Transfer Potential and Scheme Optimization of the Central Encryption Well Area of Block A-1

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Abstract. After the encryption adjustment in the central encryption well area of block A-1, the production in the well area is improved, but at the same time, the production decline of old wells in the well area is accelerated, and water injection is not effective in some oil wells. In order to improve the wells development effect, the adjustment of injection-production system in this well area is analysed in detail, three transfer schemes are designed, the feasibility of different schemes is compared and analysed, it is preferred to select scattered transfer as the best transfer scheme.

1. Introduction
The structure of the central encryption well area of block A-1 is located in the yongle syncline. The sedimentary facies are mainly the outlying frontal subfacies of the delta, the objective layer is grape flower oil layer. The average thickness of sandstone is 6.9m, the average porosity is 18.4% and the average permeability is 22.3mD. The well area is developed with 300m×300m inverse nine-spot pattern to develop. Development began in 2002 and the well area development process is divided into three stages: natural depletion, water injection adjustment stage and the encryption phase. By June 2015, there are 24 oil wells in the block, including 21 oil wells, which produced 29.4t of liquid per day and 19.1t of oil per day, with a combined water content of 35.0%. There are 3 water injection wells, and the average single-well daily water injection is 11m³.

2. The Main Contradiction in Block Development
2.1. Production Decline of Old Wells is accelerated and Development Effect becomes worse
In 2012, the well area is adjusted for encryption. There are 13 oil wells before encryption, and the number of oil wells after encryption reached 21. The number of injection wells remained unchanged. Water injection is not effective in some oil wells, and the annual decline rate of production of old wells increase from 7.63% to 12.50% (figure 1).

2.2. The Ratio of Oil and Water Wells is increased and the Water Drive Control Degree Decreases
Before the encryption, there are 13 oil wells, 3 water injection wells, the oil-water well number ratio is 4.3, and the water drive control degree is 77.14%. After the encryption, the oil-water well number ratio increased to 7.0 and the degree of water drive control decreased to 74.43% (table 1).
Figure 1. Production change curve of old wells before and after encryption

Table 1. Statistics of water drive connectivity before and after encryption of block A-1

| Effective thickness (m) | period | One-way connected | Two-way connected | Multidirectional connected | A combined |
|-------------------------|--------|-------------------|-------------------|---------------------------|------------|
|                         |        | sandstone (m)     | effective (m)     | proportion (%)            | sandstone (m) | effective (m) | proportion (%) | sandstone (m) | effective (m) | proportion (%) |
| <1.0                    | before encryption | 38.3 | 15.6 | 36.03 | 9.7 | 4.1 | 9.47 | 0 | 0 | 0 | 48 | 19.7 | 45.5 |
| 1.0~2.0                 |        | 14.2 | 10.1 | 23.33 | 6.8 | 3.6 | 8.31 | 0 | 0 | 0 | 21 | 13.7 | 31.64 |
| ≥2.0                    |        | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| subtotal                |        | 52.5 | 25.7 | 59.35 | 16.5 | 7.7 | 17.78 | 0 | 0 | 0 | 69 | 33.4 | 77.14 |
| <1.0                    | after encryption | 52.3 | 23.7 | 33.66 | 9.7 | 4.1 | 5.82 | 0 | 0 | 0 | 62 | 27.8 | 39.43 |
| 1.0~2.0                 |        | 5.2 | 17.7 | 25.14 | 6.8 | 3.6 | 5.11 | 0 | 0 | 0 | 32 | 21.3 | 30.26 |
| ≥2.0                    |        | 2.5 | 2 | 2.84 | 0 | 0 | 0 | 0.7 | 2 | 2.84 |
| subtotal                |        | 80 | 43.4 | 63.49 | 16.5 | 7.7 | 10.94 | 0 | 0 | 0 | 94.7 | 51.1 | 74.43 |

2.3. Some Oil Wells are not Effective, and the Difficulty of Injection-production Adjustment Increases

Before the encryption of the well area, the water injection pattern is 300m×300m, inverted nine-spot pattern. For most of the well, water injection can be effective, but after the encryption, the well network became irregular, such as well A-1-1-2 and well A-1-1-4, the water injection became ineffective, and the difficulty of injection-production adjustment increased.

