Small well-spaced area development adjustment practices and awareness

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Abstract: The small well spacing block was encrypted and adjusted three times from 2009 to 2012, with the injection and extraction well spacing shortened from 250m to 106m, and the proportion of small well spacing wells accounting for 71.3% of the water drive, mainly distributed in Area A, Area B and Area C. The current well network density in the small well spacing area is 90.7 wells/Km2, the formation pressure is 9.12Mpa, there are more exploited layers vertically, the contradiction between layers and within layers is prominent, and there are large differences in oil formation mobilization, resulting in a rapid rise in water content. Through fine geological research, the focus is on improving the use of thin and poor oil formations, controlling the rate of water-bearing rise and restoring the energy of the formation, and constantly exploring effective methods for "controlling water-bearing and decreasing" during the period of exceptionally high water-bearing, so as to improve the development effect of the block and achieve the purpose of stabilizing oil and controlling water.

Keywords: dense well network, interlayer conflicts, planar adjustment, oil stabilization and water control

1. Basic overview

After three encryption adjustments from 2009 to 2011, the proportion of small well spacing wells accounted for 71.3% of water drive, mainly in Area A, Area B and Area C. The injection and extraction well spacing were shortened from 250m to 106m

Table.1 Basic information about the Koi Distance area

Block Name	Block A	Block B	Block C	Totally
Well network density (well/km^2)	104.1	94.9	76.8	90.7
Number of injection and extraction wells ratio	0.93	1.1	0.84	0.93
Stratigraphic pressure (Mpa)	9.06	9.49	8.81	9.12
Total differential pressure (Mpa)	-0.94	-1.93	-2.19	-1.69

2. Geological overview

The sedimentary phase type in Block B is the delta frontal subphase, mainly developing narrow submerged divergent channel sands and large matted sands; Block A mainly develops divergent channel and delta frontal phase sands; Block C mainly develops unstable delta outer frontal matted sands. The reservoir profile shows that from the bottom to the top, the riverine sands of different periods are cut and stacked on top of each other, and different sedimentary phase types alternate with strong inter-stratigraphic inhomogeneity.

3. Major problems exist

3.1 Outstanding planar and inter-stratigraphic contradictions and uneven oil formation mobilization

The span of the well sections in the small well spacing area is long, with the average single well span reaching 138m, of which Block C and Block A reach 200m. Four different inorganic ion tracers were selected and injected into different layer sections according to the different mineral ion concentrations of the formation water in different layer sections. The tracer test results show that: from a vertical perspective, the number of seen agent layer sections is small, and the inter-layer contradiction is prominent; from a planar perspective, the planar seen agent direction is single, and the planar contradiction is prominent.

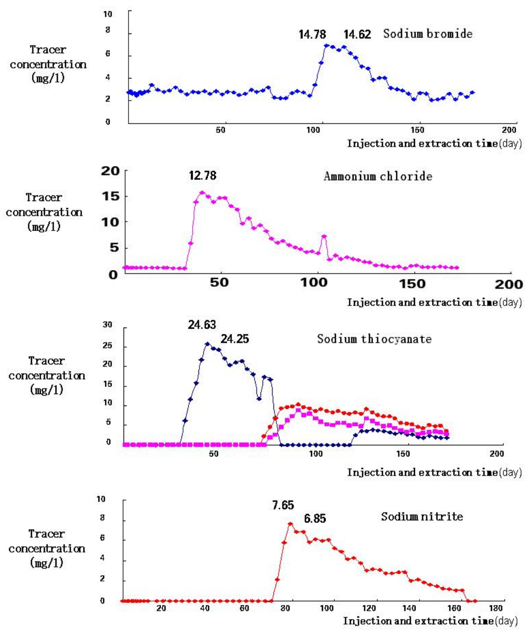

Fig. 1 The planar contradiction is prominent.

In terms of the mobilization status of each formation group, the mobilization status of each formation group varies, with the G3 and G4 groups being better mobilized and the S1 and S2 groups being worse mobilized. When comparing the overall utilization of the small well spacing area with the mine as a whole, the percentage of sandstone thickness utilization is 4.03% lower than the mine as a whole, and the percentage of effective thickness utilization is 3.11% lower than the mine as a whole.

