The comprehensive application of test data in the test area of lamadian oilfield

Yanbo Quan
Interpretation and Evaluation Center on Monitored Information of Daqing Logging & Testing Services Company. China
2296795605@qq.com

Abstract. In order to improve the oil production of the buffer area in Lamadian oilfield, slow down the decline rate of oil production and explore effective methods for a gas cap oilfield development, a test of injecting polymer in buffer area was carried out in the gas cap oilfield of south Sa Ⅱ 2 + 3 for the technical reserves of gas cap development and buffer area development in Lamadian oilfield. As this block is the key test area in an oil production plant, the comprehensive application of the test data provided a strong technical support for adjusting the injection production measures of the wells and improving the development effect of the test area.

1. Introduction
Lamadian Oilfield is a layered sandstone gas cap oilfield controlled by its structure. The gas cap reservoir is mainly distributed in 17 layers of Sa I ~ Sa Ⅲ 4-7, and its geological reserves is 99.59 × 10⁸ m³. Each layer has its own independent oil and gas boundary due to its structure. In the early stage of development, a 450m ~ 600m buffer strip for preventing hydrocarbon migration was reserved outside the hydrocarbon boundary. Figure 1 is a structure chart of the test area with polymer injection barrier. In order to improve the oil production of the buffer area in Lamadian oilfield, explore the effective methods for a gas cap oilfield development, a test of injecting polymer in buffer area was carried out in the gas cap oilfield of south Sa Ⅱ 2 + 3 for the technical reserves of gas cap development and buffer area development in Lamadian oilfield. The idea of the test was to drill a row of wells nearby the hydrocarbon boundary of gas cap oilfield and the oil and gas areas were separated by a barrier which was formed by injecting polymer into wells. The buffer area was directly developed with polymer flooding, and the gas area was not mined. The block is located in the structural axis of the south oilfield and is composed of three parts including the gas area, the buffer area and the three rows of old oil area with perforations. The target layer of the test was Sa Ⅱ 2 + 3 oil layer and the geological reserves of the buffer area was 179.8 × 10⁴ t. The total number of wells in the test area was 168, including 81 injection wells and 87 producing wells. After the polymer barrier wells injecting the polymer in the test area, the oil and gas layers could be separated to make the oil in the buffer area flow smoothly [1]. Wang Hua [2] studied the geological characteristics and development techniques for the oil and gas buffer area of the gas cap in south Lamadian oilfield. Fan Wen ke [3] analyzed the practice and understanding of the development of buffer area with polymer injection for the gas cap in Lamadian oilfield. These studies provide a strong technical support for the development of the buffer area with polymer barrier wells. But in the process of development, it is also needed to study the
comprehensive maintenance technology of polymer barrier in the test area, ensure the sealing and stability of polymer barrier, analyze the pressure distribution and injection-production status, adjust the production parameters of the production wells and control the balance of pressure system in the test area.

![Figure 1. Structure of polymer injection barrier in test area](image1)

2. Sealing evaluation of polymer barrier strip

After the polymer barrier was formed, according to the monitored polymer barrier morphology and the distribution of its leading edge, a maintaining method of polymer barrier that injecting the barrier with two batches was established. The strength of the barrier at the equilibrium point between adjacent barrier wells was enhanced, and the extension of the barrier to the gas cap area and buffer area was reduced. In the process of forming the barrier, part of the gas cap gas in the oil and gas transition area was separated from the barrier strip because the barrier wells were located in the gas cap.

![Figure 2. Test report on pressure wells](image2) ![Figure 3. Curve of gas production and gas to oil ratio of the first row of oil wells in the buffer area](image3)
Monitoring well A in gas cap area. By monitoring the pressure change of well A and analyzing the stability of gas cap area, Figure 2 shows the continuous pressure change in well A. As can be seen from the chart, the pressure of the A well in the gas cap area is continuously monitored for up to 21 months. With the increase of the time for the polymer barrier, the formation pressure rose. As the gas cap was compressed when the polymer barrier was initially formed, the pressure of the gas cap area increased obviously, and the pressure increased 0.8MPa in 2 months. After entering the maintenance phase in May 2015, the pressure increased 0.5MPa in the first 3 months, with the reduction of the maintenance for the barrier well, the pressure in the gas cap area remained stable and increased 0.5MPa in 8 months. At present, the pressure of the gas cap area is stable at about 7.8MPa, which is in the stable stage, which fully showed the sealing property of the polymer barrier strip. The formation pressure in buffer area was 9.2MPa and the formation pressure in old oil area was 10.8MPa. The pressure in the three zones was relatively stable, indicating that the gas cap area and the buffer area have been separated into two independent pressure systems. The pressure change during normal production of the buffer area did not affect the pressure of the gas cap area. According to the data above, the oil and gas can be separated by injecting polymer barrier nearby the oil and gas interface, in the case of gas temporarily not being mined, the buffer area can be injected and developed normally without oil and gas migration.