Therefore, it is necessary to adjust the injection-production system in this well area in order to improve the proportion of multi-direction water drive, expand the water drive sweep volume, gradually restore the formation pressure, and delay the decline rate of production in old wells.

3. Transfer Potential and Scheme Optimization

3.1. Presentation of the Transfer Scheme

According to the characteristics of geology and development, and combined with the adjustment scheme of transfer well, three kinds of transfer schemes are designed, including determinant transfer, inverse nine-spot transfer and scattered transfer (figure 2).

3.2. Optimization of the Transfer Scheme

3.2.1. Determinant Transfer. In this well area, east-west fractures are developed, and the two wells in the drainage wells are of high water cut. In combination with the actual production situation, the transfer well is combined with high shut-in and inefficient well treatment to achieve the minimum loss of output and to control the comprehensive water-cut rise speed of the oil field. Thus, determinant injection can be carried out.
According to the principle of transfer, 10 oil wells are transferred, which resulted in great loss of output. In combination with the production situation in the well area, two oil wells A-1-3-2 and A-1-3-4 could be prioritized for the transfer well. After the transfer, the water-driven sandstone thickness decreased from 94.7m to 78.1m and decreased by 16.6m, and the water-driven connection ratio decreased from 74.43% to 73.13% and decreased by 1.3 percentage points (table 2). The average daily output of the two transfer wells is 3.2t per day and no oil is produced (table 3).

![Figure 2. Schematic diagram of different transfer modes](image1)

**Table 2.** Basic information of transfer wells with determinants mode

| scheme                | transfer well | production ways | shooting thickness (m) | effective thickness (m) | daily fluid (t) | daily oil (t) | water cut (%) | working fluid level (m) | note |
|-----------------------|---------------|-----------------|------------------------|-------------------------|-----------------|---------------|-----------------|--------------------------|------|
| Determinant transfer  | A-1-3-2       | pumping         | 12.1                   | 6                       | 1.2             | 0             | 98              | 1192                     |      |
|                       | A-1-3-4       | pumping         | 8.4                    | 4.1                     | 2               | 0             | 98              | 1216                     |      |
| subtotal              |               |                 | 20.5                   | 10.1                    | 3.2             | 0             | 100             | 1204                     |      |

**Table 3.** Control degree of water drive after determinant transfer

| Effective thickness (m) | One-way connected | Two-way connected | Multidirectional connected | A combined |
|-------------------------|-------------------|-------------------|-----------------------------|------------|
|                         | sandstone (m)     | effective (%)     | proportion (%)              |           |
| <1.0                    | 30.1              | 14.2              | 23.55                       |           |
| 1.0~2.0                 | 9.6               | 7.4               | 12.27                       |           |
| ≥2.0                    | 2.5               | 2                 | 3.32                        |            |
| subtotal                | 42.2              | 23.6              | 39.14                       |            |

3.2.2. *Inverse Nine-spot Pattern Transfer.* The pre-infill well pattern in the central encryption well area is 300×300m square well pattern, and water is injected in the reverse nine-point pattern. After encryption, according to the encryption scheme, the original pattern angle well is transferred to form a new inverse nine point pattern.

According to the principle of transfer, 4 oil wells are transferred, average daily production of liquid is 8.7t and average daily production of oil is 5.7t. At present, average daily production of liquid of this well area is 29.4t and average daily production of oil is 19.1t, with an average water-cut rate of 35.1% and a loss rate of 29.84% (table 4). After the transfer, the water-driven sandstone thickness increased from 94.7m to 94.8m, and increased by 0.1m, and the water-driven connectivity proportion increased from 74.43% to 81.16%, increased by 6.73 percentage points (table 5).

