Field Test and Discussion on Individualized Test Cycle of Water Injection Wells

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Abstract. As the oilfield enters the late development stage of ultra-high water cut, the number of separate layer water injection wells increases year by year, and the single well interval becomes finer and finer, which makes the test adjustment more difficult and the qualification rate of periodic test matching lower, and finally affects the decline of water injection qualification rate. In view of the above reasons, it is urgent to formulate a personalized test cycle. It is a major task to ensure the stable production of the oilfield to ensure the water injection, enough water injection, improve the quality of water injection, and ensure that the water drive oilfield development meets the program requirements at the injection end. In the past year, the influencing factors of water injection qualification rate of water drive separate layer wells have been analyzed, and the change law of inspection qualification rate has been explored. Through the demonstration of experimental work, the personalized test cycle is discussed. The original 4-month test cycle is shortened to 2 months, and the test cycle is extended for wells with 100% qualified rate, and the test cycle is shortened for wells with less than 80% qualified rate. The problems such as long inspection period, low qualified rate of water injection and difficult single well test and adjustment are solved. To achieve accurate water injection, and ultimately achieve the purpose of stabilizing oil and controlling water.

1. Introduction

In the late development stage of ultra-high water cut oilfield, the number of separate layer water injection wells is increasing year by year, the single well interval is becoming more and more fine, and the factors affecting the qualified rate are complex, which leads to more and more difficult test adjustment and low qualified rate of test and matching. By exploring the factors affecting the qualified rate of water flooding separate layer wells, exploring the change law of qualified rate of water flooding, and carrying out the test, we can accurately formulate the personalized design This will have a guiding and reference significance for improving the quality of testing and water injection.

2. Raising of the problem

In the late development stage of oilfield with ultra-high water cut, separate layer test of water injection well is a conventional and effective method to check and adjust whether small layer water injection can meet the requirements of geological scheme and understand the condition of underground water injection. It is an urgent problem to be solved when the water injection status of each section of water injection well changes and cannot be adjusted in time. Therefore, it is very
important to explore the change law of water injection qualification rate and work out the personalized test and adjustment cycle for water injection.

2.1. The difficulty of layered test adjustment is increasing year by year

Since 2005, the number of separate layer water injection wells has increased by 1.9 times, the number of total intervals has increased by 2.4 times, the number of single well intervals has increased by 1.3 layers, and the number of testing and adjusting wells has increased by 3.7 times. As the number of single well intervals is increasing, it is more and more difficult to adjust the layered test. It takes three days to test a well by using an efficient test team, and the workload is increasing year by year.

2.2. The qualified rate of separate layer water injection well is low

According to the 4-month conventional separate layer testing cycle, 3540 separate layer wells and 9289 well times (deduction scheme, measure well, etc.) were tested in three testing and adjustment cycles. The average qualified rate was 53.9%, including 57.3% for conventional well spacing and 50.4% for slim well spacing. The proportion of wells with 100% qualified rate for two consecutive cycles is 1.2%; the proportion of wells with 100% qualified rate for one consecutive cycle is 2.5%; the proportion of wells with 80-100% qualified rate is 8.6%; and the proportion of wells with less than 80% qualified rate is 87.7%.

3. Study the qualification rate of different well pattern, well spacing, water volume and pressure space

3.1. qualified rate of different well patterns

3540 wells and 9289 times of testing wells were continuously tracked and inspected. Compared with Sapu well pattern, the qualified rate of Gaotaizi well pattern was 4.3% lower than that of Sapu well pattern.

3.2. qualification rate of different well spacing

A total of 232 fixed-point wells with different well spacing (including wells with influencing factors) were selected. 143 conventional well spacing and 89 small well spacing were continuously tracked in half a year. The qualified rate of matching is high. The qualified rate of matching of Taizi well pattern is about 4% lower than that of Sapu well pattern.

The Sapu formation is mainly developed as delta front sand body with well-developed oil layer and good plane continuity. Once the water injection relationship is formed, it is easy to be affected. The number of intervals in single well is small, the injection allocation is high, and the injection pressure space is large.

Most of the Gaotaizi strata are developed as stable sheet sand in the delta outer front, with poor reservoir physical properties, large permeability difference, large difference in reservoir plane development and prominent plane contradiction. There are many intervals in single well, low injection allocation and small injection pressure space.

3.3. qualified rate of different water quantity

The qualified rate of 135 wells with daily injection distance of less than 50 m$^3$ is 64.3%. 410 wells with daily injection distance of 50 m$^3$ to 100 m$^3$ are 68.1%. 355 wells with daily injection distance of 100 m$^3$ to 150 m$^3$ are 73.0%. 171 wells with daily injection distance of 150 m$^3$ to 200 m$^3$ are 72.9%. 147 wells with daily injection distance of 200 m$^3$ to 300 m$^3$ are 73.7%; and the qualified rate of daily injection distance is more than 300 m$^3$. The qualified rate of 52 m$^3$ wells was 76.7%.

