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Research on Cyclic Water Injection with Periodic Rotation in Small Well Spacing Patterns

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Abstract: After more than 60 years of development and adjustment, the Sazhong Development Area has gradually transitioned from a wide-well-spacing line drive pattern to a compact well pattern with small well spacing. However, in the late stage of ultra-high water cut, the composite water cut of waterflooding has reached as high as 97%, leading to increasingly scattered remaining oil distribution and intensified conflicts of inefficient and ineffective circulation. It has become difficult to identify the main potential tapping direction through stratified water injection. Furthermore, under the condition of multi-layer subdivision, it is challenging to ensure stable water injection in thin layers for an extended period. Traditional stratified adjustment methods have shown issues such as heavy adjustment workloads, high control difficulties, and limited effectiveness. Therefore, we need to change our adjustment approach, aiming at tapping the potential of remaining oil in bypass flow lines and altering the direction of injection-production flow lines. By adopting cyclic water injection in small layers as a means, simplifying water injection control methods, optimizing cyclic water injection techniques, and enhancing reservoir pressure disturbances, we can expand the swept volume of water injection, mobilize remaining oil in bypass flow lines, and gradually establish a new method for water control and potential tapping suitable for the late stage of ultra-high water cut.

Keywords: Small well spacing pattern; cyclic water injection; periodic rotation; oil recovery; reservoir utilization.

1. Introduction

In typical small-well-spacing waterflooding blocks, well areas with relatively independent well patterns, numerous subdivided layers, high water cut, and severe low-efficiency and ineffective cycling were selected as the experimental zones. Water injection wells conducted cyclic water injection with shortened layer intervals. Different layers were opened in different injection directions within the same well group, with layer rotation implemented on a monthly basis to significantly reduce the difficulty of layered measurement, adjustment, and regulation. Simultaneously, fluid flow redirection was achieved through pressure perturbation to control the rate of water cut increase.

2. Overall Approach

2.1. Selection of Experimental Zones

Based on waterflooding development blocks, considering factors such as well pattern improvement, low interference between drive methods, good well conditions, and representative well spacing, a block M with poorly produced oil layers and high water cut was selected to conduct a 9-injection and 16-production cyclic injection-production experiment (Fig. 1).

In the experimental area, there were a total of 25 water injection wells, with 24 wells in operation. The injection pressure was 11.18 MPa, the daily allocated injection volume was 845 cubic meters, and the actual daily injection volume was 725 cubic meters. There were 16 production wells in total, with 15 wells in operation and one well shut down due to casing damage. The daily liquid production was 959 tons, daily oil production was 11 tons, comprehensive water cut was 98.9%, submergence depth was 567 meters, and flowing pressure was 5.24 MPa.

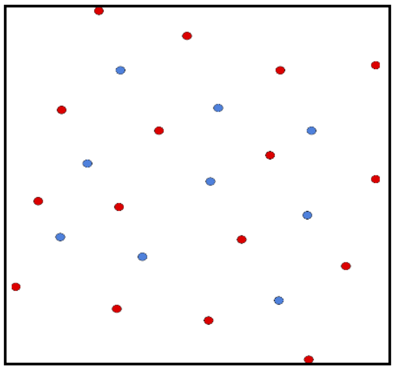

Figure 1. Schematic Diagram of Cyclic Water Injection Test Area

2.2. Design of Cyclic Water Injection Scheme.

Guided by the macro principle of "injecting good and sufficient water," the goal of improving stratified water injection and enhancing reservoir utilization is achieved by formulating a cyclic water injection layer scheme, reasonably setting the water injection adjustment cycle, and ensuring efficient scheme execution through on-site supervision.

2.2.1. Unified Layer Design for Water Injection Scheme

Considering the reservoir development characteristics of the small-well-spacing pattern in Block M, the relatively stable interlayer parts of the reservoir are selected for unified layer and subsection design. Based on depth, the reservoir is specifically divided into four subsections from low to high: Subsection A, Subsection B, Subsection C, and Subsection D. While adjusting water injection in these subsections, the overlying rock pressure can be adjusted according to the perforation top boundary of the water-absorbing layer. This allows the "difficult-to-inject poor layers" at the bottom to be injected with increased pressure, thus making them productive. This overcomes the contradiction of some well layers being unable to meet the allocated injection due to geological development conditions, ensuring that all subsections receive water injection and enhancing reservoir utilization (Fig. 2).

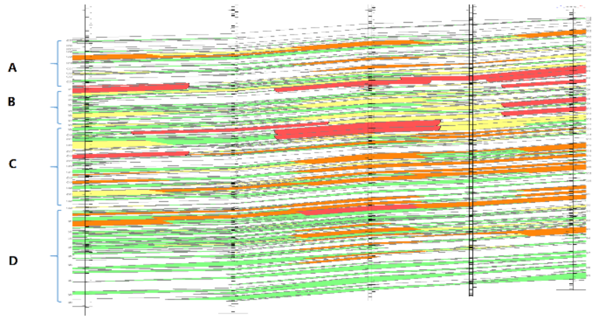

Figure 2. Cyclic Water Injection Test Area - Unified Layer Schematic

2.2.2. Design of Cyclic Water Injection Scheme

Cyclic water injection subsection scheme for well groups: To ensure balanced utilization of cyclic water injection subsections and avoid large fluctuations in water injection volume within well groups, this subsection rotation scheme adopts a "cyclic water injection with a four-well, four-subsection rotation cycle for well groups." Considering that the effective time of water injection is approximately one month, the cyclic water injection period is initially designed to be one month（Fig. 3）.