The problem of this scheme is that the production loss is large, and as the east-west fracture is developed in this well area, after the original pattern angle well is converted, the oil well with the same row of the transfer well may be affected by the crack and the water cut up speed will increase.
3.2.3. **Scattered Transfer.** In order to further improve the injection-production relationship of single sand body, improve the control degree of water drive in the well area as much as possible, increase the thickness ratio of multi-direction water drive and the minimum loss output of the transfer wells, the scattered transfer can be carried out according to the principle of "control single sand body in plane and consider each small layer between layers".

| Table 4. Basic information of transfer wells with inverse nine-point transfer mode |
|---|
| scheme | transfer well | production ways | shooting thickness(m) | effective thickness(m) | daily fluid(t) | daily oil(t) | water cut(%) | working fluid level(m) | note |
| Inverse nine-spot pattern | | | | | | | | | |
| A-1-1-2 | pumping | 4.4 | 1.8 | 1.6 | 0.6 | 63.7 | 1285 |
| A-1-1-4 | pumping | 5.2 | 2.6 | 2 | 0.9 | 53.8 | 1291 |
| A-1-5-1 | pumping | 8.3 | 2.6 | 2.5 | 1.7 | 31.1 | 1205 |
| A-1-5-3 | pumping | 4.7 | 2.9 | 2.6 | 2.5 | 3.2 | 1214 |
| subtotal | | | 22.6 | 9.9 | 8.7 | 5.7 | 34.5 | 1249 |

| Table 5. Control degree of water drive after inverse nine-point transfer |
|---|
| Effective thickness (m) | One-way connected | Two-way connected | Multidirectional connected | A combined |
| sandstone (m) | effective proportion (%) | sandstone (m) | effective proportion (%) | sandstone (m) | effective proportion (%) | sandstone (m) | effective proportion (%) |
| <1.0 | 24.3 | 8.5 | 14.05 | 28.2 | 12.4 | 20.50 | 9.8 | 3.8 | 6.28 | 61.7 | 25.1 | 41.49 |
| 1.0~2.0 | 10.8 | 7.9 | 13.06 | 19.2 | 13 | 21.49 | 2.4 | 1.1 | 1.82 | 32.4 | 22 | 36.36 |
| ≥2.0 | 0.7 | 2 | 3.31 |
| subtotal | 35.8 | 18.4 | 30.41 | 47.4 | 25.4 | 41.98 | 12.2 | 4.9 | 8.10 | 94.8 | 49.1 | 81.16 |

According to the principle of transfer, 3 oil wells are transferred, average daily production of liquid is 3.2t and average daily production of oil is 0.2t, and the output loss ratio is 1.05% (table 6). After the transfer, the water-driven sandstone thickness increased from 94.7m to 95.7m, with an increase of 1.0m. The water-driven connectivity ratio increased from 74.43% to 79.65%, with an increase of 5.22 percentage points (table 7).

The problem of the scheme is that the injection wells are adjacent after transfer and the well pattern is irregular, which is not conducive to the subsequent comprehensive water injection adjustment.

| Table 6. The basic information table of transfer wells in scattered transfer mode |
|---|
| scheme | transfer well | production ways | shooting thickness(m) | effective thickness(m) | daily fluid(t) | daily oil(t) | water cut(%) | working fluid level(m) | note |
| scattered pattern | | | | | | | | | |
| A-1-2-2 | bailing | 7.7 | 3.3 | 0.2 | 0.1 | 74.2 |
| A-1-2-4 | bailing | 7 | 4.3 | 0.2 | 0.1 | 33.8 |
| A-1-4-3 | bailing | 9.8 | 4.7 | 0 | 0 | 0 |
| subtotal | | | 24.5 | 12.3 | 0.4 | 0.2 | 50 |