The qualified rate of 79 wells with small well spacing less than 50 m$^3$ per day is 62.6%. The qualified rate of 490 wells with daily injection between 50 m$^3$ and 100 m$^3$ is 64.1%; the qualified rate of 183 wells with daily injection between 100 m$^3$ and 150 m$^3$ is 70.2%; the qualified rate of 22 wells with daily injection between 150 m$^3$ and 200 m$^3$ is 73.0%.
3.4. qualified rate of different pressure space

The results show that 321 wells with normal distance from the top overburden pressure free space have a qualified rate of 65.9%. 567 wells with water injection pressure between 0 and 1MPa have a qualified rate of 71.1%. 258 wells with water injection pressure between 1 and 2MPa have a qualified rate of 77.2%. 124 wells with water injection pressure greater than 2MPa have a qualified rate of 76.2%.

There are 41 wells with no pressure space above the top of the slim well, 256 wells with water injection pressure between 0 and 1MPa, 168 wells with water injection pressure between 1 and 2MPa, and 309 wells with water injection pressure more than 2MPa.

4. Establish test cycle and select test area

According to the statistics of 6156 wells (without influencing factors) in the three periods, the average qualified rate is 69.2%, including 71.5% for conventional well spacing and 65.8% for small well spacing.

Reasonable matching qualified rate, conventional well spacing high platform matching qualified rate 68.9%, Sapu matching qualified rate 73.4%, small well spacing high platform matching qualified rate 66.4%, Sapu matching qualified rate 72.1%.

According to the reasonable matching qualified rate, the reasonable matching qualified rate of conventional well spacing and small well spacing wells is about 70% in two months. Therefore, the overall testing cycle should be two months.

4.1. test cycle formulation and optimization of test methods

In order to keep the effective water injection qualification rate at a high level, change the mode of the previous four months test cycle, shorten the original 4 months test cycle to 2 months.

For the well group centered on the well, the monthly water cut change of the connected well is judged first, and the well with stable or falling water content is inspected and observed.

The well with rising water cut is shortened to once in two months, and the unqualified layer is found to be adjusted immediately. The optimization of test cycle, refinement of layered water injection standard, determination of "double determination" method of layer properties and "six methods" test method in the process of measurement and adjustment are adopted to improve the test efficiency and quality, so as to achieve the purpose of sufficient water injection and good water injection.

4.1.1 develop test cycle. For the wells with stable or falling water cut, it is not necessary to test them, and they are checked every two months. The qualified wells are injected with water according to the original scheme, and the unqualified wells are re prepared according to the checking situation and dynamic combination.

For the wells with water cut rising, the test and adjustment should be conducted once every two months, and the unqualified layers should be adjusted immediately. For the wells with 100% qualified rate for two consecutive cycles, the cycle should be extended to 8 months. The proportion of wells with 100% qualified rate for one continuous cycle is increased to 6 months, and the proportion of wells with 80-100% qualified rate for three consecutive cycles is increased to 4 months. For wells with 70% - 80% qualified rate for three consecutive cycles, the cycle is 3 months. If the qualified rate is less than 70%, the period can be shortened to 2 months.

4.1.2 "double determination" method to optimize test method and determine the property of layered water injection interval."Double determination" means "qualitative measurement, final reorganization", and measuring the layered indication curve under the same conditions. Master the difference of water absorption capacity of each interval, judge the nature of each interval, analyze the production status of well group based on the results of dynamic and static data, and determine the next water injection adjustment scheme.
One is the method of testing layered indicator curve. Put each interval into a water nozzle (or net) with the same aperture, and measure the layered water injection indication curve. Master the starting pressure of each section, distinguish the difference of water absorption capacity of each section, and find out the "actual" high permeability layer. According to the field results, the property of the interval and the water injection intensity (water lifting layer, water control layer and balance layer) are determined.

The second is to use "double determination" to work out the adjustment plan of water injection well. Improve the traditional water injection well adjustment program preparation process. Traditional methods: well change - static results - isotope profile - Preparation of adjustment plan - Test adjustment. Double determination method: oil well change test verification dynamic and static data determination of interval properties preparation of adjustment scheme.

4.2. select the test area for the experiment

In May 2018, the test was carried out in 83 conventional well spacing and 125 small well spacing of water drive stratified water injection wells in test area 1 and test area 2 respectively. Each injection well is inspected once every two months, and the unqualified layer is adjusted in time. Through several rounds of implementation, we have achieved the following understanding:

4.2.1 the workload of measurement and adjustment increases, but the difficulty of single well adjustment decreases. At the beginning of the test, the number of adjustment intervals in the first cycle and the second cycle increases, and after stabilization, the number of adjustment intervals in the third cycle gradually decreases and remains in a certain range. Compared with before implementation, the number of conventional well spacing measurement and adjustment wells increased by 24, the number of matching layers increased by 166, and the number of adjustment layers increased by 45. The number of small well spacing testing and adjustment wells increased by 18, the number of matching layers increased by 82, and the number of adjustment layers increased by 64. However, because the test cycle time is shortened, the water nozzle clogging and pricking section can be found in time. Through fine-tuning, it can be adjusted in place, so as to reduce the adjustment range of water nozzle and shorten the time of voltage stabilization, reduce the difficulty of test adjustment, and improve the test efficiency. At the same time, it can timely check the water injection process and equipment working state, reduce the water injection error and improve the water injection quality.

