Field test of thermal gas treatment for the Bazhen formation development

A V Sarancha, M V Deneko

Tyumen Industrial University, 38, Volodarskogo street, Tyumen, 625000, Russian Federation

E-mail: 89044914477@mail.ru

Abstract. Nowadays, there is a great number of articles on the Bazhen formation and the huge hydrocarbons’ amount lurking in it. The main purpose of this article is to highlight the results of the Bazhen formation development and wells operation in one oil field. The thermal gas treatment technology impact on source rocks was tested on this field. It was the first experience of thermal gas influence application on the Bazhen formation source rocks. Now it is of great interest for specialists from scientific-research and design institutes working on the design and development of oil and gas fields.

1. Introduction

Field tests and development of equipment and technology for air and water injection, as well as air injection process control systems, were started in October 2009 at the pilot site of this field well 219. The wells’ location, the presence of a horizontal wellbore with hydraulic fracturing (HF) in well 401, the lack of normal hydrodynamic connection of well 3002 with other wells did not allow one to organize a regular system of influence. According to everything mentioned above the main task of the pilot area was to study the possibility of a new thermal gas method realization and its main features in Bazhen formation development.

2. Results and Discussion

Field tests, equipment development, air technology and water injection, as well as air injection control systems at the pilot well site 219 of this field were started in October 2009. At first, oil production at this site was carried out from five wells in the natural mode. The accumulated production at the beginning of the pilot works amounted to 82.4 thousand tons or 2.7% of the initial geological site reserves. At the same time, the reservoir pressure in the wells area of the site decreased to 14-16 MP, it was 2 times more. Consequently, the oil production potential in the natural regime before the saturation pressure (11.7 MP) was almost exhausted.

Well operation continued until the pressure cut by no more than 10-15% below the saturation pressure (Saturation pressure – 11.7 MP).

Almost 3-4 months after the start of injection, oil recovery began to increase in comparison to the natural regime. At the beginning of 2016, the efficiency of the method was 33.7 thousand tons of oil. It corresponded to 26% of the increase in oil recovery, from 3.1 to 4.1%.

The difference in oil production using the method and without one reached the maximum values in 2012-2013. It was due to the fact that during this period (about 3-4 years), an active input into the
development of undrained zones with thermal effects and the extraction of additional oil and hydrocarbon gas with pyrolysis and kerogen cracking in the drained and undrained zones of the formation has started.

It should be noted that according to the preliminary assessment of the work efficiency on well section 219, additional production from the method application was about 25 thousand tons of oil. According to the updated geological model prepared at the beginning of 2016 and taking into account the development history adaptation, including conducted on the gas content of oil and on the component of the extracted gases composition, the efficiency of the thermal gas effects used at the end of 2013 has amounted to 23 thousand tons. It has shown a good agreement of the technological assessment results and the correctness of the previously used methodological approaches.

During depletion in October 2009 (this month pumping started) 82.4 thousand tons of oil was selected during the developed period of the deposit on the area site of the well 219.

Air injection was carried out periodically into the injection well. At the beginning of 2016, the accumulated air injection amounted about 7.3 million m$^3$. The small water volume was pumped during periods of cessation in air injection. The accumulated water injection was 435 m$^3$.

The following are the main results of the four-year period at the first phase of pilot work. They are important to assess the prospects in realization of the thermal gas method for the Bazhen formation deposits development at the oil field and similar to this one.

It is necessary to assess the following additional parameters for analyzing the efficiency of air injection in the 219 well section, in addition to assessing additional production.

Firstly, there is a significant increase in the share of nitrogen (up to 60%) and carbon dioxide (up to 7%) produced gases after air injection in the producing wells. It happens in the complete absence of oxygen, even in the first months of the pilot works and it indicates a high activity of intraplastic oxidation processes.

There is also a significant increase (1.5-2.0 times) in the volume of hydrocarbon gases production. It confirms that kerogen as the main fuel and a decrease in the proportion of heavy fractions with a significant increase in the proportion of light and medium fractions are important for intraplastic oxidation processes.

The most important fact is that the method of thermal gas influence can be and actually it is the method of reservoir pressure maintenance (RPM). It is the method for designing such collectors as the Bazhen deposits (similar to shale formations). It is a fact of the recovery in the reservoir pressure at the site for a short time to 20-25 MP. This is important, because of the fact that the natural regime formation pressure decreases very quickly. Respectively, there is a significant decrease in the flow rates of all producing wells, especially when carrying out massive hydraulic fractures in directional wells and multistage hydraulic fractures in horizontal wells (well 100G).

There is additionally evaluated injection of flue gas (primarily nitrogen $\text{N}_2$) for the area of experimental-industrial well development 210 (3003) in comparison with the thermal gas impact. Injection of only gas agents (not air, or water-air mixture) is more effective than development in the natural mode, due to the possibility of maintaining reservoir pressure during gas injection. But it is limited in application at the field because of the agent high mobility at the real heterogeneity of the reservoir.

In addition, the residual oil saturation is significantly higher and the displacement coefficient during injection of only gas agents is correspondingly lower for the conditions without created activities in the formation reservoir for the rim of mixing displacement due to oxidative processes.

It should be noted that the thermal effect, which ensures the involvement in the development of non-draining rock matrix, is not involved during the flue gases injection. The thermal effect is the element of thermal gas influence.

Thus, in comparison with the flue gas injection the high potential of oil recovery thermal gas treatment method of deposits with high initial reservoir temperature is a consequence of the intraformational generation for a highly efficient gas-displacing agent. The thermal gas method distinctive feature is the agent formation not only through intraformational combustion (flue gases), but
mostly due to the thermodynamic exchange processes. They enrich the flue gases by light and middle fractions of the oil reservoir under the heat influence.

