

THE USE OF CO₂ AND COMBUSTION GASES FOR ENHANCED OIL RECOVERY IN RUSSIA

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Abstract: The use of carbon dioxide and combustion gases in EOR technologies is of interest from the point of view of CO₂ geological sequestration. During the period of 1980-1990 large-scale pilot tests were carried out in Russia to utilize carbon dioxide and combustion gases, formed at different petrochemical production plants, to enhance oil recovery in different hydrocarbon fields. The analysis of field data indicates that the greater part of CO₂ injected into oil reservoirs was recovered from production wells during the 1-1.5 years of the experiment. The total amount of CO₂ which was irreversibly stored in the reservoir was not measured. To reveal mechanisms of CO₂ geological sequestration it is recommended to study in detail carbon dioxide interactions with oil, formation water and with the reservoir rocks under the conditions of miscible and immiscible oil displacement with carbon dioxide.

Key words: EOR in Russia; sequestration; carbon dioxide

1. INTRODUCTION

The use of carbon dioxide and combustion gases in EOR technologies is of great interest from the point of view of CO₂ geological sequestration, as there is the potential for both decreased disposal costs while increasing resource recovery.

During the period from 1980-1990 large-scale pilot tests were performed in Russia to inject carbon dioxide and combustion gases, formed at different petrochemical plants, into petroleum hydrocarbon reservoirs in order to enhance oil recovery (Table 1). This paper summaries some of the results obtained during this project from one site.

Table 1. The results of CO₂ injection into oil pools in Russia.

	Radaevskoye	Kozlovskoye	Sergeevskoye	Elabuzhskoye
Start of CO₂ injection	August 1984	May 1986	September 1986	July 1987
Injection of CO₂ for 01.07.89, thou. t.	787.2	110.1	73.8	58.3
Oil after production, thou. t.	218	12.6	17.7	no data
Specific oil after production, t./t. CO₂	0.277	0.114	0.24	no data

2. RESULTS

Most often the technical approach consisted of continuous injection of CO₂ as carbonated water and alternate injections of CO₂ and water slugs. This technology proved to be effective in fields containing heavy oils, highly mineralised waters, and in steeply dipping strata having lower reservoir permeabilities. The most successfully carbonated-water EOR project was in the Aleksandrovskaya area of the Tuymazinskoye oil field, where the final oil recovery increased by 12%.

An inexpensive source of CO₂ and a heterogeneously structured oil deposit are considered as necessary conditions for continuous CO₂ injection. During pilot tests two problems complicated the continuous injection of carbon dioxide, one organizational and the other technical. The organizational problem lied in establishing a reliable system of CO₂ collection from the plants, where it is a waste product, and transportation to the oil fields. The technical problem, which was not completely solved, consisted of strong carbon dioxide corrosion of the equipment and communications in the CO₂ collection and transportation system.

The results obtained during the injection of CO₂ into a Devonian reservoir in the Elabuzhskoye oil field in 1987 have been analysed and are presented below as an example. The CO₂ used for this project was formed as a waste by-product during ethylene oxide production at the Nizhnekamskneftekhim petrochemical plant, located 5 km away from the oil field. The Elabuzhskoye oil field has been developed by perimeter water-flooding since 1972. The test area is show schematically in Figure 1, where average inter-well spacing is 500 m. From the beginning of development of the test area a total of 89.2% of the initial recoverable reserves have been recovered; the current oil recovery factor equals 0.437 (finite - 0.490) and the water cut exceeds 61%.

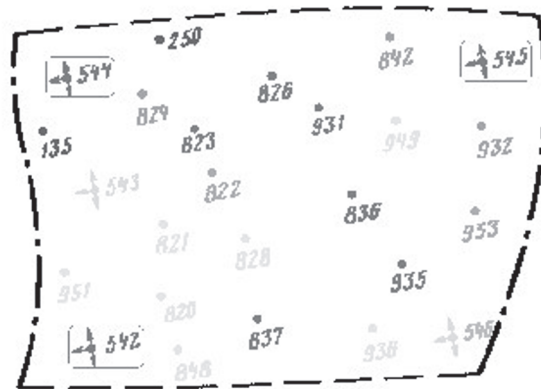


Figure 1. Scheme of well spacing in the test area.

CO₂ was injected into four injection wells (numbers 542, 544, 545 and 546) located along the test area perimeter. Monthly dynamics of the CO₂ injection are presented in Figure 2.

