Research and Discussion on Increasing the Coincidence Rate of Water Injection Scheme

Liwei Gong
Geological Brigade of the Ninth Oil Production Plant of Daqing Oilfield Co., Ltd., 163853, China
gongliwei@petrochina.com.cn

Abstract. "Enough water injection, good water injection and effective water injection" is the foundation of water flooding to develop oil fields, and whether the water injection scheme is reasonable and effective is an important symbol of effective water injection. Affected by complex reservoir types and geological conditions, the coincidence rate of water injection schemes in some oilfields is low. In this paper, based on effective water injection, guided by the problems existing in the development of various oilfields, the overall adjustment idea is formulated, and then the injection-production status of single well, single layer and single sand body is analyzed accurately and carefully by comprehensive application of dynamic and static data, so as to implement accurate water distribution. At the same time, cooperate closely with production and management units to ensure timely discovery, adjustment and tracking of problem wells, and strengthen the work of each node, so as to improve the compliance rate of water injection scheme, realize effective water injection in oilfield and improve oilfield development effect.

Keywords: Water injection scheme, precise water distribution, effective water injection.

1. Introduction
A factory develops 16 oilfields /2 blocks by water injection. The reservoir types and geological conditions are complex, which can be divided into medium permeability and high water cut oilfields, fractured oilfields, scattered sand bodies oilfields, poor physical properties oilfields and horizontal well scale application areas according to reservoir characteristics. Different oilfields, different types of reservoirs and sand bodies of different scales have different contradictions, so should the corresponding water injection policies and water injection intensity. In previous years, due to the influence of sand body recognition, the coincidence rate of water injection schemes in some oilfields/blocks such as XZ, LN and L26 was low [1].

For this reason, in recent years, a factory based on effective water injection, guided by the problems existing in the development of various oilfields, formulated the overall adjustment ideas, and then comprehensively applied the dynamic and static data to accurately and carefully analyze the injection-production status of single well, single layer and single sand body, and implemented accurate water distribution. At the same time, cooperate closely with the operation area and management room to ensure timely discovery, adjustment and tracking of problem wells, and strengthen the work of each node, so
as to improve the compliance rate of water injection scheme, realize effective water injection in oilfield and improve oilfield development effect.

2. Macro law of oilfield development

On the basis of determining the development characteristics of different oilfields, this paper further clarifies the current development stage of different oilfields, the main contradictions and development adjustment countermeasures.

**Table 1. The development contradictions and adjustment countermeasures of different types of oilfields in a factory**

| Type                          | Oilfield/block (number) | Oil-bearing area (km²) | Geological reserves (10⁴t) | Principal contradiction                                                                 | Adjustment countermeasures                                                                 |
|-------------------------------|------------------------|------------------------|---------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| Medium permeability and high water cut oilfield | 5 | 76.53 | 3504.17 | The utilization degree of the two types of strata is close | High injection and low production layer, reasonable optimization |
| Fractured oilfield            | 2 | 192.27 | 4280.91 | Local fracture development, Poor production of thin and poor reservoirs | Various forms of periodic water injection, Control inefficient and ineffective cycle |
| Sand body scattered oil field | 4 | 78.74 | 1749.14 | Scattered sand, Big difference in usage | According to the sand water injection, improve production |
| Oilfield with poor physical properties | 3 | 66.17 | 1458.89 | Poor water absorption, Low efficiency of oil wells | Treatment of under-injection and contact according to sand body, Relational water injection |
| Horizontal well area          | 3 | 75.35 | 1084.64 | Water control and liquid retention after water breakthrough, Coordination is difficult | Periodic water injection in old district, Reduce injection allocation and adjust ahead of time in the new district |

Medium permeability and high water cut oilfield: in view of the fact that the production degree of the two types of reservoirs is similar, and the remaining oil is scattered and mainly concentrated in the parts with poor water drive, the main reservoirs carry out various forms of periodic water injection to control inefficient and ineffective circulation. Subdivision and reorganization of non-main layers are combined with oil well fracturing to promote effective production.

Fractured oilfield: Based on the quantitative description of fractures, finding out the distribution of remaining oil, carrying out irregular infilling and flexible injection transfer, and effectively tapping the remaining oil on both sides of fractures, classified treatment is implemented according to the injection status of well layers, and the injection allocation is reasonably optimized for high injection and low production well layers to reduce ineffective water injection. For the main low-efficiency water injection layer, if the remaining oil is concentrated in the drainage area of oil wells and the reservoir deterioration area, and is scattered, periodic water injection shall be carried out among drainage areas, inter-wells and intervals respectively. For non-main thin and poor reservoirs, measures such as subdivision of single
card, profile control and plugging of high permeability reservoirs are implemented to strengthen water injection.