The effects from the heat and gas component of the method function together in the thermal gas exposure. The existing synergistic effect with pumping air is the distinctive feature of thermal gas impact.

Returning to the work assessment, it can be noted that stabilization and even a small increase in reservoir pressure in the area of producing well 3002 is a manifestation of a positive effect after injection into wells 219. Producing well 3002 is located in an area with degraded filtration characteristics. This well did not have hydrodynamic connection with the rest of the experimental site according to the results of hydraulic monitoring before the air injection. In this regard, the stabilization of well 3002 reservoir pressure is associated with the improvement of hydrodynamic connection between the well zones after a short period of water injection (hydrodynamic effect) and then with air injected into the well 219.

A zone with high fracturing was formed on the well 401 (horizontal well), in which a massive hydraulic fracturing is carried out. Possibly this zone combines both zones. They are the zone with man-made fractures and the zone of tectonic disturbances (anomalies) isolated from seismic studies.

Reaction in well 401 to injection into well 219 (October 2009) was immediately recorded. The \( \text{N}_2 \) content in simultaneously produced gases began to increase and the gas factor increased sharply (according to irregular measurements carried out up to 600 m\(^3\)/t). Within 6 months after the injection starts, according to the analysis results of the surface oil sample, the density of oil (May 2010) decreased and amounted to only 683 kg/m\(^3\) (at the base – 830 kg/m\(^3\)). It has happened due to the dominant content of C\(^5+\) components. This fact suggested that the rim of the mixing displacement was formed in a short period. The gas factor increased above the critical for the operation of the mechanized method (more than 500 m\(^3\)/t) and the well was stopped, due to the fractured zones. However, after the air injection stopping into well 219 in 8 months (May 2014) production was resumed and even in March 2016 (2.5 years after the end of air injection), the flow rate was 6-8.6 m\(^3\)/day, the gas factor was about 230-250 m\(^3\)/t, the content of \( \text{N}_2 \) and \( \text{CO}_2 \) in the produced gas was 10-15\% mol and 4.1-4.5\% mol, respectively.

The results of gas and oil analysis in this well show that the presence of highly developed fracture zones (complicated by the structural factor) lead to premature gas breakthroughs in narrow formation intervals at the first short period of time. It happens when the edge of the mixing displacement does not have time to form and as a result, we have a minimum section coverage.

Additionally, the rock is decomposed carbonate-containing rocks. It gives a significant addition to the generation of hydrocarbon gas and HCO\(_3\).

A similar analysis of wells’ work 3001 at the period of February-March 2016 shows the thermal gas effects efficiency. The well flow rate is 11-20 m\(^3\)/day, the gas factor is about 150-200 m\(^3\)/t, the content of \( \text{N}_2 \) and \( \text{CO}_2 \) in the associated gas is 8.3-11\% mol and 3.3-3.5\% mol respectively.

The continuation of the 3000 well effect is less significant. Its analysis shows that the flow rate is 8-15m\(^3\)/day, the gas factor is about 100-110 m\(^3\)/t (close to the initial values), the content of \( \text{N}_2 \) and \( \text{CO}_2 \) in the simultaneously produced gas is 8.3-11\% mol and 3.1-4.1\% mol, respectively, at the period of February-March 2016.

3. Conclusion
Analyzing the work of individual wells and summarizing the main data, the results of the efficiency assessment should be noted as follows:

- the results were obtained, confirming the results of experimental work at the air injection works in well site 219 of the field;
- the share of nitrogen and carbon dioxide in the produced gases increased in wells 401, 3000 and 3001;
• there was almost complete absence of oxygen in the extracted gases and an increase in the gas factor in 2-3 times due to an increase in the share of hydrocarbon gases;
• there was a significant reduction in the oil density and viscosity; change in the oil composition by increasing the content of light fractions in wells 3000 and 401.

References
[1] Baturin Y E 2010 Bazhen without benefits so it will remain. Oil and Gas vertical 23-24 12-16
[2] Deliya S V, Drandusov K A, Karpov V B and Mamaev D.A. 2015 RITEK: Prospecting experience, prospecting, reserves calculation and deposit developments of bazhen formation. Subsurface management XXI century. 1 (51) 80-83
[3] Korovin K V, Pecherin T N 2016 Analysis of operating results from the bazhenov formation of deposits of the territory of KHMAO-Yugra. International research magazine 12 (54) 91-94
[4] Nesterov I I, Brekhuntsov A M 2010 Oil bituminous clay, siliceous clay and carbonate-silica-clay rocks Vestnik CKR Rosnedra. 6 3–16
[5] Sarancha A V, Sarancha I S 2014 Analysis of the bazhen formation development at Ulyanovskoe field. Academic magazine of West Siberia. 10-1 128-129
[6] Sarancha A V, Garina V V, Mitrofanov D A and Levitina E E 2015 Pilot Development Planning’s results of bazhenformation of Zapadno-Sakhalinskoe field. Fundamental researches. 2-14 3052-3055
[7] Sarancha A V, Mitrofanov D A, Sarancha I S and Ovezova S M 2015 Bazhen formation development of Ay-Pimskoye field. Current problems of science and education. 1-1 204-208
[8] Tolstolytkin I P 2012 Oil reserves use at the fields of KHMAO-Yugra. Science and FEC 5. 4 26-28
[9] Shandyrin A N, Shpurov I V, Bratkova V G 2015 State and prospects of shale oil deposits development. Subsurface management XXI century. 1 (51) 52-63