Study on Gas Recovery Program Optimization in Deep Water Gas Reservoir

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Abstract. LS-17 gas field is China's first self-operated deep-water gas field in the south China sea. Located in the southeast of hainan island, the gas field has a depth of 1220-1560 meters. According to the gas reservoir characteristics of LS-17 gas field, the gas reservoir model and numerical model of water control process of LS-17 gas field are established, the productivity of existing wellhead gas reservoir is predicted, the gas production plan of gas reservoir is optimized, and the optimal solution of recovery rate of compressed gas reservoir is given under different system changes, different processes and different development modes. In this paper, the gas production rate and recovery rate at different gas production rates are predicted, and the gas recovery rate is optimized. The development method of intermittent gas production is put forward, and the parameters of intermittent gas production are not optimized. The deep water gas reservoir is characterized by high energy and serious water intrusion. This paper compares and evaluates the recovery efficiency under different water control technologies, and proposes a method for selecting water control technology measures in the process of gas reservoir development. The research ideas and methods in this paper effectively support the scientific decision-making of gas recovery program in LS-17 gas field and have certain guiding significance for the development of deepwater gas reservoirs in the south China sea.

1. Introduction
LS-17 gas field is located in the central valley of the northern part of qiongdongnan basin, and is located in the southeastern part of hainan island[1].In 2014, the offshore oil 981, a drilling platform independently developed by China, drilled seven exploratory Wells and confirmed that LS-17 gas field is a large gas field of 100 billion cubic meters, which is also the first self-operated deep water gas field discovered by China in the south China sea. The water depth of the sea area where LS-17 gas field is located is 1220 ~ 1560m. The gas reservoir is relatively scattered, with an independent accumulation span of about 30.4km from north to South and 49.4km from east to west. The formation in which the main gas reservoir is located is the yellow current formation, with good physical properties of sand body, good porous and permeable structure, and sufficient energy in water body, but the water body is widely distributed, and the gas reservoir is easy to see water[2-3].The pure hydrocarbon content of natural gas in gas reservoir is high (the pure hydrocarbon content is more than 98%), and the main products are natural gas and condensate oil.
2. Establishment of gas reservoir model

Structural location of LS-17 gas field: in the central valley of LS sag, qiongdongnan basin, yacheng 13 gas field is 160km away from yacheng to Hong Kong pipeline 87km away. Main target layers: yellow stream group I, II, III, IV, buried depth 3,200-3,400m, about 1900m below the mud line. The reservoir has good physical property, which belongs to the high-to-extra-high-porosity and high-to-extra-high-permeability reservoirs. The pure hydrocarbon content in the gas component was high: 98.2-99.52%, and the formation water type was NaHCO₃. In the target block, 86.49% of the total geological reserves are controlled by edge-bottom water drive. There were 11 Wells and 9 Wells with medium and high flooding risk.

![Figure 1. LS-17 Gas Field Tectonic Location.](image1)

![Figure 2. LS-17 Geological Model.](image2)

Considering that the numerical simulation study of water intrusion law in the later water control process should be carried out in the petre-re environment, the ECLIPSE gas reservoir model in the well area of LS-17 block was firstly restored, and the PETRE-RE work area of each gas reservoir was established[4-6].

3. Numerical model construction of water control process

This project uses Petrel RE software to set up and simulate the wellbore and formation of water control technology, and studies the gas production effect of different water control technology[7-9]. Firstly, the horizontal well section model is established. The horizontal well trajectory modeling was established in the Petrel RE software environment, and the wellbore model was constructed under the Define well segmentation module according to the actual parameters of the horizontal Wells in the work area, and the wellbore friction, fluid velocity, acceleration, hydrostatic column, wellbore inclination, and horizontal section parameters were set. Then, the water model of the research area was constructed under the Make aquifer module to reflect the water conditions of each working area. Finally, the process parameters for the horizontal segment of the horizontal well are set under the completions manager module (perforation number, segment diameter, packer type, etc.).

![Figure 3 Setting of Process Parameters and Data Output of Horizontal Well Section Model](image3)

4. Mesh encryption of work area model

At present, the plane mesh precision of each model in the research area is 100×100m, and the model precision is too small. The horizontal section of the horizontal well in the work area is 300m in length, and the whole horizontal section only takes up three grids, which cannot reflect the waterline advance
in the gas reservoir development process. Therefore, it is necessary to encrypt each model in the work area. Considering the need to accurately describe the water intrusion law of horizontal well section during gas reservoir development, the work area model was encrypted to 10×10m. In the process of model grid encryption, due to the large amount of computation, it is necessary to select the mode of model grid encryption to reduce the computation amount in the process of model calculation.

