff interpretation for the first coal seam test, from Well APCT2 at approximately 4,200 ft depth in the Wilcox Group.

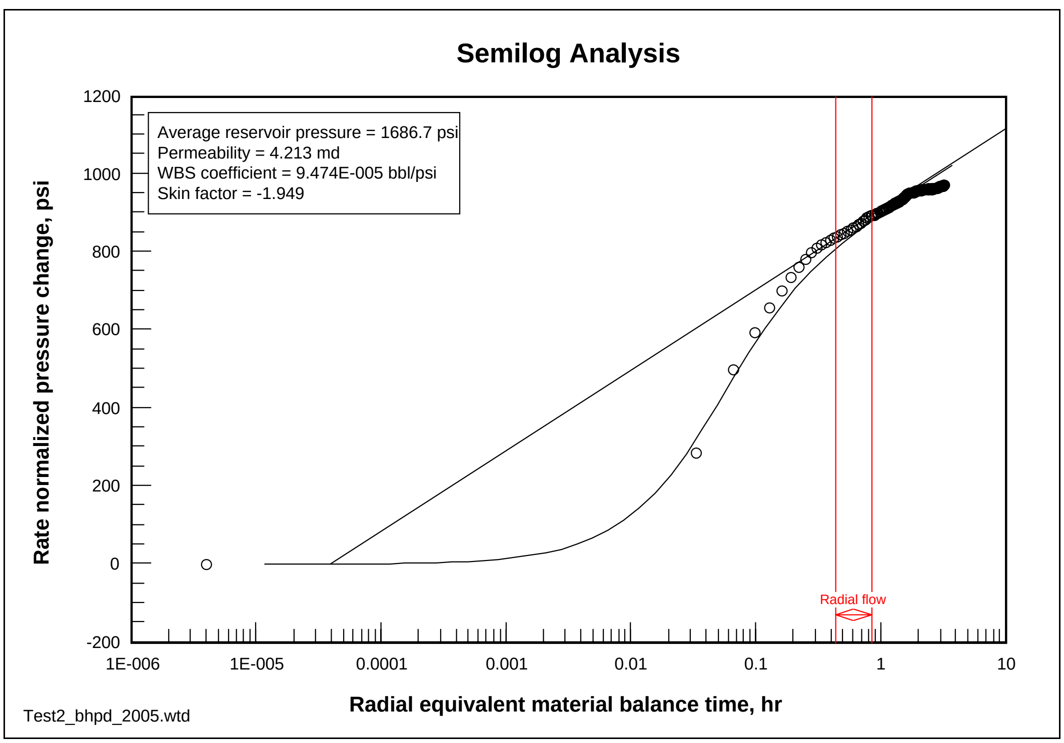

Fig. 2- Pressure falloff interpretation for the second coal seam test, from Well APCT2 at approximately 4,000-ft depth in the Wilcox Group.

