Adjustment of infill in transition zone to improve oilfield productivity

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Abstract. Affected by the high viscosity of crude oil, the large injection-production well spacing, the poor injection condition, and the low oil recovery rate, the overall development effect of transition zone is poor, besides, the low produced degree and the poor utilization of thin oil layer makes transition zone have some potential excavation. Under the condition that the current conventional measures to improve block development are not clear, it is necessary to further optimize the injection-production system. Based on the principle of "Well pattern rules, Well spacing optimization, Injection-production perfecting, Facilitation of adjustment", layer combination is thus optimized. This paper analyzes the effect of encryption adjustment and tracking adjustment.

Keywords: Transition zone; produced degree; encryption adjustment.

1. Introduction

The transition zone was put into development in 1971 and is currently divided into four sets of strata well pattern mining. The basic well pattern develops the main reservoir the first to the third strips which adopts 300m four-point well pattern; 250m inclined linear well pattern was used in exploitation of C Oil Layer in the fourth stripes which adopts in 1989. The area well pattern of 173m four-point method was used to encrypt and adjust the first to the second strip C and P oil layers in 1996. The well pattern of 250×250m five-point method was used to develop polymer in P formation in 2000, a series of strata complementary tests were carried out in the first to the second strip in 2010. With the method of filling holes corresponding to the encryption well and the foundation well, reducing well spacing to improve injection-production relationship of narrow sand body, improving the degree of water flooding control and multi-directional connectivity ratio, development effect of water flooding in transition zone is improved.With the continuous development of oil fields, the effect gradually decreases. Because the third and fourth zones are affected by factors such as high crude oil viscosity, large injection-production well spacing, poor injection condition and low oil recovery rate, the overall development effect is poor. The third and fourth zones have low recovery degree, poor production degree of thin and poor reservoirs, and there is a certain potential tapping space. Facing the current situation that conventional measures are not obvious to improve block development, it is necessary to further optimize the injection-production system.Based on the general principle of "well pattern rules, well spacing optimization, perfect injection-production and favorable adjustment", optimize the combination of strata series, reduce the well spacing of high viscosity reservoirs and maximize the recovery factor. In the third and fourth zones, new wells were drilled between rows of old wells and between wells, and the old wells were transferred to injection, forming a regular 150m five-point area well pattern. A total of 106 new wells (69 oil production wells and 37 water injection wells) were drilled, and 23 wells were transferred to injection. According to the numerical simulation results, combined with the current exploitation situation of old wells, the waterflooding development index after encryption adjustment is predicted. It is predicted that the recovery ratio of water flooding will increase by 3.08 percentage points, the geological reserves of the adjustment area will be 389.41×10^4t, and the recoverable reserves will increase by 11.99×10^4t.

2. Main problems in the development of transition zone

The third and forth stripes in the eastern transition zone of S Development Zone were put into development in 1971. The third stripes were mined by four-point method with 300m well spacing, and the fourth stripes were mined by oblique linear well pattern with 250m well spacing. At present, it has entered the stage of extra high containing water and the comprehensive containing water is as high as 96.0%[1]. Due to the high viscosity of crude oil and low well pattern density, the problems of low water flooding control, poor injection-production condition and

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low recovery degree are mainly manifested in the following three aspects:

Table 1. Single well production classification table of the third and fourth stripes.

Stripes	classification	Wells proportion	daily liquid production	daily oil production	water content ratio	flow pressure	submergence depth
the third stripes	<1	70.6	13.6	0.5	96.33	5.76	450
	2~3	29.4	75.5	2.6	96.60	5.41	444
	total	100.0	31.8	1.1	96.52	5.64	448
the fourth stripes	<1	80.0	7.1	0.3	95.62	3.87	193
	1~2	10.0	50.5	1.7	96.70	5.82	474
	2~3	10.0	63.2	2.2	96.50	5.08	345
	total	100.0	17.0	0.6	96.27	4.40	265
the third and the fourth stripes	<1	74.1	11.0	0.4	96.15	5.18	364
	1~2	3.7	50.5	1.7	96.70	5.82	474
	2~3	22.2	73.4	2.5	96.58	5.36	428
	total	100.0	26.3	0.9	96.46	5.27	390

Firstly is high viscosity of crude oil, large injection-production well spacing, poor water injection. In the eastern transition zone, the viscosity of underground crude oil in the third stripes is 20.9mPa.s, and the viscosity of ground crude oil in the fourth stripes is 40.7mPa.s, which is 32.6mPa.s higher than that in the pure oil zone. The third and fourth stripes are mined by well pattern with 250~300m well spacing. Affected by the high viscosity of crude oil and the large injection-production well spacing, the starting pressure of the reservoir is relatively high. At present, the starting pressure of the third and fourth stripes is 12.5MPa and 13.4MPa respectively, which results in the non-water absorption ratio of the third and the fourth stripes reaching 43.5%.

