Convertibility of depleted jurassic gas reservoir to underground greenhouse gas storage

Rychlicki S. *and* ***Stopa J.***[1]

Abstract

In the paper the project of underground storage of greenhouse gases, emitted by one of the chemical plants in the south of Poland, in a depleted gas field was analyzed. This project is compliant with world's environmental trends and search for new forms of activities of oil companies. The feasibility of the project has been briefly analyzed. Preliminary computations based on mass balance method were assessed for the process of waste gas injection. On this basis the storage capacity of the field was estimated.

Key words*: computations based, jurassic gas reservoir, greenhouse gas storage*

Introduction

In compliance with the newest world's environmental trends and prospecting new forms of activity for oil companies [6], new projects related with sequestration of greenhouse gases are worked out [7]. One of the more promising concepts involves disposal of waste gases into geological formations including depleted gas reservoirs. This process can provide collateral benefits in terms of enhancing recovery of natural gas. In this way, high methane gas could be replaced with waste gas, and the reservoir gradually transformed into an underground storage for greenhouse or other environmentally hazardous waste gases. Because gas reservoirs have held large quantities of natural gas over geologic time scales, depleted gas reservoirs offer a proven integrity against gas escape and large available capacity for carbon sequestration. There do not seem to be any technical barriers to CO2 injection, although there are certainly costs associated with the sequestration.

Preliminary investigations for geological sequestration of CO2 from chemical plant

Based on the calibrated mass balance model of gas exploitation in TJ reservoir, prognoses were made following methodics given in [1, 2]. It was assumed in the calculations that the average rate of total CO_2 injection will be q = 1.48 mln nm^3/d (fig. 1), which corresponds to the quantity of gas emitted by the analyzed plant, i.e. ca. 1.06 mln tons/year (assessed on the basis of web-sites of the environmental survey (WIOŚ Tarnów) and Nitrogen Plant in Tarnów).

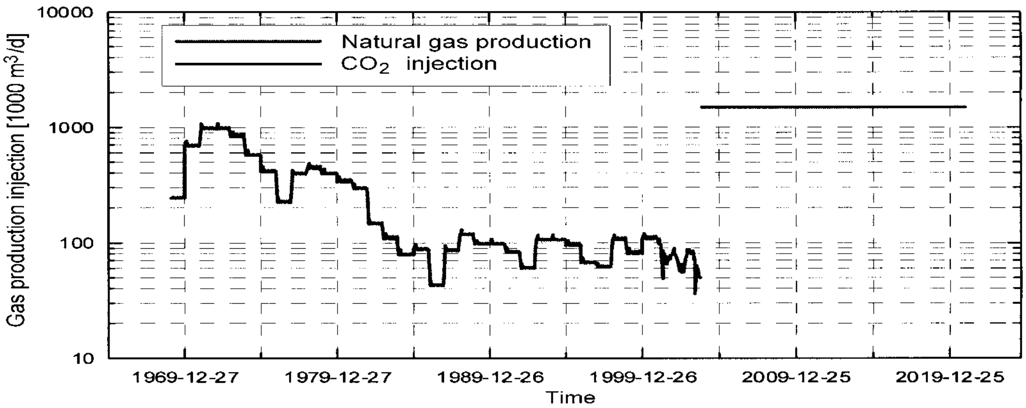

Fig. 1. Measured gas production rates in TJ field and the forecast for CO_2 injection rate

The forecast was made to 2020, assuming no gas exploitation from TJ field. The results are presented in figure 2. It follows from the simulated changes in reservoir pressure that CO_2 injection causes growth of reservoir pressure, which in a 17-year span of time of injection with the assumed rate would reach a similar value to the initial reservoir pressure value. As already mentioned, no further exploitation of the field was

[1] Rychlicki S., Stopa J, Faculty of Drilling, Oil and Gas, AGH – University of Science and Technology, Poland
(Recenzovaná a revidovaná verzia dodaná 29. 9. 2004)

assumed in the calculations. The assessed gas reserves in the field are over 2 mld nm^3. Further gas exploitation would result in the reservoir pressure drop, thus extending the period of CO_2 deposition.

