The practice and effect analysis of gas production with plunger drainage in tight sandstone gas reservoirs: Taking Bajiaochang Xusi gas reservoir as an example

Huiqiang Wang 1,*, Benjian Zhang 1, Min Jing 2, Haitao Hong 1, Mingqiu Li 1
1Exploration and Development Research Institute of PetroChina Southwest Oil and Gas Field Company, Chengdu, China
2School of Energy, Chengdu University of Technology, Chengdu, China
*Corresponding author e-mail: 2020050162@stu.cdut.edu.cn

Abstract. The Bajiaochang Xusi gas reservoir has the characteristics of low porosity, low permeability and high water saturation, and is a typical tight sandstone gas reservoir. Gas wells are generally low in productivity and generally produce water. Gas wells carry fluid smoothly under the conditions of large pressure difference in the initial stage of production. However, as the formation pressure drops, the ability of gas wells to carry fluid weakens. Some wells can only maintain production through indirection. The Tibetan production organization has brought difficulties. For gas wells with low production, low pressure, high water content, and easy accumulation of liquids, Xusi gas reservoirs have carried out drainage gas recovery technology tests such as bubble drainage and plunger gas lift, and comprehensively selected plunger gas lift as the main drainage of the block. Gas production process measures, and promoted and applied. At present, the plunger gas lift drainage gas production technology has been implemented in 13 wells, accounting for 48% of the total wells, and the measured production accounted for 31% of the total production. It is already in the stage of wide application. Through this measure, the stable liquid carrying of water-producing gas wells was realized, the productivity of gas wells was maintained, and the production decline was delayed. The production decline was controlled at about 6%, and good application effects were achieved.

1. Introduction
With the development of the Bajiaochang Xusi gas reservoir, the formation pressure continues to drop and the ability of gas wells to carry liquids weakens. Some wells can only maintain production through indirection, which brings difficulties to the production of the entire gas reservoir. How to carry out drainage gas recovery technology tests for gas wells with low production, low pressure, high water content, and easy accumulation of liquids, and to maintain the productivity of gas wells, has become a key factor restricting the improvement of gas reservoir recovery [1-2]. In order to solve the problem of fluid accumulation in the wellbore, by investigating and analyzing the geological factors, conditions and causes of the water-producing gas wells, the foam drainage gas recovery process test and the plunger gas lift process test were carried out, and finally a more intelligent plunger gas lift was selected as the
area The main drainage gas production technology measures of the block were promoted and achieved good results.

2. General Situation of Gas Reservoir Geology
The Bajiaochang block is located in Yanting County, Sichuan Province. It is a hilly area. The regional structure is located at the northwestern edge of the low-level structural area in the Paleo-central Depression in northern Sichuan. In April 1979, the Xusi obtained industrial gas flow in J13 well (tested daily natural gas production of $1.01 \times 10^4 \text{m}^3/\text{d}$), and found the Bajiaochang Xusi gas reservoir. The gas reservoir has the following characteristics [3-4]. The Xusi gas reservoir is based on faults, Anticlines together form a trap with a nearly uniform gas-water boundary; the Xusi member reservoir has the characteristics of a typical tight sandstone gas reservoir with low porosity, low permeability and high water saturation, and the porosity is mainly distributed in the interval 4-13%. The average value is 7.87%, the permeability is mainly distributed between 0.1 and 1mD, the water saturation is between 9.31-79.87%, and the average is 50.52%; the reservoir space is mainly intergranular pores and intragranular pores Dissolved pores and underdeveloped fractures, the reservoir type is mainly pore type; Xusi gas reservoir has a unified pressure and temperature system, and the pressure coefficient is 1.79, which is a high-pressure gas reservoir; Xusi gas reservoir generally contains more than 90% methane. Containing hydrogen sulfide, the content of condensate oil is generally between 35-50g/m3, and the formation water is mainly CaCl₂ type. The overall characteristics are similar to those of the Xujiahe Formation gas reservoir in Dachuan, Sichuan Basin.

3. The principle and requirements of plunger gas lift technology

3.1. Process principle
The fully automated plunger lifting system is used in spontaneously unstable or interjet wells. It can effectively use the energy of natural gas to lift the liquid accumulation in the wellbore, effectively reduce the bottom hole pressure, and improve the production rate and recovery rate of the gas well. At the same time, due to the auxiliary liquid-carrying capacity of the plunger, the self-jet wells or interjet wells can discharge liquid and produce gas stably, thus simplifying the management of such wells.