Secondly is the low well pattern density, the low degree of water flooding control. A set of strata development is deployed in the third and fourth stripes of the eastern transition zone. The third stripes are mined by four-point method with 300m well spacing, and the fourth stripes are mined by oblique linear well pattern with 250m well spacing. The well pattern density is only 14.3 per km^2, which is 26.3 per km^2 and 31.2 per km^2 lower than the pure oil area and the first and second strips respectively.

The degree of water flooding control and the proportion of multi-directional connectivity are low. The degree of water flooding control is 75.8%, 10.6 percentage points lower than that of the first and second strips, 18.2 percentage points lower than the pure oil area, while the proportion of multi-directional connectivity is 18.3%, 18.4 percentage points lower than the first and second strips, and 42.3 percentage points lower than that of the pure oil area. It is necessary to further adjust the well pattern to improve the degree of water flooding control and the development effect of the block.

Thirdly is low single well production, high containing water, high and uneven flow pressure level. The average daily liquid production of single well in the third and fourth stripes of the eastern transition zone is 26.3t, the daily oil production is 0.9t, and the comprehensive containing water is 96.46%, of which the proportion of oil wells with daily oil production less than 1.0t accounts for 74.1%. Among the third stripes, the average daily liquid production of single well is 31.8t, daily oil production is 1.1t, and the comprehensive containing water is 96.52%. The fourth stripes' average daily liquid production is 17.0t, daily oil production is 0.6t, comprehensive containing water is 96.27%. The flow pressure level of the third and the fourth stripes reaches 5.27MPa, of which the proportion of wells above 5MPa reaches 50%. The flow pressure level of the third stripes is 5.64MPa, while more than 5MPa wells accounted for 57.1%, the flow pressure level of the third stripes is l4.4MPa, while more than 5MPa wells accounted for 33.3%. The pressure imbalance between strips and wells is serious[2].

In conclusion, the overall development effect of the third and the fourth stripes of the transition zone is poor due to the high crude oil viscosity, large injection-production well spacing and poor injection-production conditions. Besides the adjustment of conventional water flooding is difficult. It is necessary to further optimize the injection-production system[3].

3. Potential for well pattern adjustment of the third and the fourth stripes

First and foremost, flooding data show that the thin and poor layers are less flooded. From the interpretation results of the new well flooded layer drilled in 2015 in the weak alkali ternary test area of the second type oil layer in the eastern transition zone, all the water has been seen, and the proportion of water flooded thickness reaches 99.28%, among which the proportion of low unflooded thickness is 7.63%, and the proportion of medium water flooded thickness is 40.94%. which means there is a certain adjustment potential. According to the flooding condition of different thickness oil layers, the effective thickness more than 1.0m oil layer has higher flooding degree, the ratio of low unflooded thickness is 2.73%, and the ratio of medium flooding thickness is 35.59%. The water-flooded degree of layer with effective thickness less than 1.0m is low, and the proportion of low unflooded thickness is 28.30%, and the proportion of medium water flooded thickness is 63.55%. From the different reservoir groups, the degree of flooding in the first group is relatively low, the ratio of low and no water flooded is 29.36%, the ratio of medium flooding is 60.61%, the degree of flooding in the CII and CIII groups is relatively high, the ratio of low unflooded is 4.83%, the ratio of medium flooding is 38.75%.

Secondly, numerical simulation results show that, recovery of the third and the fourth stripes is low, the total recovery is 28.0%, while recovery of CII is 31.1%, correspondingly higher. The remaining geological reserves still account for 69.7% of the total remaining geological reserves, which is the main potential tapping object[4].

4. Changes of indicators after layer adjustment

The third and the fourth stripes is poor due to the high viscosity of crude oil, the large injection-production well spacing, the poor injection condition, and the low oil production rate. At the same time, the recovery degree of the third and the fourth stripes is low, and the utilization degree of thin and poor reservoirs is poor, so there is a certain potential space. Faced with the current situation that the conventional measures to improve block development are not obvious, it is necessary to further optimize the injection-production system[5].

