Research on Classification Management Method of Xushen Gas Field

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Abstract. Xushen gas field not only exploits volcanic gas reservoir, but also develops glutenite reservoir. In the production process, there are great differences in gas well productivity, formation pressure and single good reserves. By establishing the fine management mode of four types of wells, the "one type, one method, one well, one policy" has been realized. It mainly forms the multi-factor comprehensive production allocation technology with "two optimizations and three control" as the means, improves the winter peak regulation mechanism of withdrawal, supplement and short-term emergency peak shaving, determines the drainage gas production technology to meet the current development needs, explores the treatment method of easy freezing plugging well with "three-step" as the main method, and effectively governs Low-yield and low-efficiency wells.

Keywords: Xushen gas field, Classified Management, Reasonable production allocation, Peak shaving management, Hydrate freezing and plugging treatment.

1. Development status of Xushen Gas Field

Xushen Gas Field is located in the Xujiaweizi fault depression zone in the northern Songliao Basin. It belongs to a "low porosity, low permeability, and medium abundance" structural-lithological gas reservoir. It mainly exploits glutenite and Yingcheng Formation 4th Member and Ying1 and Ying3 The volcanic rock reservoir and the glutenite reservoir of the Shahezi Formation. The glutenite reservoir of the Yingcheng Formation has poor physical properties, with an effective permeability ranging from 0.01 to 46.8 mD and a porosity of 0.8 to 8.8%. It is a low-porosity and low permeability reservoir; volcanic rock The lithology of the reservoir is mainly rhyolite, the effective permeability is between 0.002~13.6mD, the porosity is 0.6~20.7%, and the fractures and pores are developed. It is a low-porosity and low permeability reservoir. The average glutenite reservoir of Shahezi Formation The porosity is 5.7% and the average permeability is 0.085mD. Since the gas field was put into development in 2004, with the increase in the number of production wells, the gas production and water production have increased.
First, the productivity of single wells in gas fields varies greatly, with type IV wells dominated. Gas wells in the Xushen Gas Field can be divided into four types according to parameters such as formation coefficient, initial stable productivity, and gas production per unit pressure drop. Among them, four types of wells are the main type, with the number of wells accounting for 52%, and the second type of wells with the highest productivity. The number of wells accounted for 33%. Type I wells are mainly distributed in Xushen 1 and Shengshen 2-1 blocks. Type IV wells are distributed in all blocks. The Xushen 1 block has the largest number of wells and has the highest productivity.

Second, the gas field formation pressure drops steadily, and the pressure drop rate varies greatly. The pressure drop rate of weak water drive gas reservoirs in gas fields is higher than that of medium and strong water drive gas reservoirs. The pressure drop of weak water drive is about 1.2MPa/year, while the pressure drop of strong water drive is less than 1MPa/year. The gas production per unit pressure drop varies greatly between different blocks, and the formation pressure drop of a single well in each block is uneven. Only the Shengshen 2-1 block has a basically unified pressure system, and the formation pressure decreases simultaneously. The connectivity of single wells in other blocks is poor, and the formation pressure mainly drops unevenly.

The third is the large difference in gas field reserves, and the degree of production is gradually increasing. The highest single well reserves in the gas field are $28 \times 10^8 m^3$, while the lowest reserves are only $0.5 \times 10^8 m^3$. And as the degree of recovery increases, well-controlled reserves also gradually increase. Compared with the same type of gas fields in China, the gas reservoir has a dynamic-to-static reserve ratio of 0.25, which is far lower than 0.4 of other gas fields. Since 2010, by strengthening the potential of old areas and accelerating production in new areas, the degree of production of reserves has increased by 12%.

Fourth, the type of gas reservoir is mainly water drive, the water-gas ratio remains low, and some wells have high water production. The 6 blocks that have been put into development as a whole show different degrees of water drive characteristics. A total of 39 gas wells produce formation water, with a water-gas ratio between 0.1-43$m^3/104m^3$, and 69% of the wells with a water-gas ratio of 1.0$m^3/104m^3$, the water wells are mainly located at the edge of the gas reservoir and the lower structure.