Oil field with scattered sand bodies: In view of the fact that the sand bodies are scattered and small in scale, and there are great differences in the utilization of sand bodies of different scales, we insist on strengthening the adjustment of injection-production system, increasing production and injection, implementing accurate water injection according to sand bodies, and promoting the balanced utilization of each sand body. That is to say, the single sand body is taken as the adjustment unit, and the water injection intensity is reasonably optimized according to the macro injection-production ratio determined by numerical simulation and the scale of sand body.

Oilfield with poor physical properties: in view of the fact that the reservoir has poor physical properties, it is difficult to establish effective displacement, low formation pressure maintenance level and poor oil well efficiency. On the basis of classified treatment of water injection wells, guided by reasonable injection-production ratio, the water injection intensity is optimized according to the contact relationship of sand bodies according to the characteristics of rapid change of facies belts in the plane of sand bodies.

In the horizontal well area, it is difficult to coordinate water control and liquid conservation after water breakthrough in old oil wells. In order to adjust water injection, periodic water injection is implemented in a "quantitative and flexible" way to expand the swept volume of water injection [2]. In view of the fact that the effective thickness, reservoir physical properties and drilling rate of oil-bearing sandstone in the new area are obviously lower than those in the old area, in order to improve the initial productivity of single well and the fracturing scale is large at the initial stage, mild water injection is adopted at the initial stage, the injection allocation intensity is appropriately reduced, water breakthrough is prevented, and the advance adjustment is intensified at the same time.

3. Accurate water distribution of various wells
On the basis of macro-control, in order to make the adjustment targeted, each type of oilfield is divided into several types of well layers, and the injection-production status of single well, single layer and single sand body is analyzed accurately and carefully by comprehensive application of dynamic and static data. According to parameters such as physical property, thickness, scale, output and water cut of single sand body, water injection intensity is reasonably optimized to realize accurate water distribution.

Taking the oil field with scattered sand bodies as an example, the precise water distribution of various well layers is described in detail.

3.1. Multilayered and multidirectional aquifer
When the water cut is about 85%, the water cut of corresponding wells will decrease, but the liquid supply capacity will also decrease, so it is difficult to coordinate the water cut of liquid supply. According to the results of numerical simulation and previous adjustment experience, cyclic water injection is implemented.

Using numerical simulation and field practice, the reasonable injection production ratio of scattered sand body oilfield is determined to be 1.8, and then the injection production ratio is determined to be 1.6 when the water cut of multi-layer and multi direction water breakthrough layer is about 85%. According to the reasonable injection-production ratio and the sand body shape, the water injection intensity and cycle are optimized. The water injection intensity of river sand is 1.0m³/m, and the water injection cycle is 2 months after injection and 4 months after shutdown. The water injection intensity of the main sheet sand is 1.4m³/m, and the water injection cycle is 4 months after injection and 4 months after shutdown. The water injection intensity of non-main sheet sand is 1.8m³/m, and the water injection cycle is 6 months after injection and 4 months after shutdown.

3.2. Water layer after effect
The water layer is seen after the effect. After the effect of the oil well, the single-direction water injection front breaks through and the water cut of the oil well rises, which shows that the oil well is affected first
and then the water cut continues to rise. The adjustment countermeasures are to stop injection periodically in water breakthrough direction, strengthen water injection in water breakthrough direction, balance the pressure field between water breakthrough directions, and promote the multi-directional effect of oil wells.

Firstly, the water breakthrough direction is judged by using the dynamic and static data of oil and water wells. After water breakthrough in the oil well, look at the structural diagram of chloride ion binding block to judge whether formation water or injected water is seen. After seeing the injected water, look at the sedimentary facies belt map or sand body map of the oil well, determine the reservoir physical properties of each layer, and determine the main production layers in combination with logging curves and oil well production data. According to the connectivity relationship, determine the connectivity with the main producing layers, and see how the corresponding water injection wells inject water. According to isotope data of water injection wells, cumulative water injection rate and cumulative water injection intensity of single layer, water breakthrough layer and water breakthrough direction are determined. In water injection adjustment, stop injection of this layer, but resume water injection when water cut drops, determine the adjustment period, and then make periodic adjustment. Strengthen water injection in other directions without water, balance the pressure field in the direction without water, promote efficiency in new directions, and reduce production loss of oil wells due to water breakthrough.

3.3. No water layer is found after effect

There is no water layer after the effect, and this kind of well layer has obvious effect trend, that is, the liquid volume and liquid level rise or keep at a stable level continuously, without decreasing trend. The adjustment countermeasure is to advance adjustment and prolong the low water cut harvesting period of oil wells.

