DEVELOPMENT OF A FIELD EXPERIMENT OF ECBM IN THE UPPER SILESIAN COAL BASIN OF POLAND (RECOPOL)

F. van Bergen, H.J.M. Pagnier, L.G.H. van der Meer, F.J.G. van den Belt and P.L.A. Winthaegen, Netherlands Institute of Applied Geoscience TNO (the Netherlands)

P. Krzystolik, Central Mining Institute (Poland)

ABSTRACT

In 2001 the RECOPOL project, which aims at the development of the first European field demonstration of CO₂ sequestration in subsurface coal seams, started. The required research, design and operation of the pilot field test is executed by an international consortium of research institutes, universities and industrial partners. A site was selected in the Upper Silesian Basin in Poland where two CBM-wells are present at short distance from each other. One injection well will be drilled in between; drilling is scheduled in summer 2003. Injection is planned to start in September 2003 and will continue until the end of 2004. Reservoir modelling shows that the distance between the injection well and the updip production well should be less than 200 m to increase the chance of breakthrough of CO₂ within the test period. Breakthrough is important for a thorough understanding of the process. After and during the injection period monitoring will be performed by direct measurements of CO₂-concentration and by time lapse seismic monitoring.

INTRODUCTION

One option to reduce carbon dioxide emissions in order to control the overall levels of CO₂ in the atmosphere, which has become an international priority in the wake of the Kyoto protocol, is permanent storage in subsurface coal seams, while simultaneously producing methane. This option has gained increasing interest world-wide during the last couple of years (e.g. [1-4]). Although several desk studies illustrated the potential of the process, there are world-wide only two demonstration sites: one in Alberta, Canada (e.g. 5, 6) and one in the San Juan Basin, U.S.A. (e.g. [3], [6], [7]). In November 2001 the EU-funded RECOPOL project started which aims at the development of the first European demonstration plant of CO₂ storage in coal seams while enhancing CBM production. An international consortium was formed to execute the research, design, construction and operation within the RECOPOL project. This consortium is formed by research institutes, universities and companies from the Netherlands (TNO-NITG and Delft University of Technology), Poland (Central Mining Institute), Germany (DBI-GUT and Aachen University of Technology), France (IFP, Gaz de France, GAZONOR and Air Liquide), Australia (CSIRO), U.S.A. (Advanced Resources International) and by the IEA Greenhouse Gas R&D Programme. Feedback to the project from industry and governmental organisations is realised through the participation of Shell International, Jcoal (Japan) and the Federal Region of Wallonie (Belgium) in an enduser group. Overall co-ordination of the project is in the hands of TNO-NITG.

This paper gives an overview of the project and status of the activities within the project.
CHARACTERISTICS OF THE PILOT SITE

The Upper Silesian Basin (Figure 1) was selected as the best coal basin in Europe for the application of ECBM [1, 2]. This basin has (relatively) favourable coalbed properties (depth, permeability, gas content, etc.), was subjected to CBM production before, and drilling costs in Poland are relatively low compared to many other European countries. A site with an already existing infrastructure for CBM production, located about 20 km south of the city of Katowice, was selected within the Upper Silesian Basin. It is ideal because two existing CBM-wells are available that are relatively close to each other (375 m) and given the existing concession rights. This short distance allows the injection tests within a short period (see “Reservoir Modelling”). CBM-production tests from these wells, drilled in 1994/1995, took place during 1996.

GEOLOGICAL SETTING

The Upper Silesian Coal Basin, bounded on the south by the Carpathian foredeep, is structurally complex compared to commercial coalbed methane basins in the U.S.A. [8]. The area of interest is located on a large block that was upthrust during the Alpine orogeny. The principal targets for CO₂ injection are coal seams of Carboniferous age in the depth interval between 900-1250 m. The Carboniferous deposits are disconformably covered by Miocene shales. The depth from the surface of the top of the Carboniferous deposits in the test area (7 km²) is about 250 m. The Carboniferous deposits, which have a total thickness of at least 1000 m in the test area, consist of an alternation of sandstones, shales and coal seams. The test area comprises a fault-block bounded by a major normal fault (NE-SW) and another normal fault, which abuts the former at an angle of 50° (NW-SE). Wells (11) on all three fault blocks were studied. These faults were pre-Miocene and already active in the Carboniferous. Probably activity of these faults ceased after the Carboniferous. The CBM-wells are located on the triangular fault block (Figure 2a). The Carboniferous deposits dip 12° to the north and consist of alternating layers of sandstone, clay and coal (Figure 3). The majority of the sandstone bodies are between 10 and 20 metres thick and are syn-sedimentary deposited along faults (Figure 2b). Some of these bodies cut into underlying coal seams, thereby destroying the lateral continuity of the coal. There is an upward decrease in sandstone bodies (Figure 3). The sealing capacity of the Miocene shales is proven by the occurrence of natural gas pockets in the sandstones of the top Carboniferous.