2. Research on classification management of gas fields
The Xushen gas field reservoirs are low porosity, low permeability, strong heterogeneity, discontinuous development, large differences in gas well productivity and production characteristics, and the characteristics of "high in winter and low in summer" in production. According to gas well pressure, productivity, and reserves, Gas reservoir types, reservoir conditions and management methods adopted, carry out classified and seasonal management. Mainly according to the productivity level of the gas wells and the problems in production, the gas wells are divided into four types based on reasonable production allocation, and the fine management mode of the four types of wells is established. A management method of "reasonable production allocation for fixed production wells, scientific peak shaving for peak- and low-efficiency wells, and effective management of low-production and low-efficiency wells" has been formed to achieve reasonable and efficient development of gas fields. During the development and management process, targeted production allocation technology and management methods were established for Type I, II, Type III and IV respectively, realizing "one type, one method, one well, one policy". Focus on peak-shaving wells and low-yield and low-efficiency wells, do a good job at both ends, and combine management to ensure stable production of Type I and II wells, and increased efficiency of Type III and IV wells.
1) Reasonable production allocation for fixed production wells

Through the study of gas well pressure changes in different blocks and different structural positions, a comprehensive method for determining formation pressure of "two measurements and three pushes" in low-permeability reservoirs has been formed. Through research on gas well productivity evaluation methods at different development stages, Productivity evaluation technology based on product testing and productivity instability analysis; based on the use of six gas reservoir engineering production allocation methods including indicator curve method, pressure drop rate method, open flow method, and minimum liquid carrying flow method, combined with Xu The actual development of the deep gas field has formed a multi-factor comprehensive production allocation technology using "two excellences and three controls" as the means. Two advantages: optimal utilization of formation energy and optimal coordination of facility capabilities; three controls: control production pressure difference avoid side Bottom water intrusion; control the liquid-carrying flow to effectively remove the bottom hole liquid; control the gas production rate to reduce the damage of equipment erosion. Through reasonable production allocation, the productivity decline rate of fixed production wells has decreased from 8.9% year by year and stabilized at around 4.2%, providing a reliable guarantee for the continuous stable production of the gas field.

2) Peak shaving well scientific peak shaving

Since natural gas consumption is high in winter and low in summer, and the current gas field does not have complete supporting gas storage facilities, the peak period of gas consumption in winter have better reservoir conditions, high productivity, relatively quick recovery of formation pressure, and edge bottom. Type I and II wells with relatively little water impact are peak-shaving to meet gas demand during peak periods. In peak-shaving well development management, based on gas reservoir type, gas well productivity, reserves, stable production capacity, select peak-shaving gas wells and grasp the "three degrees" in the process of peak-shaving well management, that is, explore the peak-shaving amplitude: adopt Production performance + gas reservoir engineering calculation + field test method to determine reasonable peak shaving amplitude; optimize peak shaving system: adopt well test analysis + software simulation prediction + field verification method to develop optimal peak shaving system; ensure good recovery degree: according to The relationship between peak shaving pressure drop rate + shut-in time + recovery degree determines the reasonable summer shut-in time, and the peak-shaving well is shut in or reduced production during the low gas consumption period in summer, and the shut-in time is extended as much as possible to ensure the formation of summer energy. Fully recover to ensure the stable peak-shaving capacity of peak-shaving wells. Improve the "exit, supplement, and short-term emergency peak-shaving" mechanism to realize a virtuous cycle of peak shaving. Due to the decline, when the pressure and productivity of the peak-shaving well drop to a certain extent, the peak-shaving capacity decreases or the peak-shaving capacity does not have the continuous and stable peak-shaving.
shaving capacity, adjust the gas well to the constant production well or reduce the peak-shaving volume. In addition, select part of the pressure and Gas wells with higher productivity and better stable production capacity are used as peak-shaving wells to ensure a stable total peak-shaving volume. In addition, when the demand for gas in winter reaches the peak, it is necessary to select the wells with sufficient energy in the existing formation and the ability to re-peak or select the gas wells with relatively high pressure and short-term peak-shaving ability from the fixed production wells for emergency peak shaving. So as to achieve the balance of supply and demand at the peak of gas consumption. Through the development and improvement of the reasonable production technology of peak-shaving gas wells, the formulation of reasonable gas well opening and summer closing systems and procedures, and improved management systems, the orderly replacement of peak-shaving wells and the continuous stability of peak-shaving capacity have been realized.