In order to further verify the accuracy of the test pressure data, the gas production and gas-oil ratio out of the gas cap area were counted, as shown in Figure 3. In the early stage of production, the average single well gas production rate reached 429m³, and the production gas was mainly the gas separated by the polymer barrier.

With the extension of production time, the daily gas production reduced gradually. After 3 months of production, the average daily production of single well reduced down to 381m³. At present, the average single well daily gas production is 283m³. The gas production tends to be stable. By observing the oil and gas ratio change of the producing wells at the first row, the oil and gas ratio was not high but was stable, the current average single well oil and gas ratio was 34m³/t.

The analysis above shows that after the oil wells in buffer area putting into production, the amount of gas separated by polymer barrier outside the barrier strip decreases, and the gas in the strip does not pass through the polymer barrier to the buffer area outside the strip and the polymer barrier strip is closed. Through a comprehensive analysis of the test data, the pressure of the test data can be used to accurately determine the sealing of the barrier strips.

3. The main contradiction in the development experimental zones

Using the test data, comprehensively analyze the change of the water absorption capacity in the buffer area, the influence of the interlayer difference on the production and the development status of the wells.

3.1. Analysis of water absorption capacity at the producing position

After the injection of the polymer in the test area, the water absorption capacity of each layer was determined by isotope measurement. Statistics of isotope water injection profile of 45 wells, there were 12 wells of the Sa II2 + 3 layer unabsorbed water in the upper half, and the ratio for the wells without water absorbed capacity was nearly 30%. In order to confirm the reason why these parts do not absorb water, the geological department analyzed the connectivity of the oil layer.

The results show that the connectivity of oil wells and water wells were good, and there was no possibility for not absorbing water due to the poor connectivity of oil layer. Furthermore, the permeability of these parts which could not absorb water was quiet high which was caused by slush entering these parts during the drilling process [4-5].

Further statistics on the well test data for the 45 wells in the buffer area indicated that there were 10 wells whose skin coefficients were greater than zero, accounting for 22.2% of the wells, the value of the average skin factor S was up to 9.24, which was mainly the injection wells with unusual water
absorption capacity shown on the water absorption profile. And this further indicated that the formation contamination of some wells in the test area was quite serious.

3.2. Some injection wells have high permeability and inefficient circulation strip in the buffer area
Analysis of the well test data showed that the double logarithmic well pattern of 45 wells in the block reflected two reservoir characteristics [6-7], one was the typical double-seepage reservoir characteristics, there were 12 wells; the other was a clear homogeneous reservoir characteristic, there were 33 wells.

The double logarithmic well pattern indicated that there was a high permeability zone in this part of the wells, and the permeability difference was large and the contradiction in the layers was prominent. The homogeneous reservoir characteristic curve shows that the water absorption capacity was quiet uniform in this part of the well, there was no strong water absorption site, or there was a strong single layer of the phenomenon, the injected water only entered the high permeability zone, low permeability deposition unit did not absorb water.

The PI (90) data of the 45 wells above were recorded with an average value of 7.6 MPa.(PI (90) value reflects the pressure drop velocity after injection wells were closed, the better the formation seepage characteristics is, the stronger the water absorption capacity is, the smaller the PI value is; or PI value is large) The PI index of 15 wells in 45 wells was lower than the average value of 7.6MPa, accounting for 33.3% of the total number of wells, indicating that this part of the injection wells had a strong water absorption zone with high permeability, the contradiction within the layer was prominent.

3.3. Abnormal of well pressure curve, reflect low formation pressures in some well groups
During the interpretation of oil well pressure data in the test area, some liquid recovery wells appeared to rise at the beginning and then fall, and even the flow pressure was higher than the static pressure. For this anomaly, in order to ensure the accuracy of the data, we selected five typical wells which had significant fluid level fluctuation to retest, and proved that the test equipment was reliable.