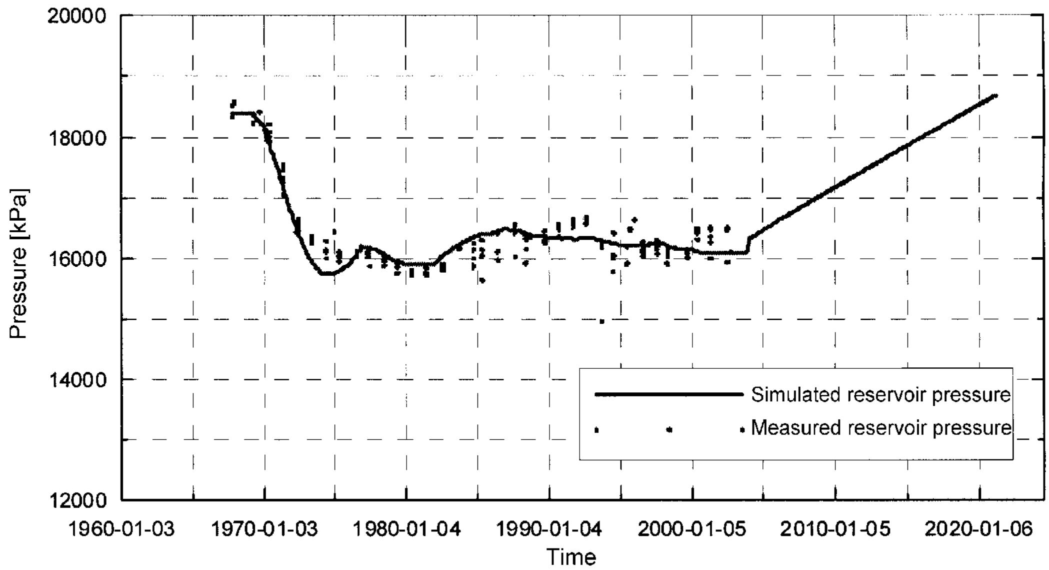

Fig. 2. Change of reservoir pressure in TJ field

In the calculations for CO_2 injection to the TJ field, two water injection wells were selected: TJ-21 and TJ-23. They are favorably located with respect to the gas-saturated zone. At present, TJ-21 well is used for injection of reservoir waters at a rate of 600 ton/month. The well injectivity is very high, however due to the lack of reservoir tests, it cannot be evaluated precisely. Approximated injection rate can be evaluated using backpressure equation of the form [3]:

$$\bar{p}^2 - p_{wf}^{\,2} = a \cdot q + b \cdot q^2$$

Where: $\bar{p}$ – reservoir pressure, p_{wf} – bottom hole well flowing pressure, q – flow rate. Coefficients a, b were calculated from old field "four-point test":

a = 0.629 at^2·min/m^3, b = 0.198· at^2·min^2/m^6

and then re-calculated for the CO_2 injection case to obtain:

a = 1.202 at^2·min/m^3, b = 0.378· at^2·min^2/m^6

Basing on the above formula, the CO_2 injection rate could be assessed for individual wells, assuming increased flowing bottom pressure at a level of 60 bar above the actual reservoir pressure. The determined well injection rate is: q = 353 000 nm^3/d.

Thermodynamic properties of CO_2 for pressure values from 150 to 200 bar at reservoir temperature are presented in Table 1. The pressure-temperature diagram for CO_2 is presented in figure 3. It can be seen from the fig. 3 that CO_2 easily condenses at temperatures close to normal temperature (273 K) and at pressures of some tens of bars. The analysis of Table 1 shows that in the reservoir conditions, injected CO_2 would be in the supercritical state, i.e. in the form of a dense gaseous phase. CO_2 density in reservoir conditions would be over 800 kg/m^3, and the formation volume factor in the same conditions would be $2 \cdot 10^{-3}$.

The CO_2 emission from the considered chemical plant is 1.06 mln tons/year, which is equivalent to rate of $1.48 \cdot 10^6$ nm^3/d. Therefore, the injection of this amount of CO_2 would require a greater number of injection wells. Having assumed a similarity to TJ-21 well, 3 to 5 injection wells would be needed.

One of the basic criteria for geological sequestration is a good sealing of the storage reservoir. The TJ natural gas reservoir is located at the Jurassic horizon. Its geological conditions are exceptionally good. Jurassic strata and the related gas accumulation are covered by discongruent impermeable marl-limestone Turonian-Senonian complex. This complex in the region of the TJ reservoir is 250 to 300 m thick; and it also plays the role of a regional screen for the Cenomanien-Jurassic hydrocarbon accumulations. Moreover, a monotonous Miocene series resides in the erosion Palaeozoic surface. In the bottom part, they assume a subevaporate form, represented by sandy-clayey strata, and evaporate series, consisting of anhydrites with clayey, saline and gypsum intercalations. The basic part of the Miocene complex is made of the Sarmatian shale-sandstones with almost zero vertical permeabilities. Therefore, the whole geological setting favors good sealing of the Jurassic strata. This is confirmed by the behavior of some production wells, which after finished exploitation from the Jurassic horizon started gas production from the Miocene horizons. The produced gas had a definitely different chemical composition (high methane, without hydrogen sulphide) from the gas in the Jurassic horizon (wet, nitrided with hydrogen sulphide content). This is also an argument for the lack of contact of the Jurassic horizon with the higher Miocene horizons.

