Experimental study on reasonable production allocation of tight sandstone gas reservoir

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Abstract. Due to the characteristics of poor physical property, low natural productivity, and rapid production decline of tight sandstone gas reservoir[1]. Therefore, it is usually necessary to optimize the working system of gas Wells after fracturing in tight gas reservoirs and determine the length of stable production period to ensure the large accumulated gas volume. In this paper, through the reasonable production allocation experiment on tight sandstone reservoir cores, the comparison diagram of instantaneous flow and cumulative gas volume at the end of stable production at different stable production rates is established, and the optimization experimental results of reasonable production allocation working system of gas Wells are obtained to determine the optimal stable production rate interval. Understanding and mastering the stable production capacity and reasonable production allocation of gas Wells in tight gas reservoirs provides the corresponding basis for formulating reasonable development measures of gas fields, and provides quantitative analysis means for optimizing the production allocation of gas Wells[2].

1. Preface
To study the reasonable production allocation of tight gas reservoirs, to understand the gas well productivity and the main influencing factors of gas well production, and to make full use of the energy of the gas well to effectively and accurately control the pressure drop so as to improve the stable production time and recovery factor of oil and gas[3~4]. So reasonable production allocation analysis for tight sandstone gas reservoirs is the key to achieve stable production and improve the recovery degree of the gas reservoirs. According to predecessors' summaries of gas well production allocation methods, currently commonly used theoretical methods include empirical method, systematic analysis curve method, gas production curve method and liquid carrying calculation method, etc. [5~6], but none of them can directly reflect the influence of steady production rate of gas well on accumulated gas volume under what conditions. Therefore, this article through to the tight sandstone gas reservoir core reasonable proration experiments, because of the differences between different categories in the dense reservoir permeability had an effect on the experimental data, through the correlation analysis showed that all kinds of evaluation parameters and permeability of certain correlation, reservoir parameter distribution can be divided into four types, set up under the different stable speed and instantaneous flow rate and production plateau wood cumulative volume contrast diagram, then get the optimization result of the gas well reasonable working system of the allocation of the interval and conversion for the mine
production. According to the new analysis method and experimental data, the real-time production
dynamic changes of gas Wells can be understood more clearly, and the reasonable production allocation
model of tight sandstone gas reservoir can be established to extend the stable production period and
increase the final production, to ensure the efficient and reasonable development of the gas reservoir.

2. Reasonable production allocation experiment process

2.1. Experimental methods
Put the rock sample to be tested into the core gripper, set the confining pressure as (2.5MPa) and the
inlet pressure as (1MPa). A flow controller is added at the end of the core gripper to set different flow
rates or pressures to simulate the optimization experiment of production allocation of gas Wells with
constant flow and constant pressure until the abandoned flow rate.

2.2. Experimental procedures
① The core was made into a 5cm long and 2.5cm diameter pillar saturated with formation water (8%
mass fraction of KCl) and its bound water saturation was measured;
② Place the rock pillar into the core gripper and set the confining pressure at 2.5MPa and the inlet
pressure at 1MPa;
③ The nitrogen bottle was closed and the flow rate of the flow controller was set at 0.7L/min,
0.6L/min, and 0.5L/min, respectively, so as to conduct experiments on different stable production rates
of the gas well
④ Close the nitrogen bottle and set the pressure of the flow controller as 0.3MPa to simulate the
constant pressure test of gas well production;
⑤ When the upper-pressure failure is completed, the experiment is ended and the experimental
results are recorded.

Figure 1. Flow chart of optimization experiment of gas well production allocation mode in different
types of tight sandstone reservoirs

Different categories density is the most significant difference in permeability in the reservoir, through
the correlation analysis showed that all kinds of evaluation parameters and permeability of certain
correlation, so according to the distribution of the parameters and the influence on reservoir quality, the
artificial data distribution of each parameter can be divided into four intervals, as classification criteria.
Table 1. Tight sandstone gas reservoir classification evaluation table

| Evaluation parameters | Reservoir types |
|-----------------------|----------------|
|                       | Type I | Type II | Type III | Type IV |
| porosity (%)          | ≥10    | 8~10    | 6~8      | <6      |
| permeability (mD)     | ≥1     | 0.5~1   | 0.1~0.5  | <0.1    |
| Gas saturation (%)    | >70    | 60~70   | 50~60    | 40~50   |
| Main rock type        | Quartz sandstone | Quartz sandstone, lithic quartz sandstone | Lithic quartz sandstone | Lithic sandstone |
| Main pore type        | Intergranular pore, intergranular pore, solution pore | Intergranular pores, dissolved pores | Solution pores | microporous |

3. Experimental results of rational production matching
As can be seen from the instantaneous flow comparison diagram (Figure 2) of a type of reservoir gas well at different steady rates, the larger the steady production rate of a type of reservoir gas well, the shorter the stable production time and the faster the decline rate of the gas well.

![Figure 2. Comparison diagram of the instantaneous flow rate of gas Wells with different steady production rates in type I reservoirs](image)

It can be seen from the comparison diagram of cumulative gas production at the end of stable production under different stable production rates of a type of reservoir (Figure 3) that the larger the stable production rate of a type of tight sandstone is, the smaller the cumulative gas production at the end of stable production is.
As can be seen from the instantaneous flow comparison diagram (Figure 4) of gas Wells with different stable production rates in Type II tight sandstone reservoirs, the greater the stable production rate of gas Wells in Type II tight sandstone reservoirs, the shorter the stable production time and the faster the decline rate of gas Wells.