Based on the overall principle of "Well pattern rules, Well spacing optimization, Injection-production perfecting, Facilitation of adjustment", layer system is well optimized. The final adjustment scheme is that a regular well pattern of 150m five-point method area is formed by the combination of new drilling among the old rows， new wells， old wells and old diversion wells in the third and the fourth stripes. A total of 106 new drilling wells(69 production wells and 37 injection wells) and 23 diversion wells are implemented.

After encryption adjustment, the adjustment well area achieves the following effects:

First of all, the degree of water flooding control has been significantly improved. Water drive control degree of the third and the fourth stripes increased from 75.8% to 96.2%, and the multi-directional connectivity ratio increased from 18.3% to 66.8%, which increased respectively by 20.4 and 48.5 percentage points. Numerical simulation predicted that water flooding recovery increased from 32.74% to 35.82%, which increased by 3.08 percentage, while predicted recoverable reserves increased 11.99×10^4t[6].

Secondly, the water injection condition is improved significantly. At present, the daily water injection rate in the north of Eastern transition zone reaches 5184m3, of which the daily water injection rate in the third and the fourth stripes reaches 1468m3, which is 1050m3 higher than that before adjustment. The proportion of non-suction wells decreases from 43.5% to 19.6%, which is 23.9 percentage lower. The injection pressure of single well also decreases from 12.6MPa to 12.0MPa, which is 0.6MPa lower than that before adjustment.

Thirdly, both single well production and oil recovery rate increases. At present, the daily liquid production in the north of Eastern transition zone reaches 31.5t and daily oil production is 1.2t, which is 5.2t and 0.3t higher than those before adjustment respectively, and the water content ratio decreases by 0.23 percentage. Among them, the third and the fourth stripes' old wells increase oil by 0.1t and water content ratio decreases by 0.3%. From the point of view of production classification, the proportion of less than 1t decreased from 74.1% to 66.7%, which decrease by 7.4 percentage, and the proportion of 1 to 2t increased by 9.6 percentage.

Fourthly, the flow pressure level is well controlled and the distribution is more balanced. After the strata adjustment, the flow pressure levels of the third and the fourth stripes decreased from 5.27MPa to 4.33MPa. Among them, the flow pressure of the old wells in the third and the fourth stripes decreased from 5.27MPa to 4.32MPa which decreased by 1.04MPa. From the point of view of the strip, the flow pressure of the third stripes decreased from 5.64MPa to 4.49MPa, and the flow pressure of the fourth stripes decreased from 4.40MPa to 4.12MPa, indicating that the pressure difference between the strips is reduced. From the classification of single well flow pressure, the proportion of wells in the reasonable well area between 3~5MPa increased from 50% to 76.9%, which increased by 26.9%. The pressure difference between wells is gradually reduced, and the pressure distribution is more balanced.

5. Complementary tracking adjustment after hierarchy adjustment

In the first place, the adjustment of water injection wells in the adjustment area. A total of 32 wells were adjusted for the water injection well, the water injection volume increased by 88m3, the single well of the surrounding 53 wells increased by 0.11t, and the water content ratio decreased by 0.12 percent. Among them, 20 wells were subdivided, 37 layers were increased after adjustment, the daily water injection rate increased by 121m^3, and the single well oil production of 42 wells increased by 0.13t, and the water content ratio decreased by 0.14 percentage. In addition, four old wells were matched by the new-old water injection relationship, and the water injection in the old direction was controlled to 76m^3. The 11 production wells around increased oil by 0.05t individually, and the water content ratio decreased by 0.07 percentage.

The second is to take out methods to improve oil and water wells. In order to ensure inject smoothly, Acidizing was carried out in 15 wells when putting into production. In addition, in order to ensure enough water injection, 16 wells around were taken measures, including 2 old well acidified, 1 old well and 8 new wells fractured, which correspondingly adding daily injection to 28m3, 183m3 and 230m3.The average daily oil increment per well is 0.15t, and the water content ratio decreases by 0.18 percentage. When the new wells were put into production, 9 wells were fractured by limiting flow method. In addition, 24 wells' production parameters are reasonably adjusted, and 4 wells' pump setting depth are deepened for low submergence wells.

Third, through the above work, the oil production of new well increased from the initial 27t to the current 34.6t. water content decreased from 97.18% to 96.05%, with a decrease of 1.13 percentage points. The oil well opening rate has always remained above 90%.

6. Conclusion

First, physical properties of crude oil in transition zone is poor and the potential tapping effect of conventional measures is not ideal, reasonable well pattern adjustment can better improve the development effect of transition zone.

Second, timely subdivision adjustment and matching of old and new wells are needed to effectively slow down the rising rate of water content ratio in the area of strata adjustment.

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