The coal seams of interest are of high volatile bituminous rank and vary in thickness between 1.3 and 3.3 meter (Figure 4). Main component of the coal is vitrinite (48-72%), with lesser amounts of inertinite (15-32%) and exinite (6-14%). Mineral matter ranges between 5 and 19%. The gas from canister tests from the wells MS-1 and MS-4 showed CH₄ concentrations of usually 90% or higher, with some percentages of N₂ (0.5-3%) and CO₂ (1-3%) and traces of other gases.

DEVELOPMENT OF THE SITE

In the initial design of the field experiment the two existing production wells were used. The water that is produced will be disposed via the nearby mine. One injection well will be drilled in between the two production wells (Figure 5). The exact location of the well will be mainly defined by spatial constraints at the surface. In case for some reason (e.g. cost, permits) it appears impossible to drill a new well, one of the existing wells will be used as an injection well instead of drilling a new well. However, this fall-back scenario is not preferred. The CO₂ for injection will be supplied on site by trucks. Surface facilities for CO₂ storage, handling and injection will be constructed at the site.

At the moment of publication (May 2003) preparations are being finished for the development of the pilot site. Drilling of the injection well is scheduled in the summer of 2003. Injection can start in September 2003, and the period for injection will last at least until the end of the project in November 2004. The period available for injection is thus about 1.5 years. The net operational time depends strongly on the success of the operation and on available CO₂ (circa 3000-4000 tonnes) It is anticipated that 10,000 m³ CO₂ (20 tonnes) per day can be injected during a 24h operation.

After the period of injection of 1.5 years, which corresponds with the end of the project lifetime, a breakthrough of CO₂ is preferred in one of the production wells. This breakthrough is important for a
good and thorough understanding of the whole process, which is the main goal of this demonstration project.

**RESERVOIR MODELLING**

The feasibility of the breakthrough, within the project lifetime, was investigated by reservoir modelling of the operation. Two software packages were used: SIMED and COMET. SIMED-modelling was done by TNO-NITG and CSIRO, COMET-modelling by Advanced Resources International. A set of 13 simulation cases was modelled. Both the scenario with a new well and the fall-back scenario was modelled. With the set of simulation cases the sensitivity of several parameters (porosity, permeability, anisotropy, injection/production scheme) was investigated. Figure 6 shows the layer model that was used in the modelling, with the six major coal seams in the depth interval under consideration. Based on the models it can be concluded that breakthrough is unlikely within 1.5 years when the CO$_2$ is injected in all six coal seams, as a result of the limited amount of CO$_2$. It was therefore decided that only the top three coal seams (357, 364, 401) are used for injection, which are positioned within a 20 m thick package of alternating shale and coal layers. From a sedimentological point of view, the top three coal layers are more likely to be continuous than the lower seams in absence of large sand bodies (Figure 3). Also, these top seams are more tightly packed in impermeable shales than the lower seams, which reduces the chance of leakage. Modelling results show that breakthrough is unlikely within 1.5 years when the distance between injection and production wells is more than 200 meters. In the fallback scenario, with a distance of 375 meters between the wells, no breakthrough is predicted to occur.

To increase the chances on a breakthrough, the new well should be drilled in line with the two production wells, within about 150 m from the updip well. However, spatial constraints at the surface could require a deviation from this line.

Based on these results it was decided to take only the updip well MS-4, closest to the injection well, back into production. A workover of this well is scheduled to be performed in advance of injection.