To determine the timing of advance adjustment, calculate the water drive front of each affected layer according to the calculation method of water drive front, and make advance adjustment in combination with the water drive front of water layer after effect. In the calculation of water drive front, because of the strong heterogeneity of oilfield reservoir, the influencing factors of reservoir physical properties are considered. Taking the water well as the center, divide the accumulated water injection quantity of the water well into the direction of the oil well, and obtain the water injection quantity of the water well corresponding to each direction. At the same time, taking the oil well as the center, the water yield of the oil production well is divided into the directions of each connected water well, and the water yield of the oil well corresponding to each water well direction is obtained [3].

$$Q = \sum_{i=1}^{n} \frac{SP_i h_i}{\sum_{j=1}^{n} SP_j h_j} Q_w = \frac{Q_t}{\sum_{j=1}^{n} Q_i} q_{wi}$$

Where:

- $Q_i$ — Single layer and single direction water injection
- $Q_t$ — Single layer water injection volume of well
- $q_w$ — Oil well single layer water production
- $q_{wi}$ — Oil well single layer and single direction water production
- $SP_i$ — Natural potential value
- $h_i$ — Well shot thickness
- $n$ — Number of connected wells

Calculation of flooded radius by volume method

$$r_w = \sqrt{\frac{(Q_t - q_{wi})^* n}{\eta * \pi h^2 (1 - S_{wi})}}$$

Based on the calculation of the affected well layers and the water flooding front after water breakthrough, it is determined that the average distance between the water injection front and the oil well is 90m when water breakthrough occurs in scattered sand oil fields after effect. Therefore, in order
to prevent premature water breakthrough in the affected direction and promote the effect in other directions, for the layer without water after the effect, advance adjustment is implemented about 120m from the water injection front to the oil well, so as to extend the effective period.

3.4. Ineffective layer
Ineffective layer, which is the layer with decreased liquid supply caused by interlayer interference or reservoir heterogeneity. The adjustment countermeasures are to strengthen water injection in such layers according to sand bodies by means of subdivision, profile control, etc., and to improve oil well fracturing efficiency at appropriate time.

In water injection adjustment, water is allocated according to sand body scale, that is, the ineffective layers are classified according to water cut, and optimized according to the reasonable injection-production ratio at different water cut stages in combination with sand body scale. The injection allocation strength of small-scale sand body with medium water cut is reduced from 1.5 m$^3$/m to 1.2m$^3$/m, and that of large-scale sand body with low water cut is increased from 1.7m$^3$/m to 2.0m$^3$/m.

4. Timely discovery, timely adjustment and timely tracking
Whether the water injection scheme is effective or not depends on whether the wells with changed water cut for liquid supply are found in time and adjusted in time, which requires close cooperation among the operation area, management room and development room.

In order to adjust the scheme in time and minimize the impact on the development block, a three-level early warning system of "changing wells with liquid supply and water cut" has been established between the development room of the geological brigade and the oil production team and technical team in the operation area. Grade I: if it is found that the fluctuation range of daily fluid production and produced fluid water content in oil production wells exceeds the latest oil well data acquisition regulations, the workers on duty should immediately report to the technicians of oil production team. Level II: After the technicians of the oil production team have verified the situation, they will report it to the operation area on the same day, and re-verify it with the dynamic management team of the operation area within 48 hours. After confirmation, the influencing factors such as ground and pump condition will be eliminated and reported to the development room of the geological brigade. Grade III: The dynamic management team of the geological brigade shall use the dynamic and static data to find out the cause of the problem and determine the corresponding measures together with the operation area within 3 working days, and issue the water injection adjustment plan.

After the water injection adjustment plan is issued, the periodic water injection shut-in requires the operation area to complete the shut-in within 2 working days, and the test team needs to complete the commissioning within 10 working days. In this process, the technicians of the oil production team in the operation area communicate with the test in time to determine the test time, and the development room and the management room communicate continuously, so that the management room can arrange the test team to debug as soon as possible to ensure timely adjustment.

After the water injection scheme is adjusted, the dynamic management team of the geological brigade tracks the change of water cut in the oil well in time. If the dynamic response period of the corresponding block is adjusted, the oil well remains unchanged. Re-analyze whether there is new direction influence or other ground and pump conditions, and give new measures.

According to the above practices, a total of 1,251 water injection schemes were implemented in 2019, with 1,189 effective wells. The coincidence rate of water injection schemes increased from 90.8% in 2015 to 95.0% in 2019, which slowed down the natural decline of old wells by 0.23 percentage points.

5. Conclusions
The macro adjustment laws of various types of oil fields can effectively guide the water injection adjustment of the entire block.
Comprehensive application of dynamic and static data to accurately and carefully analyze the injection and production conditions of single wells, single layers, and single sand bodies. According to sand body, well layer, classification adjustment, accurate water distribution can be realized.

Timely discovery of water-supply water change wells, timely adjustment and timely tracking are important guarantees for improving the compliance rate of the water injection plan.

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