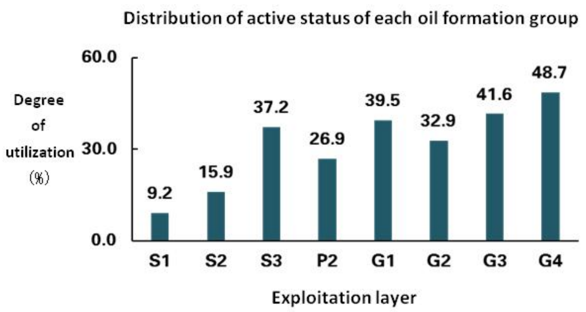

Fig.2 In terms of the mobilization status of each formation group

3.2 High injection rate, low check rate and rapid rise in water content

The rate of water injection and fluid production in the small well spacing area is higher than that in the conventional area since the three encryptions, while the water absorption in the injection wells is more variable, resulting in a lower check rate and a faster rise in water content. In comparison with the conventional zone, the rate of check and match and the rate of increase in water content in the small well spacing zone are both higher than those in the conventional zone.

4. Adjustment ideas and governance methods

In response to the three contradictions in the small well spacing area, we have developed corresponding adjustment ideas, implementing measures such as test cycle optimization, layer segment re-organization and shallow dissection at the injection end, so as to improve the check and match pass rate and alleviate the contradiction between layers; implementing fracturing, re-injection and water plugging at the extraction end, so as to achieve the purpose of controlling water content and decreasing, and improving the degree of oil use.

4.1 "Rotation check and adjustment", exploring reasonable measurement and adjustment cycles

Explore the "turn-by-turn inspection and adjustment" testing method, and explore a reasonable measurement and adjustment cycle for small-well spacing wells to improve the water injection qualification rate and control the rate of water content rise. In August 2015, the company started to select three areas in the small well spacing area of the dense well network in Area A and Area B, with a total of 125 stratified wells, to carry out the test in batches.

Through the implementation of encrypted testing of 125 wells in 2 batches of 3 areas, the testing period was shortened from 3 months to 2 months. After 5 rounds of testing, the passing rate of testing in the rotation area was improved, with the passing rate of testing in the first rotation area increasing from 42.5% to 69.2% before the rotation, and the passing rate of testing in the second rotation area increasing from 58.7% to 71.7% before the rotation.

The current pass rate for the small well spacing area is 68.9%. In response to the low pass rate, we have counted the number of wells with a pass rate of less than 60%, a total of 139 wells, with a pass rate of 52.3%. The next step is to optimize the testing period for these wells. The principle of optimization is to reduce the number of wells with two consecutive cycles below 60% to one cycle and those with two consecutive cycles below 70% to two months, so as to further improve the passing rate.

4.2 Optimize programmer adjustments to improve oil formation mobilization

1. Anti-nine-point method well network implementation transfer, improve well network injection and extraction relationship

For the imperfect injection and recovery area in area B, the injection and recovery well distance was shortened from 300m to 106m by changing from the large distance anti-nine-point method to the small well distance five-point method. After the transfer, the well network relationship was improved and the proportion of multi-directional connections in the well group increased from 42.9% to 82.9%, with a better adjustment of the connected oil production wells, an increase of 3t of oil production per day, a 0.16% decrease in integrated water content and a 26m increase in sinkage. The original inverse nine-point method well network planned for oil to water conversion of nine wells, a total of eight wells are currently implemented and one well is pending drying.

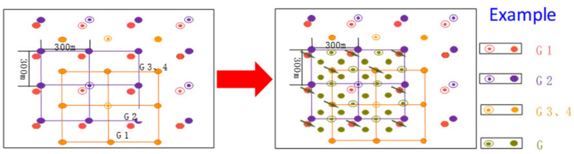

Fig.3 The original inverse nine-point method well network planned for oil to water conversion of nine wells, a total of eight wells are currently implemented and one well is pending drying.

5. Optimized adjustment of layer segments to mitigate inter-layer conflicts

In response to the large number of layers in the small well spacing area in the longitudinal direction and the contradiction between layers, the wells are implemented with subdivided single cards, stopping the injection of high permeability layers and increasing the degree of thin differential layer activation, in the longitudinal direction, to make the profile activation more balanced.