**MONITORING OF INJECTED CO$_2$**

For any subsurface CO$_2$ storage operation it is very important to be able to monitor the injected CO$_2$. Not only one would like to know that the CO$_2$ is injected at the intended location, but also that the CO$_2$ migrates towards the correct direction(s) and no leakage occurs. Hence, as CO$_2$ can be suffocating at elevated concentrations, monitoring is important for safety reasons. Release of the injected CO$_2$ at the surface must therefore be prevented at any time. Another aspect is that monitoring could become important for accounting of CO$_2$ credits in a future international CO$_2$ market. Two types of monitoring are foreseen within the RECOPOL project: direct CO$_2$ measurement and seismic monitoring.

For direct measurements, devices will be placed in a nearby (about 100 m to the west) abandoned mine gallery, vertically about 700 meters above the injection depth. At the surface, soil gas will be measured at locations sensitive for leakage: injection and production casings, abandoned wells and faults. If the CO$_2$-concentration at these locations increases it can be detected in an early stage. Also, the isotope signature of the injected and produced CO$_2$ will be regularly measured. It is expected that the isotope signal from the injected CO$_2$, from an industrial source, can be distinguished from the naturally occurring CO$_2$ in the coalbed gas.

Seismic monitoring methods have already been used for monitoring of injected CO$_2$ (e.g. [9],[10]), but they have never been applied for CO$_2$ injected in coal. Therefore, 3 techniques are currently evaluated. The methods being evaluated by using synthetic data sets are: surface High Resolution seismic acquisition, (reverse) Vertical Seismic Profiling and crosswell seismology (see Figure 7).

The target, low velocity, coal seams are located at about 1000 meters depth and are maximal a few meters thick. The obtained resolution of the seismic method is therefore important. Also, before, during and after injection the seismic survey will be repeated in order to monitor CO$_2$ migration and possible other changes, such as methane desorption.

From the discussed methods, HR surface seismic acquisition, VSP and crosswell seismology, the latter will result in the highest resolution and repeatability. A disadvantage might be the lateral resolution and the costs. The crosswell technique uses first arrivals to obtain an inversion result. Attention must be paid to the low velocity layers, e.g. coals, because it might be difficult to pick the correct corresponding arrival.
Gassmann modeling approximating the situation during injection indicates that differences in the seismic signal can only be observed when the injected CO$_2$ content is smaller than the first approximately few percent, depending on the porosity of the coal. This implies that only the CO$_2$/water front can be monitored, which is sufficient for the monitoring purpose. For the final choice on which seismic method will be used besides the technical also the financial limitations will be taken into consideration.

FURTHER WORK WITHIN THE PROJECT

Until May 2003 much effort is put in the development of the site. Along with the development activities, laboratory work on coal samples from the site is ongoing at Delft and Aachen Universities of Technology. The laboratory experiments involve adsorption/desorption and flow-through tests for CO$_2$, CH$_4$ and mixtures. At the Institut Français du Petrol a detailed petrophysical model is constructed based on coal samples and geophysical logs. A 3D geological model was constructed, which will be used for upscaling of permeability data from logs to provide a 3D permeability model. The results from these activities will be used for the history matching of the injection/production process. History matching will be done by numerical simulation of the process during and after injection of the CO$_2$. Along with the technical work, an economical evaluation and a future-technological assessment will be executed, based on pilot results. A Decision Support System will be developed to assess the before-mentioned evaluation, thus providing European companies a rational tool for possible future investment opportunities.

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FIGURES

Figure 1: Location of the site in Poland. The existing CBM-wells are indicated with the symbol.

Figure 2: Cartoon of the structural framework of the Carboniferous deposits of the pilot site (a) and cartoon of the sand deposition in incised valleys along faults (b)
Thickness variations across faults indicate synsedimentary fault movement

Decreasing sand content in time indicates decreasing fault movement

Figure 3: Cross section (N-S) of the site through 6 wells.

Figure 4: Coal seams in the existing wells MS-1 and MS-4, both drilled for conventional CBM production
**Figure 5:** Cartoon of the layout of the pilot site

**Figure 6:** Layer model in SIMED for reservoir modelling of the injection/production
Figure 7: Schematic view of travel paths in the subsurface of the proposed seismic methods for monitoring CO₂ in a coal bed: HR seismic acquisition (solid arrows), reverse VSP (dashed arrows) and crosswell seismology (dotted arrows).