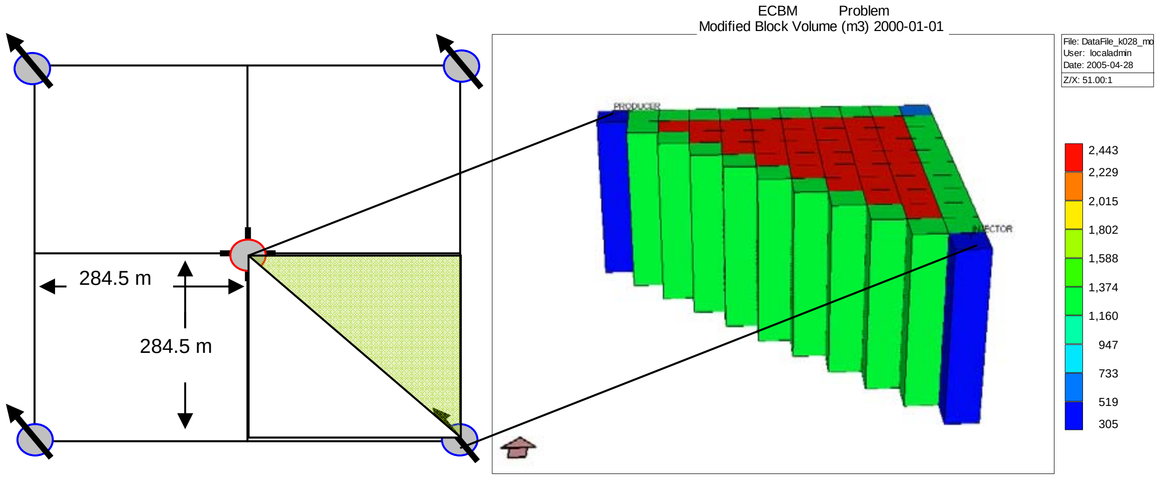

Fig. 3- Reservoir simulation model of a 1/8 5-spot a 40-acre well spacing.

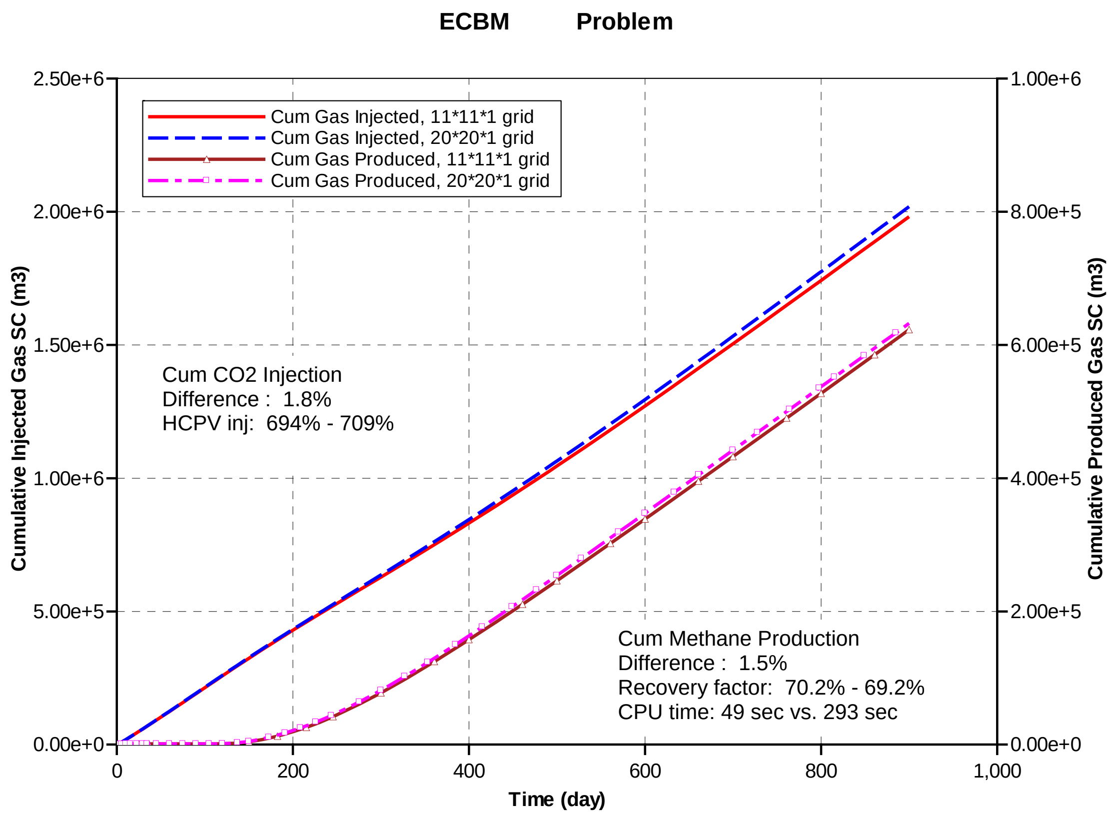

Fig. 4- Comparison of cumulative CO_2 injection and CH_4 production profiles for two grid sizes at 900 days of simulation time. Differences are about 1.5%, indicating adequacy of the coarse grid.