Tab. 1. Thermodynamic properties of CO_2

Pressure [bar]	z [-]	μ [cP]	ρ [kg/m^3]	Bg [-]
150	0.312	0.081	833.266	2.23E-03
155	0.32	0.081	838.897	2.22E-03
160	0.328	0.081	844.215	2.20E-03
165	0.337	0.081	849.305	2.19E-03
170	0.345	0.082	854.243	2.18E-03
175	0.353	0.083	858.947	2.16E-03
180	0.361	0.083	863.397	2.15E-03
185	0.37	0.084	867.694	2.14E-03
190	0.378	0.085	871.939	2.13E-03
195	0.386	0.086	875.983	2.12E-03
200	0.394	0.087	879.773	2.11E-03

Conclusions

To resume, the Jurassic gas-bearing horizon of the TJ field fulfils a significant criterion of tightness for gaseous wastes disposal. Moreover, it follows from preliminary calculations, it has a suitable capacity and injectitivity. Before taking the final decision, geochemical analyses for hydrocarbon content in soil gas have to be made; besides, measurements and tests checking the wells integrity have to be carried out.

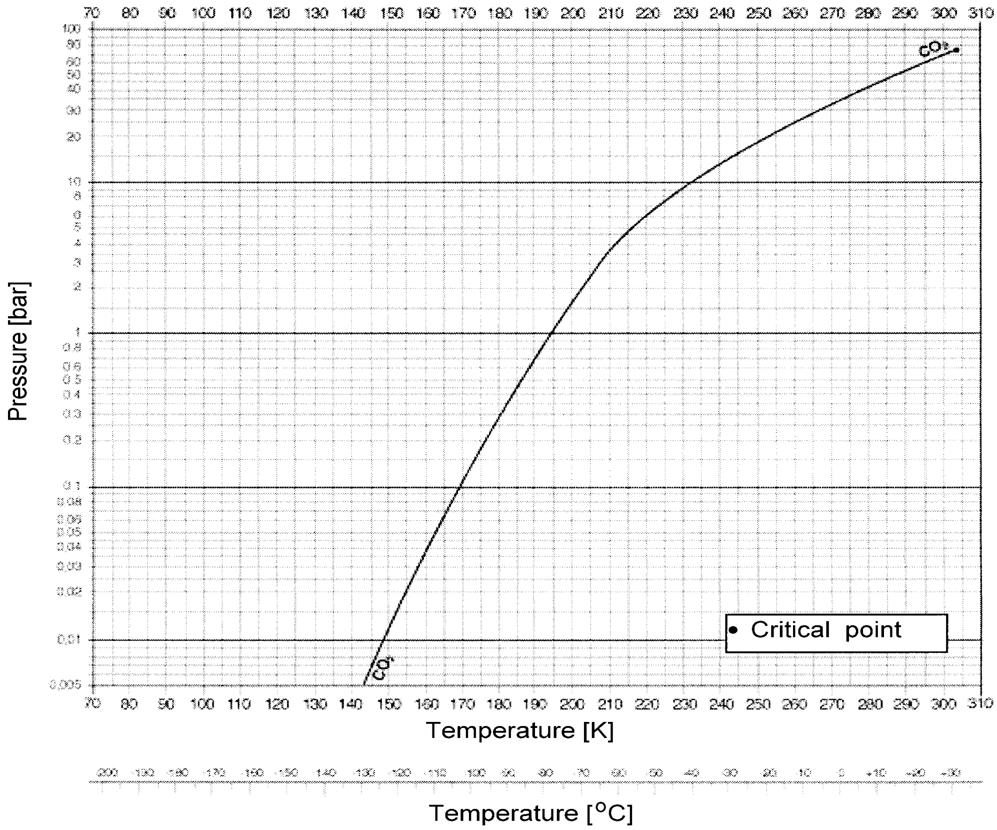

Fig. 3. CO_2 phase equilibrium curve

Carbon dioxide produced by a chemical plant in the vicinity of the considered gas reservoir could be all injected the TJ field through 3 to 5 wells for at least 17 years. Determination of the influence of injection on the gas production requires a detailed reservoir simulation and the respective forecasts. It can be stated from the literature [8], that for suitably located injection wells, gas production will initially enhance, and then at the second stage, the injected gas will appear in the production wells. It is expected that owing to the good solubility in water, supercritical pressure and temperature conditions, favoring the appearance of CO_2 in a dense gaseous phase, the movement of the injected gas in the reservoir should be slow.

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