Table 1 shows the depth changes of the five wells. It can be seen from Table 1 that these five well all had an phenomenon that, in the short time after the closure of the wells, the liquid surface rose and then fell until the end, the fluid level of well 5 which had the largest fluid level drawdown declined 540m after the closure of the wells, and the pressure declined from 0.923 to 5.886MPa. Reflecting it on the pressure curve, the pressure rose and drop suddenly at the beginning, after the well was shut down for 11.3 hours, the pressure rose to 10.1MPa, and latterly there was a downward tendency, when the well was shut down for 71.3 hours, pressure declined down to 7.53MPa. We analyzed that the underground deficit was serious, and had no energy to supply and resulted in serious degassing in the well.

| Well | Turn off time (h) | Initial level (m) | Final level (m) | Liquid level drop (m) | Flow pressure (MPa) | Terminal pressure (MPa) |
|------|------------------|------------------|----------------|----------------------|--------------------|------------------------|
| J1   | 68.7             | 600              | 993            | 393                  | 6.86               | 7.58                   |
| J2   | 68.7             | 309              | 662            | 353                  | 7.2                | 8.26                   |
| J3   | 68.7             | 326              | 584            | 258                  | 5.29               | 7.66                   |
| J4   | 68.7             | 319              | 702            | 383                  | 8.04               | 9.43                   |
| J5   | 71.3             | 313              | 853            | 540                  | 7.82               | 7.53                   |

4. Adjustment of injection and production wells in buffer area
In the first half year of 2016, according the formation contaminant shown by the test data, the existence of high permeability and inefficient circulation strip and the contradiction of low formation pressure in some well groups, the geological department had an adjustment in time
4.1. Injection well acidification to solve plugging
The 12 injection wells with abnormal water absorption were selected for acidizing treatment. After the treatment, the thickness of the formation which did not absorb water decreased from 10.5m to 1.1m, the skin factor decreased from 5.65 to -0.37; deep profile control measures were carried out for 15 wells, and the relative water absorption of the main water absorbing unit of high permeability decreased from 55% to 23% after the treatment. At the same time, in order to restore the formation pressure of the well group, the 40 injection wells have been carried out with super water injection scheme. Figure 4 shows the double logarithmic fit curve of the E-well before and after acidification. The test data PI (90) was 8.01 and the skin coefficient was 5.211, indicating that there was contaminant near by the well bore. Figure 4 shows that, before the acidification, the pressure derivative curve hump was high which meant that the formation contaminant was serious; the pressure derivative curve hump position after acidification slowed, and the skin coefficient was -4.72, which reflected that the acidizing effect was good, the degree of pollution had been improved.

![Figure 4. Double logarithmic fit analysis chart before and after measures](image)

4.2. Improvement of oil well fracturing
For the production wells with low liquid production, low water content and poor reservoir property, choosing the mid-low permeability area which have better connectivity with surrounding injection wells to fracture to improve oil production, there were 10 wells designed, and there were 8 wells had been operated. F was a fractured well, this well was fractured in July 2016. Before fracturing, the production was 13.8t/d, the water content was 54.8%, the formation pressure was 8.43MPa; after fracturing, the production was 52.0t/d, the water content was 73.9% and the formation pressure was 9.25MPa. It can be analyzed from the double logarithmic curve of the well that after fracturing, there were cracks at the bottom of the wells, the pressure curve and the derivative curve did not coincide in the early stage, it can be seen that the fracturing received good results.

5. Conclusions and recommendations
(1) By monitoring the pressure in the three areas including the gas-cap area, the buffer area and the old oil area, it is helpful for the geological department to analyze the pressure distribution and injection and production conditions in the test area, adjust the production parameters of the production wells in the test area and control the balance of pressure system.

(2) By comprehensively analyzing the test data, understand the development contradiction of the test area, adjusting the measures with targeted purpose.

(3) Aiming at the production of the first row of well outside the gas cap, we can reasonably arrange the test, reduce the impact on the stability of the polymer barrier, determine the reasonable production parameters of the first row of oil wells under the stable condition of in the barrier strip, ensure the closure and stability of the polymer barrier in the buffer development.

(4) According to the monitoring data of pressure and gas production, we analyzed the sealing and stability of polymer barrier strips, determined the reasonable timing and injection quantity for the maintenance of the polymer barrier wells in the middle and later stage of the buffer development.
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