

Dry Gas Injection or Underground Gas Storage

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ABSTRACT: In almost depleted oil reservoir the high gas injection can help to produce additional oil, if the process is in immiscibility or miscibility conditions. By using this reservoir for underground storage of natural gas the substantial quantities of oil can be recover. For that reason, the simulation both, high gas injection and underground gas storage has been performed. The two studied possible ways of future oil field management result by enrichment of dry gas with valuable components as underground storage of gas, rather than oil recover by high gas injection.

I. INTRODUCTION

When the oil field is almost depleted, there are some ways of using it. One way is gas injection for miscible displacement and to enhance oil recovery, or using it as underground gas storage.

By the process of gas injection under miscible conditions, the total oil recovery also includes vaporized hydrocarbon from residual immobile oil, in addition to the oil produced by direct displacement. The process is complex and involves the influence of the interaction of extracted hydrocarbons and reservoir oil at the displacement front. Therefore, the final oil recovery under miscible conditions is higher than "conventionally" displaced oil.

By using the reservoir as underground gas storage of natural gas it possible the substantial quantities of oil can be recover.

In this paper are two studied ways of future oil field management, as additional recovery by gas injection and is the reservoir potential candidate as underground storage.

2. FIELD HISTORY

Zutica oil field is located 45 km SE of Zagreb. It is asymmetric anticline sticking from the northwest to southeast.

The sandstone layers of "A" series cover practically the entire area of the Zutica field. All layers have a common gas-water contact, and oil water contact in the deepest part. This deepest section of reservoir A₁ contains a large gas cap and an oil ring. The oil ring covers a relatively large area

of heterogeneous litho logic composition, causing variations of the net pay thickness in different parts of the ring.

Three intervals were separated within the oil reservoir A₁ defined as independent exploitation objects. The production history was short and can be divided in two phases:

Phase 1 - test production, which was short due to very fast movement of gas from the gas cap into oil ring, which simultaneously reduced the productivity of wells.

Phase 2 - maintaining reservoir pressure by injection of dry gas in the gas cap, obtaining the immiscible conditions of the injection gas with the reservoir oil.

3. METHOD OF DRY GAS INJECTION

The aim of this research was to simulate the process of oil production in the oil field named Zutica, by maintaining reservoir pressure, and to define is the process in miscibility conditions. To simulate the process, a one-dimensional reservoir simulator COMP 3 was used. Only, the thermodynamic aspect of the process is investigated.

Methods of calculating multiple vaporization contacts with an Equation of State determine the miscibility conditions by simulation processes as a vaporizing or condensing gas drive.

Changes of Zutica oil properties by maintenance of constant reservoir pressure calculated for various pressures ranges from the initial saturation pressure (128,5 bar up to 2(X) bar shows that injected dry gas is poorly dissolved in already saturated oil. Swelling

of oil is about 6%, while the oil density decrease by 3%. Fig.1.

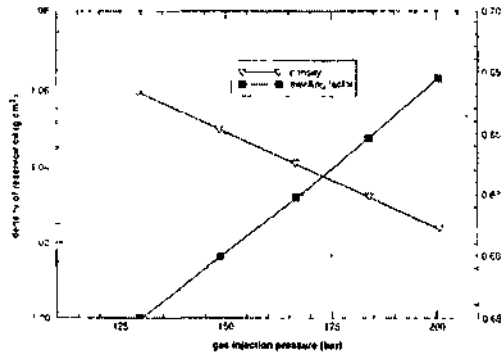


Figure 1 Changes in properties of reservoir oil during gas injection

According to the criterion (Yelling & Metcalf) the minimum miscibility pressure (MMP) is that particular gas injection pressure when 1.2 P.V. of injected gas displaced over 90% of present oil. To defining a characteristic multiple contact miscibility between injected fluid and oil the "slim tube" tests has been performed.

Results of these tests are shown in Fig.2. which shows that the miscible condition in the system saturated reservoir oil and methane, respectively dry natural gas, can be achieved only after application of very high pressure (MMP of a system is 500 bar). In other words, in oil production from the Zutica field, the regime of pressure maintenance should make modest contributions by multiple contact vaporization to oil displacement, since in the interval of real applicable pressures of gas injection the process will proceed under immiscibility conditions.

To produce more oil, the pressure in the reservoir must be maintained by injecting another fluid. Oil displacement by maintaining reservoir pressure by dry gas injection at an actual pressure of 130 bars occurs under immiscible conditions in accordance with the expected phase behavior of methane - oil system, because the minimum miscibility pressure (MMP) of injected gas in reservoir oil is about 500 bars. If the process should be performed at higher pressure (up to maximum possible reservoir pressure of 200 bar), it cannot be expected to produce a greater contribution to miscibility displacement in the total production.