| Table 7. Control degree of water drive after scattered transfer |
|---|
| Effective thickness (m) | One-way connected | Two-way connected | Multidirectional connected | A combined |
| sandstone (m) | effective proportion (%) | sandstone (m) | effective proportion (%) | sandstone (m) | effective proportion (%) | sandstone (m) | effective proportion (%) |
| <1.0 | 29.7 | 10.6 | 18.06 | 29.6 | 14.3 | 24.36 | 9.2 | 3 | 5.11 | 69.6 | 27.9 | 47.53 |
| 1.0~2.0 | 9.4 | 6.8 | 11.58 | 9.2 | 6.1 | 10.39 | 6.8 | 3.6 | 6.13 | 25.4 | 16.5 | 28.71 |
| ≥2.0 | 2.5 | 2.0 | 3.41 |
| subtotal | 39.1 | 17.4 | 29.64 | 41.3 | 22.4 | 38.16 | 16 | 6.6 | 11.24 | 95.7 | 46.4 | 79.65 |

In terms of comprehensive control degree of water drive, proportion of multi-direction communication, loss of output, the scattered transfer scheme has the best effect as far as the current production situation is concerned (table 8).
Table 8. Comprehensive comparison table of different transfer modes

| transfer scheme      | The increased proportion of water drive control (%) | The increased proportion of two-way and multi-directional (%) | Rate of loss (%) | note  |
|----------------------|-----------------------------------------------------|---------------------------------------------------------------|------------------|-------|
| Determinant          | 1.30                                                | 23.06                                                         | 0                |       |
| Inverse nine-spot    | 6.73                                                | 39.53                                                         | 29.84            |       |
| Scattered            | 5.22                                                | 38.46                                                         | 1.05             | The best |

The A-1-5 well area in this block has undergone scattered transfer adjustment in 2012. Due to the similarity between the central encryption well area and the A-1-5 well area, the effect of the transfer can be referred to the A-1-5 well area. The control degree of water drive before transfer in the A-1-5 well area is low, and the well pattern is irregular. According to the A type water drive curve (figure 3), the final recovery rate is predicted to be 19.04% before transfer, and to be 23.24% after transfer, and the recovery rate is increased by 4.2 percentage points. According to the A type water drive curve before transfer in the central encryption well area (figure 4), it is estimated that the final recovery rate is 24.96%, the recovery rate is increased by 4.2 percentage points, so after the transfer, the final recovery rate is expected to be 29.16%.

Figure 3. A type water drive curve before and after the transfer in A-1-5 well

Figure 4. A type water drive curve of a before transfer in central encryption well area

Petrel modeling software is used to carry out geological modeling for the central encryption well area of block A-1. The grid precision is 30m×30m, and the structure model, sedimentary facies model and attribute model are established respectively (figure 5).
On the basis of the modeling, the Eclipse numerical simulation software is used to fit the single well in the well area. According to the simulation results, after scattered transfer, average single well daily oil production is estimated to increase by 0.3t, the final recovery rate is estimated to increase by 4.4 percentage points.

Comprehensive the A type water drive curve and the simulation results, the final recovery rate is estimated to increase by 4.3 percentage points. After transfer, the average single well daily oil production is estimated to increase by 0.3t, the well development effect will be improved.

4. Conclusions

Comprehensive water drive control degree, multiple connectivity proportion, loss of production and other aspects, the best results are achieved with the scattered transmissions; Comprehensive the A type water drive curve and the simulation results, the final recovery rate is estimated to increase by 4.3 percentage points, average single well daily oil increase by 0.3t. The transfer wells are based on improving the injection-production relationship of single sand bodies, improving the control degree of water drive and increasing the proportion of multi-directional water drive thickness. Transfer wells should be combined with high shut-in and inefficient well treatment as much as possible to achieve the purpose of minimizing the loss of production and controlling the increase rate of comprehensive water cut in oil fields.

5. References

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