PROJECT facts

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

Carbon Sequestration

04/2008

Strategies for Controlling Coal Permeability in CO_2-Enhanced Coalbed Methane Recovery

Background

Rising levels of atmospheric carbon dioxide (CO_2), caused primarily by combustion of fossil fuels for power generation and transportation, are considered to be leading contributors to global warming. Geologic sequestration offers an option that will keep a large quantity of CO_2 out of the Earth's atmosphere for hundreds to thousands of years, thus permitting continued use of high-carbon fossil fuels to generate electrical power, while ensuring that CO_2 releases to the atmosphere are reduced.

Previous studies to determine the feasibility of geologic CO_2 sequestration have focused on oil and gas fields and deep brine formations. However, four characteristics of deep unmineable coalbeds make them extremely attractive for wide-scale CO_2 sequestration:

(1) Unmineable coal seams are widely distributed across the United States.

(2) When injected into a coalbed, CO_2 efficiently displaces adsorbed methane (CH_4). Therefore, CO_2 sequestration and coalbed methane (CBM) production are synergistic technologies, with the extra natural gas produced offsetting some of the costs of CO_2 injection.

(3) After injection, CO_2 remains tightly bound to coal surfaces; therefore, there is little risk that, over time, it will leak to overlying strata or to the surface.

(4) Many unmineable coal seams are located near coal-fired power plants, which are large CO_2 point sources. Thus, minimal pipeline transport is required to deliver CO_2 to a suitable injection site.

CBM recovery, accomplished principally by pumping formation water out of coalbeds, is a mature technology. In contrast, CO_2-enhanced CBM (CO_2-ECBM) recovery is a recent concept that has been demonstrated at only a few sites. Therefore, vigorous fundamental and applied research programs are needed to fill major knowledge gaps.

At full fruition, CO_2-ECBM could become a leading technology for combined CO_2 sequestration and enhanced methane recovery. However, the effects of CO_2 injection rate, formation temperature, total gas pressure, and gas composition on coal swelling and shrinkage, and sorption/desorption of gases on coal surfaces, must be known quantitatively for reliable numerical modeling of CO_2-ECBM production. The impacts of these effects cannot be predicted accurately by current methods of reservoir modeling and simulation.

Description

This project evaluated factors affecting coal permeability when CO_2 is injected into a subsurface coalbed. The major permeability-affecting parameters are initial coal porosity and permeability; formation temperature; CO_2 injection rate; time-dependent local gas composition, including moisture content; and characteristics of the organic and inorganic surfaces of the coal into which mixed CO_2-CH_4-H_2O gas penetrates. Results of CO_2 influx will include sorption/ desorption of gas species, coal swelling and shrinkage, migration of CH4 toward production wells

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PERIOD OF PERFORMANCE

03/15/2002 to 03/31/2008

COST

Total Project Value

$1,350,000

DOE/Non-DOE Share

$1,350,000 / $0

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and other regions of lower gas pressure, and drying of the coal near the point of CO_2 injection. These effects have time varying, interacting impacts on coal permeability. Therefore, sorting out the individual and collective effects of factors affecting coal permeability during CO_2-ECBM operations is essential for reliable prediction and full optimization of CO_2 sequestration in, and enhanced methane recovery from, subsurface coalbeds.

Absorption kinetic behavior of pure and mixed gases – CO_2, CH_4, a CO_2-CH_4 mixture (~50 mole percent CO_2), and helium (He) – was conducted on Mary Ruth coal zone samples from the Black Warrior Basin. Experiments were conducted using three crushed coal fractions (45-150 µm, 1-2 mm, and 5-10 mm) at 40 and 35 °C over a pressure range of 1.4 -6.9 MPa (200-1500 psi) to simulate Black Warrior Basin coalbed methane reservoir conditions. Experiments were conducted in a custom designed large-volume, high-velocity air bath utilizing infrared lamps to heat the air circulated over the pressure components.

Primary Project Goal

The primary goal is to acquire the critically important technical information needed to assess CO_2 sequestration in deep unmineable coalbeds.

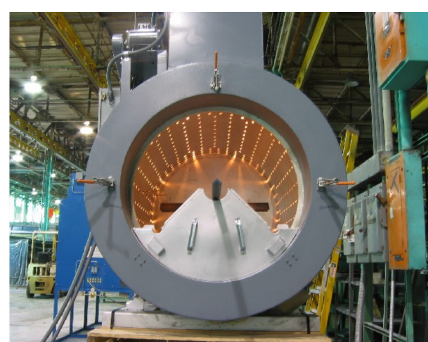
Objectives

- Acquire and characterize sections of coal core obtained from the Black Warrior Basin in west-central Alabama.
- Complete a set of sorption/desorption experiments on Black Warrior Basin powdered coal samples.
- Conduct gas permeability experiments on uncrushed Black Warrior Basin coal samples to determine the effects of: (1) the rate of CO_2 injection; (2) adsorption of CO_2 onto, and desorption of CH_4 and H_2O from, coal surfaces; (3) coal swelling and shrinkage due to gas adsorption and desorption; and (4) drying of moist coal near the site of CO_2 injection.

Benefits

One very promising technique for sequestering CO_2 from fossil fuel-fired power plants is CO_2-ECBM production. This project will develop much of the needed data on the behavior of coalbeds during and after CO_2 injection required to model CO_2-ECBM. These modeling efforts, along with demonstration programs, will establish the CO_2-ECBM feasibility and the amount of natural gas that can be produced from such projects. Coalbed CO_2 sequestration will help to enhance new field production and extend production in existing fields.

Accomplishments



End-view of a 30-inch I.D., infrared forced-air convection oven custom designed and constructed for heating powdered and solid coal samples to temperatures attained in deep unmineable coalbeds.

Experimental analyses observations have positive implications for CO_2-ECBM and CO_2 sequestration: (1) CO_2 absorption on both dry and saturated coal is more rapid than CH_4 absorption; (2) water saturation decreases CO_2 and CH_4 absorption rates on coal surfaces, but appears to have minimal effects on the final magnitude of CO_2 and CH_4 absorption if the coal has no previous CO_2 exposure; (3) adsorbed CO_2 retention on coal surfaces is significant even with extreme pressure cycling; and (4) adsorption is much faster on the smallest size fraction (45-150 µm) than the other two larger fractions. Experimental results with moderately course coal particles (5-10 mm) having dimensions of the same order as coalbed cleat spacing, indicate relatively rapid CO_2 absorption can be expected at 35 °C and 375-490 psi for dry and wet pure CO_2 and a (1:1) CO_2-CH_4 mixture.