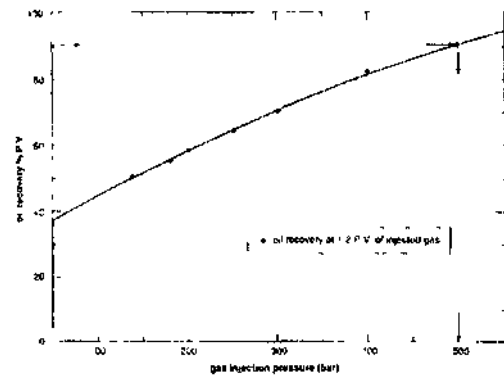


Figure 2. Determination of minimum miscibility pressure (MMP)

4. UNDERGROUND GAS STORAGE PROCESS

During the process of storing gas in depleted gas reservoirs there are practically no differences in composition between the injected gas in the fill phase, and from the gas that was produced during the production phase of the underground storage. However, by using partially or completely depleted oil reservoirs for gas storage, gas composition in reservoir changes. When injected gas comes in contact with residual oil, changes in phase behavior of new hydrocarbon mixture occur. The result of changes in phase behavior is vaporization of one part of hydrocarbons from liquid (oil) to gas phase so a change in content of C+ component in produced gas occurs. This enrichment is desired effect, because it increases energetic and potentially economic value of stored gas.

Simulation of gas storage has been conducted using following parameters or assumptions:

- Reservoir fluid of oil ring is presented by composition of oil well samples, sampled under static condition.
- Present oil/gas ratio in gas cap is about 1:45 (vol./vol.)
- Maximum pressure variation of fill-in/emptying phase is 50 to 200 bars.

In the gas injection phase, the final storage pressure is systematically increased to its maximum value.

Emptying phase has been simulated as differential vaporization in one stage

Equilibrium composition of liquid phase at lowest pressure of emptying phase is initial composition for the next cycle.

During the fill-in phase, partial dissolving of gas in oil occurs in every cycle. Composition of oil changes after each cycle of fill-in/emptying, due to step-by-step vaporization, and regarding that

swelling factor and density of remaining oil also changes.

Table 1.

Component	injected gas	produced gas		
		cycle 1	cycle 2	cycle 3
ethane	1.3	9.0	5.3	3.5
propane	0.2	5.5	4.2	3.0
butanes	0.07	2.0	1.8	1.6
pentanes	0.02	0.56	0.53	0.50

In the first cycle, injected gas comes in contact with saturated oil under reservoir pressure ($p_h=129$ bar), and dissolving of methane is small, which is represented by small values of swelling factor during the pressure increasing from 129 to 200 bars. In second and third cycle, swelling factor is twice the one in first cycle, while differences in these cycles are small.

Vaporization process of the light hydrocarbons from oil with mechanism of change in phase equilibrium at static condition is especially noticeable in change of oil density.

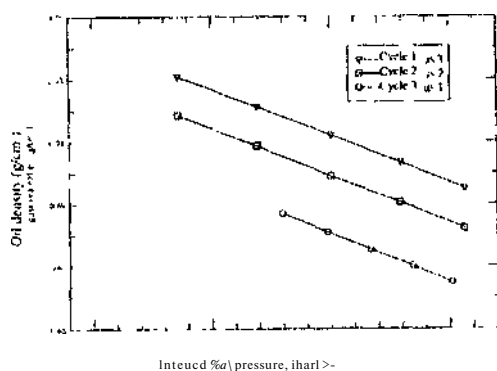


Figure 3. Change of reservoir oil density during gas storage

Effects of change of thermodynamically phase equilibrium are most responsible for enrichment of gas with C₂₊ components. In that process of enrichment, tendency to vaporization of individual component is proportional to its partial pressure at given condition of pressure and temperature, or, inversely proportional to its molecular weight. In concordance with that, increase in concentration in gas phase is greatest for ethane, smaller for propane, etc. It can be concluded that level of enrichment of injected gas, or, change in quality of vaporized hydrocarbon in each cycle of storage, is mostly function of material balance, i.e., total initial quantity of higher hydrocarbons.

5. CONCLUSIONS

- Optimal Peng-Robinson equation of state model of phase behavior of Zutica oil was used in 1-D reservoir model for simulation studies of oil production process for maintain reservoir pressure, as well as simulation study of gas storage in same reservoir.
- By processes of gas injection into reservoir oil, the composition of fluids in the area near critical point distinctly differs from the composition of the original reservoir fluid.
- Oil displacement by maintaining reservoir pressure by gas injection at an actual pressure occurs under immiscible conditions, and the contribution of multiple contact mechanism of hydrocarbon vaporizing in total oil displacement is negligible.
- Results of gas storage simulation showed: that during the first few years of storage it can be expected enrichment of injected gas due to favorable effects of phase behavior change within working pressure range.
- Using the reservoir for underground gas storage, in this case has additional benefit in increasing value of stored gas due to (1) increase of caloric value, (2) possibility of extracting valuable hydrocarbon components.
- Out of two studied possible ways of future management of Zutica oil field, results of this study favors using the reservoir for gas storage rather than continuation of oil production with high-pressure gas injection.

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