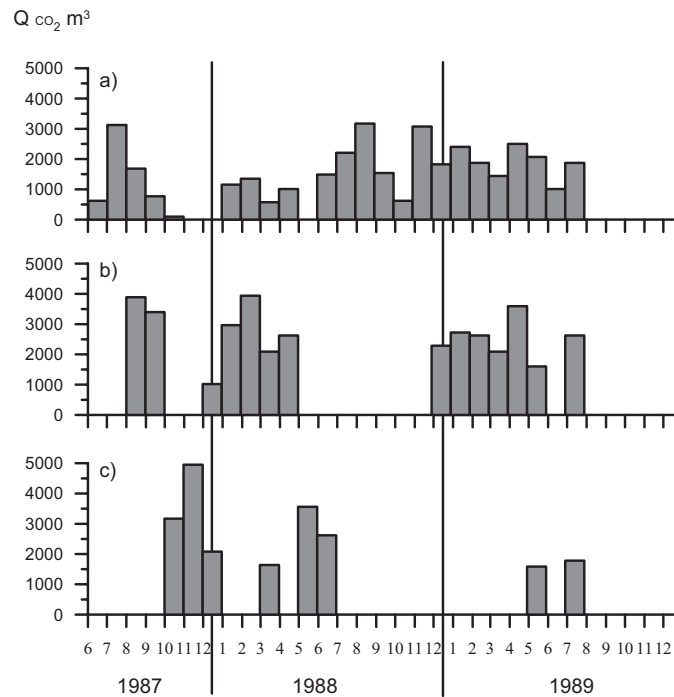


Figure 2. Dynamics of CO₂ injection into injection wells 542 (a), 545 (b) and 544 (c).

Production wells in the test area were divided into 4 groups based on their response to the CO₂ injection (Fig.3):

1. appearance of CO₂ in a well without any change in water cut (wells 842, 932 and 824)
2. appearance of CO₂ in a well and decrease in water cut (wells 250 and 135);
3. absence of CO₂ in a well, decrease in water cut (wells 826, 836, 837, 931, 935, 949 and 823) and increase in water cut (wells 822 and 933);
4. no changes were observed in well operations (wells 820, 821, 828, 848, 938, 949, 951).

The analysis of the field data indicates that the greater part of CO₂ injected into the oil pool was recovered from production wells during the 1-1.5 years of the test. The total amount of CO₂ which was irreversibly trapped within the pool was not estimated.

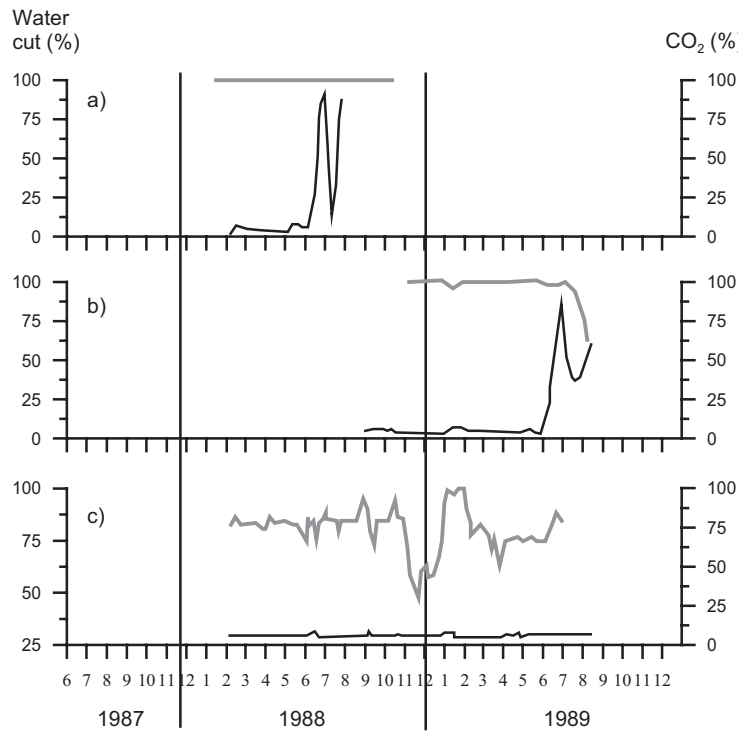


Figure 3. Dynamics of water cut and CO₂ content in wells 932 (a), 250 (b) and 836 (c).

3. CONCLUSIONS

To better understand the mechanisms of CO₂ geological sequestration it is necessary to study in detail the interactions of carbon dioxide with oil, formation water and with the reservoir lithologies under the conditions of miscible and immiscible oil displacement with carbon dioxide. It would be promising to study the physical-chemical mechanisms of long-term geological retention of CO₂ in the form of insoluble organo-carbonate complexes in the oil reservoir at a later stage of its development. It is possible to form carbonate and organo-carbonate compounds in the oil reservoir via CO₂ interaction with the mineralised formation water and any additionally injected chemical reagents. Such studies could result in the development of EOR technology which combines enhanced oil recovery and long-term geological retention of CO₂ due to the creation of flow-deflecting screens via insoluble carbonate and organo-carbonate complexes in the oil reservoir.

REFERENCES

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