Cyclic Injection Allocation Scheme for Subsections: To ensure a smooth transition of water injection volumes across different cycles of cyclic water injection and prevent excessive pressure differentials caused by large fluctuations in water injection volumes, which may lead to casing damage risks, the water injection intensity is appropriately increased during the cyclic water injection phase. Based on the perforated thickness of each subsection, a reasonable water injection scheme is designed, with the upper limit controlled below 9.0 m³/(m·d). Meanwhile, considering actual injection conditions on site, the upper limit of injection pressure is kept more than 0.5 MPa below the fracture pressure to ensure that each subsection is injected according to the cyclic water injection scheme. During cyclic water injection, close attention is paid to changes in injection pressure, and the water injection scheme is promptly adjusted to ensure that reservoir pressure and inter-well pressure differentials are maintained at reasonable levels.

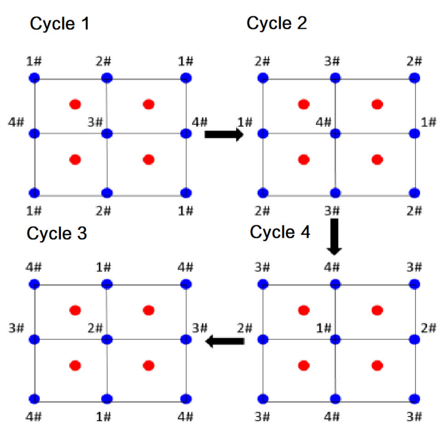

Figure 3. Cyclic Water Injection Test - Injection Interval Rotation Schematic

2.2.3. Design for Tracking and Adjustment of Oil and Water Wells

During the cyclic water injection phase, if water injection wells encounter difficulties in injection, immediate well washing and testing should be conducted to restore injection. For wells where these measures are ineffective, geological personnel in the relevant block should employ acidizing, plugging removal, and other methods for treatment and improvement to ensure the full implementation of the water injection plan.

Tracking and analysis of surrounding connected producing wells should be carried out diligently. For wells with rising water cut, based on reservoir connectivity, monitoring data, and historical profile information, the dominant water inflow direction and intervals should be accurately determined, and timely adjustments to the plan should be made. For wells with significantly improved production performance, timely matching adjustments should be made to the parameters at the production end to ensure maximum benefits.

3. Effects of Cyclic Water Injection Scheme

After implementing cyclic water injection for subsections in the pilot area, positive effects were observed. Daily oil production remained stable with a slight increase, low oil production in wells was controlled, and water cut decreased, achieving satisfactory results (Fig. 4).

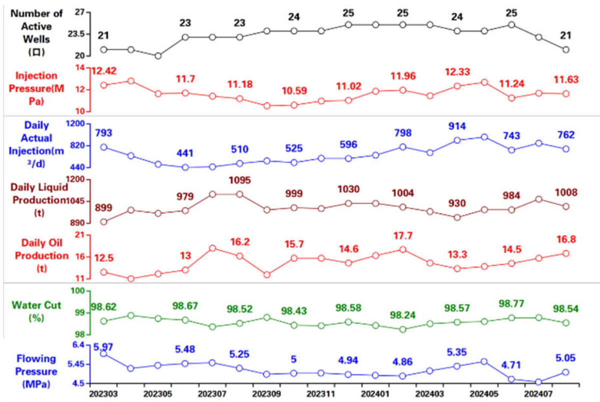

Figure 4. Integrated Production Curve of Test Area

4. Summary

By implementing cyclic water injection for subsections and altering fluid flow directions through pressure disturbances, remaining oil in diversion lines was tapped. Through multiple rounds of continuous adjustments, periodic effects of water cut reduction and oil production increase were achieved, and the decline rate of oil wells was effectively controlled.

References

[1] Zhang Yong, Su Guojun. Design Principles of Cyclic Water Injection for Low-Permeability Fault-Block Reservoirs [J]. Sino-Global Energy. 2006,(2). DOI: 10.3969/j.issn.1673-579X.2006.02.008.

[2] Gao Yangjun, Pan Ling, Lu Xiangguo. Effects of Cyclic Water Injection and Its Influencing Factors [J]. Journal of Daqing Petroleum Institute. 2004,(5). DOI: 10.3969/j.issn.2095-4107.2004.05.008.

[3] Yu Qitai, Zhang Sufang. Reservoir Numerical Simulation Study on Cyclic Water Injection [J]. Petroleum Exploration and Development. 1993,(6). 46-53.

[4] Zhang Jihong, Zhang Nan, Zhang Gang, et al. Study on Cyclic Water Injection Methods in Gaotaizi Area [J]. Science Technology and Engineering. 2011,(7). DOI: 10.3969/j.issn.1671-1815.2011.07.030.

[5] Tang Mingjie. Theory and Application of Cyclic Water Injection [J]. Inner Mongolia Petrochemical Industry. 2013,(8). DOI: 10.3969/j.issn.1006-7981.2013.08.016.