The specific working principle of the plunger [5-7]: During the shut-in process, it sinks to the top of the spring receiver installed in the production string under the action of its own gravity, as the natural gas accumulates; after the well is opened, the natural gas Under the pushing action, the plunger and the liquid above it are lifted up together. After the liquid is lifted out of the wellhead, the natural gas under the plunger is released to complete a lifting process; the wellhead is automatically closed, that is, after the well is shut down, the plunger is reset. Fall back to the top of the spring receiver, and repeat the above steps; during this up and down reciprocating operation, the wellbore gas and liquid are lifted to the ground, and the wax, salt or scale in the wellbore is removed in time. The plunger lifting system is shown in Figure 1.
3.2. Process requirements
(1) The inner wall of the tubing is regular so that the plunger can run in the well without obstruction.
(2) The gas well itself has a certain productivity, and the gas well is required to be a spout or indirect blowout well.
(3) The water output is 10-50 m$^3$/d.
(4) The water-to-air ratio is less than 30 m$^3$/10$^4$ m$^3$.
(5) The depth of the well is preferably between 2000 and 3500 m, with a certain depth of fluid accumulation at the bottom of the well.
(6) The bottom of the well is clean and free of mud and other dirt.

4. Field test and effect analysis
Aiming at the problem of difficulty in carrying liquid in water-producing gas wells at the low pressure and low production stage of the Bajiaochang Xusi gas reservoir, since 2006, field tests of bubble drainage and plunger gas lift drainage gas production technology have been carried out in wells J41, J51, J63B, etc. Both were successful.

(1) Foam drainage gas recovery technology test: In 2006, the foam drainage field test was first carried out at J41 and J51. Well J41 achieved good results. The self-spray production cycle was extended from 4 to 5 days before the measures to 10 days, which was reduced accordingly. After the shut-in time, 10×10$^4$ m$^3$/d more gas was produced per month.

(2) Plunger gas lift drainage gas recovery technology test: In September and October 2006, the plunger drainage gas recovery technology was tested in J63B and J41 wells. After the plunger technology was implemented in J41 well, the maintenance was 2.6×10$^4$m$^3$/d's stable production capacity, and the liquid is normal (Figure 2).
(3) Optimization of drainage gas recovery technology measures: Foam drainage technology and plunger gas lift drainage technology have achieved better drainage effects in Xusi gas reservoirs, but compared with foam drainage and plunger gas lift drainage technology, plunger gas lift drainage technology has the following advantages:

① The foam drainage process requires artificial pumping of foaming agent and manual opening and closing of the well. The plunger drainage process is automatically opened and closed by the equipment, and the system can be adjusted in time with the change of the gas well, which greatly reduces the labor intensity on site and improves the gas well. Management efficiency of wells.

② Most gas wells produce condensate oil. If bubble drainage is used, the anti-condensate oil and defoaming demulsification of the agent are very demanding.

③ The bubble discharge cannot achieve 100% defoaming and demulsification ability, so it has a great impact on downstream equipment.

④ Although the plunger process has a large investment in the early stage, there is only a small amount of maintenance cost in the later stage. The bubble discharge process has the continuous cost of medicine and pump defoaming. The long-term benefit of the plunger is due to the bubble discharge.

(4) Popularization of plunger gas lift drainage gas production technology

After careful evaluation, the plunger drainage gas recovery technology was selected as the main drainage gas recovery measure for stable production of gas reservoirs, and effective promotion was carried out to achieve continuous water-carrying and stable production of low-pressure, low-yield gas wells, maintain gas well productivity, and delay production decline.

At present, the plunger gas lift technology has been implemented in 15 water-producing wells, and it has been widely used. The plunger gas lift technology wells accounted for 48% of the total production wells, and the process measures accounted for 31% of the total production. It reduces production costs and improves management efficiency (Figure 3).