As can be seen from the comparison diagram (Figure 5) of accumulative gas volume at the end of stable production under different stable production rates of type II reservoirs, the accumulative gas volume at the end of stable production of tight sandstone gas Wells in type II reservoirs first increases and then decreases with the steady production rate.
Figure 5. Comparison diagram of cumulative gas volume at the end of stable production at different steady production rates

It can be seen from the instantaneous flow comparison diagram (Figure 6) of gas Wells in the three types of tight sandstone reservoirs under different stable production rates that the higher the stable production rate of gas Wells in the three types of tight sandstone reservoirs, the shorter the stable production time and the faster the decline rate of gas Wells.

Figure 6. Comparison diagram of instantaneous flow under different steady production rates of gas Wells in type III of reservoirs

It can be seen from the comparison diagram of cumulative gas production at the end of stable production under different stable production rates of the three types of reservoirs (Figure 7) that the higher the stable production rate of the three types of tight sandstone, the smaller the cumulative gas production at the end of stable production.
Figure 7. Comparison diagram of cumulative gas volume at the end of stable production at different steady production rates

It can be seen from the instantaneous flow comparison diagram (Figure 8) of gas Wells in four types of tight sandstone reservoirs under different stable production rates that the higher the stable production rate of gas Wells in four types of tight sandstone reservoirs, the shorter the stable production time and the faster the decline rate of gas Wells.

Figure 8. Comparison diagram of instantaneous flow under different steady production rates of gas Wells in type IV of reservoirs

As can be seen from the comparison diagram of accumulative gas production at the end of stable production under different steady production rates of the fourth reservoir (Figure 9), the higher the steady production rate of the tight sandstone gas well in the fourth reservoir, the greater the accumulative gas production will be, and the smaller the increase of accumulative gas production will be.
4. Discussion of experimental results

According to the optimization experimental results of reasonable production allocation working system of four different types of tight sandstone gas Wells, the following optimization results are obtained (as shown in Figure 10 to Figure 13).

Under the condition of a steady production rate of 0.5L/min~0.7L/min, the larger the steady production rate is, the smaller the cumulative gas production will be. The optimal result is 0.5L/min~0.6L/min. The gas Wells with medium and low steady production rates matching between production areas can not only obtain a longer stable production time but also obtain a larger cumulative production at the end of production.

Under the condition of a steady production rate of 0.32L/min~0.28L/min, the larger the steady production rate is, the smaller the cumulative gas production will be. The optimal result is 0.28L/min~0.3L/min. The gas Wells in the middle and low distribution zones can not only obtain a longer stable production time but also obtain a larger cumulative production at the end of production.

Under the condition of 0.03L/min~0.01L/min for four types of tight sandstone reservoirs, the higher the steady production rate of gas Wells in the three types of tight sandstone reservoirs, the higher the cumulative gas production will be, and the optimal result is 0.08L/min~0.1L/min. Although the stable production time of gas Wells in the middle and high distribution zones is shorter than that of gas Wells with low distribution, the gas Wells can obtain a larger cumulative gas production.

Under the condition of 0.03L/min~0.01L/min for four types of tight sandstone reservoirs, the higher the steady production rate is, the higher the cumulative gas production will be, and the optimal result is 0.02L/min~0.03L/min. Although the stable production time of gas Wells in medium and high distribution zones is shorter than that of gas Wells with low distribution, the gas Wells can obtain a larger cumulative gas production.
Figure 10. The optimization results of the working system of type I reservoir gas well

Figure 11. The optimization results of the working system of Type II reservoir gas well

Figure 12. The optimization results of the working system of Type III reservoir gas well
Figure 13. The optimization results of the working system of Type IV reservoir gas well

According to the similarity criterion $\pi_g$ and the gas production rate of the material model core $q_m$, the formula between the gas production rate $q_g$ of the gas well in the field is calculated:

$$q_g = \frac{bhK_{rg}}{a\mu ZT_{p_{sc}}}(\frac{K_{T} P_i^2}{bhK_{rg} K_{T} P_i^2})q_m$$

(1)

Conversion from the core flow under experimental conditions to the production of gas Wells in the field, the production of gas Wells in the first type of tight sandstone reservoir is about $1.8-2.1 \times 10^4 m^3/d$, the second type of tight sandstone reservoir is about $0.8-1 \times 10^4 m^3/d$, the third type of tight sandstone reservoir is about $0.3-0.5 \times 10^4 m^3/d$, and the fourth type of tight sandstone reservoir is about $0.1-0.2 \times 10^4 m^3/d$.

5. Conclusion

The higher the stable production rate of the four types of tight sandstone reservoirs, the shorter the stable production time and the faster the decline rate of the gas Wells; The stable production rate of reservoirs with better petrophysical properties is negatively correlated with the accumulated gas volume, while the stable production rate of reservoirs with poorer petrophysical properties is positively correlated with the accumulated gas volume.

Reservoir gas Wells with good physical property can prolong their stable production period and obtain larger accumulatively accumulated gas when they keep a stable production rate between 0.3~0.6L/min in medium and low distribution production areas. Reservoir gas Wells with poor physical property can maintain a stable production rate between 0.01~0.1L/min in medium and high distribution production areas, and obtain larger accumulatively accumulated gas when they keep stable production time short.

The optimization interval corresponding to the reasonable production allocation system can be intuitively reflected by using the comparison diagram of different stable production velocities, instantaneous flow, and accumulative gas volume at the end of stable production.

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