![Grid Encryption Diagram](image)

Mesh encryption USES local mesh encryption to encrypt the research area model. Local grid encryption method is adopted to delineate the swept range of the target well group in the work area, and the water distribution of each model in the work area is fully considered to encrypt the grid around the gas well, refine the model precision and simulation details around the target well, and optimize the encryption range. This method not only reduces the computation amount of server encryption, but also ensures the accuracy of numerical simulation. Therefore, the local grid encryption method is adopted in the subsequent research to study the water invasion law of gas reservoir in the research area.

![LS-17 Encryption Scheme](image)

5. Prediction of single well productivity
On the basis of determining the infilling method of the gas reservoir model, the accuracy of the infilling model is verified[10-11]. The original model production allocation system was applied to carry out prediction, and the model production capacity before and after the encryption was compared. The prediction results showed that the overall production trend of the gas reservoir was basically the same. The PETREL-RE numerical model not only achieves fine characterization of the target well area, but also retains the original gas reservoir property information, which can be used to predict the next gas reservoir production system.

![Well A2 Cumulative Gas Production](image) ![Well A3H Cumulative Gas Production](image)
6. Numerical simulation of marginal and bottom-water gas reservoirs

6.1. Evaluation of reasonable gas production rate of gas reservoir

Five schemes were designed, with gas production speed of 2%, 3%, 4% and 5%, respectively, to predict the daily production rate of gas in the whole region, and the repeated gas production rate in the whole region, and to evaluate the reasonable gas production rate in the research area. Finally, the reasonable gas recovery rate in the study area was determined to be 4%, the gas accumulation rate of the study area was 48.63×10⁸m³, and the recovery rate was 60.03%.

| Gas recovery rate | 2%  | 3%  | 4%  | 5%  |
|-------------------|-----|-----|-----|-----|
| Cumulative Gas Production (10⁸m³) | 46.82 | 47.26 | 48.63 | 45.02 |
| Tired water production (10⁴m³) | 23.43 | 24.71 | 26.07 | 27.48 |
| recovery (%) | 57.8 | 58.34 | 60.03 | 55.58 |

6.2. Design of intermittent gas production in gas reservoir

The intermittent gas production program was optimized for bottom-water gas reservoir, six different intermittent programs were designed, and the changes of daily gas production and recurring gas production in the study gas reservoir were predicted. Finally, the intermittent gas production program was determined to be one month in one year. The cumulative production period in the study area was 51.37×10⁸m³, and the recovery rate was increased by 3.38%.

| Intermittent Scheme | Don't Intermittent | Half a year production and half a month interim | One year production and one month interim | One year production and two months interim | Two years production and a month interim | Two years production and two months interim |
|---------------------|--------------------|-----------------------------------------------|-------------------------------------------|-------------------------------------------|------------------------------------------|-------------------------------------------|

Figure 8. Well A2 Daily Gas Production

Figure 9. Well A3H Daily Gas Production.

Figure 10. Daily Production Map of Different Gas Production Speeds.

Figure 11. Cumulative Gas Production Map of Different Gas Production rates.
6.3. Optimization of combined water-controlled gas production scheme

The superhydrophobic coated sand can keep the water drops spherical on the surface between particles, and it can block the water gas and delay the water penetration rate. The combined water control scheme of intermittent gas production/variable density screen pipe water control/coated sand can further extend the anhydrous gas production period. The final gas production of the scheme is $56.98 \times 10^8 \text{m}^3$, and the recovery factor is 10.31%.

Table 3. LS-17 Index Prediction of Combined Water Control and Gas Production Scheme

| Water Control Scheme | No Measures | The Intermittent Gas Recovery | Variable Density Screen | Coated Sand | Intermittent /Variable Density | Intermittent /Coated Sand |
|----------------------|-------------|-------------------------------|-------------------------|------------|--------------------------------|--------------------------|
| Cumulative Gas Production ($10^8 \text{m}^3$) | 48.63       | 51.07                         | 51.37                   | 50.49      | 51.04                          | 49.86                    |
| Enhanced Recovery (%) | --          | 3.38                          | 4.19                    | 1.52       | 8.15                           | 10.31                    |

7. Conclusion

(1) Establish the geological model of LS-17 gas field and conduct local grid encryption.
(2) Establish a mathematical model to predict gas production under the condition of water control technology.

(3) Optimize the rational gas recovery program under different gas recovery modes. The reasonable gas recovery rate of LS-17 gas field is 4%. The intermittent gas recovery plan is 1 year production and 1 month interim. The optimal gas recovery scheme is a combination of intermittent gas recovery, variable density sieve water control and coated sand.

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