**Figure 3.** Pie chart of the number of wells and production composition of plunger gas lift technology in Bajiaochang block

In addition, through this measure, the production decline of water-producing wells was effectively delayed, and the production decline of wells in the later stage of production was controlled at about 6%, which achieved good application effects.
5. Analysis of adaptability conditions of process measures

Through the follow-up analysis of the process status, production performance and daily management of the implementation of the plunger gas lift drainage gas production wells, the applicable conditions of the plunger gas lift technology in the Bajiaochang Xusi gas reservoir were summarized, and the company's other similar gas reservoirs plunger gas lift technology test and The promotion and application provide a basis.

(1) Gas well has moderate water production and reasonable gas-liquid ratio

The 15 plunger wells implemented in the Bajiaochang Xusi gas reservoir have an average daily gas production of $1.27 \times 10^4 \text{m}^3$ and an average daily water production of $1.68 \text{m}^3$. The water production is low and the gas-liquid ratio is reasonable; the feasibility analysis of the plunger shows that the plunger well The water-to-air ratio is $0.5-8 \text{m}^3/10^4 \text{m}^3$, which is within a reasonable range (Figure 5).

(2) The inner diameter of the tubing and the Christmas tree must be the same. There is no working barrel and choke in the wellbore, otherwise the plunger will not reach the blowout preventer and the plunger mode production will not be enabled. The tubing of 15 plunger wells in Xusi gas reservoir has the same inner diameter as the Christmas tree. Only the wellhead of the J55 well has a variable diameter. Due to the increase in the inner diameter of the Christmas tree, the plunger often cannot reach the sensor. The well has now taken out the plunger and used it instead. Model production.

(3) Sand production in the wellbore will affect the normal operation of the plunger. When the sand production is severe, the plunger well will experience sand jams, which will affect the normal production of gas wells.

A few wells in the Bajiaochang Xusi gas reservoir have experienced sand plugging, which is mainly recovered by removing the plugging with steel wire. In the case of not serious sand production, switch to brush and fishbone plungers (Figure 6) to reduce the risk of sand sticking.
(4) During the production of plunger wells, timely adjustments should be made according to changes in production conditions to ensure production capacity.

The plunger well of the Xusi gas reservoir in Bajiaochang adopts more advanced intelligent control equipment (Figure 7). The production oil casing pressure, production, plunger arrival status, and opening and closing time data of the plunger well can be automatically recorded in the controller for easy tracking of the production performance of each well. If the plunger cannot be reached or the output changes, the reasons can be analyzed in time to adjust the system.

(5) Sufficient materials should be prepared for the maintenance of the station, and the equipment that is prone to failure can be overhauled and replaced in time to make the plunger well operate normally.

In Bajiaochang, the supporting equipment for the plunger wells of the four gas reservoirs is stable, and the spare materials for maintenance are complete. Damaged equipment can be repaired and replaced in time to ensure the normal operation of the plunger wells. In addition, after many years of application of the plunger gas lift technology and on-site process improvement, some parts and consumables are processed by the staff of the well station, and they are responsible for the daily maintenance of the plunger well, which saves costs.

6. Conclusion

(1) Aiming at the problem of the difficulty of carrying liquid in water-producing gas wells at the low pressure and low production stage of tight sandstone gas reservoirs, field tests of bubble drainage and plunger gas lift drainage gas production technology have been carried out since 2006, and a more intelligent plunger gas was finally selected. As the main drainage gas production process measure in the block, this measure can more accurately regulate the production system, reduce labor intensity and cost, and improve the management efficiency of gas and water wells.

(2) The Bajiaochang Xusi gas reservoir has successively implemented this technology in 15 water producing wells. The number of measured wells accounted for 48% of the total number of wells in production, and the measured production accounted for 31% of the total production. It is already in the
stage of wide application. Through this measure, low-pressure, low-yield gas wells have been continuously carrying water and stable production, maintained gas well productivity, and delayed production decline. The production decline in the later stage of production is controlled at about 6%, and good application effects have been achieved.

(3) Through years of on-site application and improvement of the plunger gas lift drainage gas production process, a set of practical plunger well management regulations have been formed, which clarifies the main reasons that affect the effectiveness of plunger gas lift drainage, including well conditions, production Regarding system adjustment and optimization and post-maintenance of plunger technology, it provides a reference for similar gas reservoirs to implement plunger gas lift technology testing and popularization and application.

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