### Table 1. Principles and limits of peak shaving and well selection in Xushen Gas Field

| Types                   | Gas reservoir type | Water production impact                      | Block          | Formation coefficient (mD) | Yield (10^4 m^3/d) | Reserves (10^8 m^3) | Peak shaving recommendations | Peak shaving amount                        |
|-------------------------|-------------------|---------------------------------------------|----------------|--------------------------|-------------------|-------------------|-------------------------------|------------------------------------------|
| Adjustable peak         | Air drive or weak water drive | Produce a small amount of water              | Xu Shen 1      | ≥20                      | ≥4                | ≥3                | Stable peak shaving             | Total peak-shaving gas volume: 11% of gas field production |
|                         | Medium-strength water drive | There is a barrier between the water layer  | Sheng Shen 2-1 |                         |                   |                   | Single well peak regulation capacity: constraints of indicator curve method, flow pressure rate method, and modern production performance analysis method |
|                         |                   | Less affected by water invasion              | Wang Shen 1, Xu Shen 9, 21 |                         |                   |                   | Emergency peak shaving           |                                                         |
| Not suitable for peak shaving | Horizontal wells and sand production wells in the side and bottom water gas reservoirs in Xushen 8 block |                         |                 |                         |                   |                   |                               |                                                         |

3) Effective management of low-yield and low-efficiency wells

There are currently 31 low-yield and low-efficiency wells in the Xushen Gas Field, accounting for 27% of the total number of wells in the Xushen Gas Field, with a total daily production capacity of 29×10^4 m^3. The main problems are difficulty in carrying liquid and easy throttling and freezing.

In response to the increasing number of low-yield and low-efficiency wells that affect the production capacity of gas fields, the following two aspects have been carried out:

One is to continuously improve drainage gas production technology to ensure stable production of liquid wells.

Through gas production curve method, gradient test method, liquid-carrying flow method and other wellbore fluid diagnostic analysis techniques, explore the water production characteristics of different gas wells. Through field tests, the application limits of several major drainage gas recovery technologies have been determined.
Table 2. Technical boundaries of drainage gas recovery

| Technical means               | Water-gas ratio \( (\text{m}^3/10^4\text{m}^3) \) | Water volume \( (\text{m}^3/\text{d}) \) | Flow rate \( (\text{m}/\text{s}) \) | Well deep (m) |
|------------------------------|-------------------------------------------------|----------------------------------------|----------------------------------|---------------|
| Foam drainage                | <15                                             | 3-30                                   | 0.5-5                            | <4000         |
| Vortex drainage              | <2.0                                            | 10                                     | /                                | <2286(Single-stage action depth) |
| Speed string                 | <7.0                                            | <20                                    | /                                | <5400(Φ38.1mm) |
| Electric submersible pump    | >25                                             | 50-500                                 | /                                | <3500         |
| Plunger gas lift             | <17                                             | <35                                    | /                                | <3500         |

For wells prone to liquid accumulation, drainage gas production technologies suitable for current development needs have been initially formed, and the application limits of various drainage gas production technologies have been determined. Six major categories and 11 process measures have been formed, namely conventional foam drainage and optimal pipe string drainage, four mechanical drainages—vortex drainage, plunger drainage, electric submersible pump drainage, pumping unit drainage, and 3 gas lift drainage—Nitrogen gas lift drainage, compressor gas lift, and interconnected gas lift drainage, two kinds of production system adjustment drainage-intermittent production drainage and production adjustment carrying liquid drainage. At present, the most widely used drainage method in gas fields is foam drainage. This technology has the characteristics of low cost and a wide application range. It is mainly used for obvious liquid accumulation in the wellbore and affects the production of gas wells. The gas well has a certain amount of energy, and the pipe string structure is intact, and the water production is less than 30m3/d gas well. Through the technical improvement and management improvement, the bubble drainage process has the function of automatic wellhead dosing, which realizes automatic, continuous and precise dosing, reducing maintenance workload by 85% compared with manual dosing, and significantly improving process efficiency and aeration effect.