4.2.2 implement personalized test cycle to effectively improve water injection qualification rate. According to the test, the change law of water injection qualification rate is classified and counted, and the personalized test cycle is formulated. 22 wells with 100% qualification rate for three consecutive cycles account for 7.0%, and the test cycle is extended to 6 months. The proportion of 119 wells with 80-100% qualified rate for three consecutive cycles was 37.8%, and the test cycle was extended to four months. 174 wells with qualification rate less than 80% accounted for 55.2%, and the test cycle was kept at 2 months. The test time is further reduced, the test workload is controlled within the scope of ability, and the overall qualified rate of inspection and matching is always maintained at a high level of more than 70%.

22 wells with 100% qualified rate in three consecutive cycles are mainly Sapu well pattern. The average interval of single well is 4 layers, the space between water injection pressure and overlying rock pressure is large, and the average difference is 1.5MPa. There are 119 wells with 80 – 100% qualified rate for three consecutive cycles, and the average interval of single
well is 4.5 layers. The average difference between water injection pressure and overlying rock pressure is 1.0MPa. There are 174 wells with qualification rate below 80%, and the average interval of single well is 5 layers. The average difference between water injection pressure and overlying rock pressure is 0.6MPa.

4.2.3 The remarkable effect of stabilizing oil and controlling water can be achieved while the qualified rate of inspection is improved. As shown in Figure 1 and Figure 2, through several rounds of implementation, the qualified rate of inspection and matching can be maintained at a higher level, and the connected production wells have achieved good results, such as stable daily fluid production, slow rising rate of water cut, and stable daily oil production.

![Figure 1](image1.png) Conventional well spacing test

![Figure 2](image2.png) Small well spacing test

1) Effectively improve the qualified rate of inspection and matching

Compared with the conventional 4-month test cycle, the average qualified rate of inspection and matching is always around 70%, and the average qualified rate of inspection and matching is increased by 12.5%. In particular, the qualified rate of small well spacing increased by 13.9%.

2) The production of the test block is stable and the water cut is slightly decreased

In the conventional well spacing test block, the daily fluid production is stable, the oil production is increased, and the water cut is slightly decreased. The daily liquid production and oil production of oil wells in the small well spacing test block are decreased, and the water cut is slightly increased, which is better than the planned production allocation at the beginning of the year.

| Daily fluid production (m³) | Daily oil production (m³) | Moisture content (%) | Submergence depth (m) |
|-----------------------------|---------------------------|----------------------|-----------------------|
| 2150 | 2012 | 95 | 221 |
| 2078 | 1985 | 94 | 222 |
| 2112 | 1962 | 96 | 223 |
| 2067 | 1947 | 98 | 224 |
| 1960 | 1934 | 96 | 225 |
| 2022 | 1926 | 96 | 226 |
| 1983 | 1918 | 96 | 227 |
| 1947 | 1912 | 96 | 228 |
| 1952 | 1907 | 96 | 229 |
| 1967 | 1902 | 96 | 230 |
| 1977 | 1901 | 96 | 231 |
| 1946 | 1900 | 96 | 232 |
| 1941 | 1900 | 96 | 233 |
| 1928 | 1900 | 96 | 234 |
| 1962 | 1900 | 96 | 235 |
| 1963 | 1900 | 96 | 236 |
| 1974 | 1900 | 96 | 237 |

| Before personalization cycle | After the personalization cycle |
|-----------------------------|-------------------------------|
| Daily fluid production (m³) | Daily oil production (m³) |
| Moisture content (%) | Submergence depth (m) |

5
5. Conclusion

1) The accuracy of the personalized test cycle of water flooding stratified injection wells is more important.

2) The qualified rate of water injection between small well and well is lower than that of conventional well spacing in the same injection time.

3) The qualified rate of water injection well inspection and distribution in the first four months test cycle is relatively low, accounting for a large proportion.

4) The qualified rate of well inspection and matching is high with small single well interval and large space of water injection pressure and overlying rock pressure.

5) The personalized measurement and adjustment cycle of water flooding stratified injection wells has realized timely discovery and adjustment of unqualified layers. The problems such as long inspection and distribution period, low water injection qualification rate, difficulty of single well measurement and adjustment, large proportion of repeated testing, etc. are solved. The qualified rate of water injection is improved, and the purpose of stabilizing oil and water control is achieved, and it is suitable for the promotion of the whole plant.

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