In 2017 the small well spacing area took subdivided single cards for wells with single layer protrusions. A total of 17 subdivision adjustments were implemented, increasing the number of water injection layer sections from 78 to 96, and the coefficient of variation of permeability decreased by 0.24 when comparing before and after subdivision.

The following is an example of well Z. From the water absorption profile, a larger proportion of water was absorbed at the bottom of deviation 3 and the top of deviation 4. In order to improve the degree of oil mobilization, a subdivision single card was implemented for the well and the injection of high permeability layers was stopped. After the implementation, the daily oil production of the continuous recovery well was stable and the water content dropped by 0.22%, achieving a better adjustment effect.

6. Fracturing of oil recovery wells to exploit residual oil potential

Well G is an oil recovery well in Block B. Fracturing was implemented on the well in May 2017, using a combination of normal fracturing and multi-fracture fracturing, and at the beginning of fracturing, the well's daily oil increase reached 8 tons. In order to extend the validity of the measure, a test up-regulation was implemented on the well's connected water injection well. After the up-regulation, the water volume increased by 49 square meters, improving the well's fluid supply capacity, and the well is now producing 4 tons of oil, with a cumulative oil increase of 1,623 tons, achieving a better fracturing effect.

6.1 Fine injection and extraction adjustment, control the rate of water content rise

1. Planar adjustment to control ineffective recovery from exceptionally high water-bearing well areas

In 2017, following the principle of "high water content and high flow pressure, low water content and low flow pressure", planar adjustment work was carried out in Block B. Water injection wells are adjusted downward for well groups containing more than 97% of water, and oil extraction wells are adjusted downward to change the direction of fluid flow and control ineffective water circulation.

After the implementation of the plane adjustment, statistics 20 water injection wells, connected to 30 unmeasured oil recovery wells, the adjustment effect is better, daily oil production decreased by 5 tons, the comprehensive water content is stable, to achieve the purpose of liquid reduction, oil stabilization, water content control.

Injecting wells to adjust profiles, control high aquifers and reduce ineffective water circulation

At the extraction end, a shallow transfer profile is implemented for injection wells, first combining the profile information to determine the section of the profile. The following is an example of the G2 well, which is a five-stage, six-section injection well with low subdivision potential. From the well's suction profile, there is a high permeability layer in the partial 3 and partial 4 sections. The analysis suggests that there is a strong suction unit within the thick oil layer, with prominent intra-layer conflicts, and the next step is to implement a dissection of the well.

Comparison before and after dissection, the degree of oil formation mobilization was improved. A total of 9 wells were dissected and 35 oil recovery wells were connected, with good adjustment results, stable daily oil production and a 0.33% decrease in water content.

3. Plugging of high water-bearing oil wells to control ineffective recovery

For wells with high water content and large inter-stratigraphic (intra-stratigraphic) water content differences, water plugging measures are applied to change the direction of fluid flow and control inefficient and ineffective recovery. The following is an example of G3. From its fluid production profile, the well has a high fluid production and high water-bearing formation section, and its connecting water well absorbs a large proportion of water in this section, so water plugging is applied to the well. In comparison before and after plugging, the daily oil production of the well group was stable and the water content decreased by 0.81%.

7. Results obtained

Through the above combined adjustments.
(1) The annual rate of rise in water content was controlled, falling from 0.63% to 0.45%.
(2) Oil formation mobilization status improved, with the proportion of sandstone mobilization increasing from 33.82% to 34.66%.
(3) The formation pressure recovered, rising from 9.11Mpa to 9.12Mpa, and the formation pressure basically remained stable.
(4) The injection and extraction rate were slowed down, with the injection rate dropping from 20.3 to 16.2 and the extraction rate dropping from 14.8 to 11.6

8. A few points of awareness

(1) The water injection is unstable in the small well spacing area, through encrypting the measurement and adjustment, and determining a reasonable measurement and adjustment period, it can control the single-layer sudden advancement and improve the oil formation dynamic situation
(2) Small well spacing areas with large shot thickness and long well sections, multiple measures are an effective means to increase the degree of oil formation utilization
(3) Synchronized adjustment at both ends of the injection and extraction, targeted regulatory measures to control the rate of injection and extraction, is the premise of slowing down the rate of rise of water content.

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