Since 2016, a total of 16 drainage and gas production measures have been implemented for some water-flooded shut down wells and fluid-carrying wells in the Xushen Gas Field, with a cumulative gas increase of 1346×10^4m³ and a water production of 2.94×10^4m³.

The second is to continuously innovate management methods and increase the "double rate" of freezing and blocking wells

It is mainly aimed at the situation that the wellbore and surface pipelines of some wells are prone to frequent freezing and blockage at the beginning of the well opening. The gas hydrate balance curve chart of gas wells in Xushen gas field was drawn by the thermodynamic method. According to the distribution of gas well pressure and temperature in each block, the risk of hydrate freezing and blocking gas wells can be determined, so as to prevent freezing and blocking risk wells in a targeted manner.

Table 3. Formation range of hydrate in each block of Xushen Gas Field

| Block            | Hydrate formation range (winter) | Hydrate formation range (summer) |
|------------------|----------------------------------|----------------------------------|
|                  | Oil pressure (MPa) | Temperature (℃) | Pressure (MPa) | Temperature (℃) |
| Sheng Shen2-1    | 10                     | 5-7.6               | 15            | 7-8.6               |
| Wang Shen 1      | 5-20                   | 6-24.3              | 10-16         | 7.9-20.5            |
| Xu Shen 1        | 1-12                   | 4-15                | 3-16          | 5.3-20.2            |
| Xu Shen 3        | 15                     | 12.5                |               |                     |
| Xu Shen 9        | 6-13                   | 6.1-13              | 14-15         | 12.5-13.9           |
| Xu Shen 21       | 12-15                  | 5.5-7.1             | 16            | 6.5                 |
According to the temperature and pressure distribution curve of the wellbore and the critical curve of hydrate formation, the maximum depth of hydrate formation in the wellbore is determined, which is mainly located above 500m in the wellbore. Aiming at the problem of frequent freezing and blocking of gas wells, through exploration and summary, a "three-step method" as the main method for easy freezing and blocking of wells has been gradually formed to improve the rate of gas well opening:

(1) Fast heat-carrying: increase the instantaneous output when opening the well, adjust the temperature distribution of the wellbore, and prevent the wellbore from freezing and blocking at the beginning of the well opening.

As the output of gas wells decreases, the temperature gradually decreases, and the risk of hydrate formation increases. By adjusting the output of gas wells, the temperature distribution of the wellbore can be adjusted to inhibit the formation of hydrates. The minimum flow rate that inhibits the formation of hydrates is called the critical antifreeze flow. The wellhead temperature chart at the flow rate is determined, and production at this flow rate can reduce the risk of freezing and blocking the gas well. Two to three days after opening the well, the wellhead temperature and ground temperature reached a heat exchange balance, and the instantaneous flow rate of the gas well decreased accordingly. At this time, many wells can maintain normal production without adding methanol.

(2) Optimize alcohol injection: determine a reasonable methanol injection concentration, injection timing and injection volume

First determine the prediction of the decrease in the temperature of hydrate formation under the action of the inhibitor, using the Hammelsmit semi-empirical prediction formula:

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\Delta T = \frac{KW}{M(100-W)}
$$

\(M\)—the molecular weight of the inhibitor;
\(W\)—weight percentage of inhibitor solution, %;
\(K\)—represents the empirical constant related to the type of inhibitor, taking 1297 for methanol, 1228 for isopropanol, ammonia, etc., 1220 for calcium chloride, and 2425 for diethylene glycol.

Methanol injection concentration: when 10%~15%, the temperature drop of hydrate formation can reach 4.4-7.1℃, which can effectively inhibit the formation of the hydrate.

Timing of filling: Determine the hydrate formation temperature of the gas well based on the hydrate production chart. When the wellhead temperature drops to the hydrate formation temperature, add methanol in advance to prevent hydrate formation.

Filling volume: The minimum filling volume when the water content of the water sample meets the requirements through simulation calculation and field test.

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**Fig. 2** Corresponding wellhead temperature chart under different working systems

**Fig. 3** Wellhead temperature curve at the initial stage of well opening for freezing and plugging wells in Xushen 6 well area
Table 4. Relationship between methanol concentration and hydrate production temperature drop

| Serial number | Methanol concentration (%) | Hydrate formation temperature drop ℃ |
|---------------|----------------------------|-------------------------------------|
| 1             | 5                          | 2.0                                 |
| 2             | 10                         | 4.4                                 |
| 3             | 15                         | 7.1                                 |
| 4             | 20                         | 10.0                                |

(3) Balanced discharge: After the oil jacket pressure is balanced, the backpressure decreases, and the gas production is higher than the critical liquid-carrying flow at this time, so that the gas can be produced with water by its own energy.

Balanced drainage is mainly for gas wells whose production is lower than the critical liquid-carrying flow rate and the wellbore has liquid accumulation. Operation steps of a balanced draining method: 1. Close the inbound ball valve, 2. Open the casing gate to achieve the oil jacket balance. 3. Open the pit stop ball valve to bring water and produce gas instantly.

Through continuous exploration and testing, the "three-step method" was tested in the Xushen 6 well area, and the opening rate was increased by 30%, and good results were achieved. The “three-step method” work system for the management of easy-freezing well plugging was determined.

Table 5. "Three steps" treatment system for freezing and plugging wells in Xushen 6 well block

| Serial number | Well number | Governance method | Methanol filling system |
|---------------|-------------|-------------------|------------------------|
|               |             | Fast heat-carrying instantaneous flow (m³/h) | Optimize alcohol injection | Balance drainage (day/time) | Wellhead hydrate formation temperature (℃) | Add methanol when the wellhead temperature drops below 15℃, the methanol concentration is 10%-15% |
| 1             | XS6-1       | 1100m³/h          | 50Kg/ day              | 3–4                  | 10-14                        |                                                     |
| 2             | XS6-2       | 1200m³/h          | 30Kg/ day              | 4-5                  | 11-14                        |                                                     |
| 3             | XS6-3       | 1500m³/h          | 30Kg/ day              | 4-5                  | 10-14                        |                                                     |
| 4             | XS6-207     | 1200m³/h          | 50Kg/ day              | 2-3                  | 9-15                         |                                                     |
| 5             | XS6-209     | 1800m³/h          | 20Kg/ day              | 1-2                  | 10-13                        |                                                     |
| 6             | XS6-210     | 1200m³/h          | 50Kg/ day              | 1-2                  | 11-15                        |                                                     |

3. Conclusion

1) The Xushen gas field presents the characteristics of "high in winter and low in summer". According to the conditions of gas wells and reservoir parameters, it carries out classified and seasonal management. “Scientific peak shaving of wells and effective management of low-yield and low-efficiency wells”.

2) The Xushen Gas Field has formed a multi-factor comprehensive production allocation technology using "two-optimization and three-control" as a means, and the production decline rate of fixed production wells has stabilized at around 4.2%.

3) In order to meet the gas demand during the peak period, it is necessary to perform peak shaving for Type I and II wells with good reservoir conditions in winter. At present, a perfect "exit, supplement, short-term emergency peak-shaving" mechanism has been formed, which is Peak shaving virtuous circle.

4) Drainage and gas recovery technology that meets the current development needs has been initially formed, and the drainage method with foam drainage and gas recovery as the mainstay, and other drainage techniques as supplementary has been determined; hydrate freeze plugging mainly occurs in
the wellbore over 500m. Through exploration and summary, Formed a "three-step method" as the main method for easy-freezing plugging wells, so that low-yield and low-efficiency wells can be effectively controlled.

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