Economic Applicability Evaluation of Drainage Gas Production Technology in Tight Sandstone Gas Reservoir

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Abstract. With the development of Sulige gas field, the recovery degree of the gas field increases gradually, the formation energy decreases continuously, the proportion of water-producing gas wells increases year by year, and drainage gas production has gradually become the main technical means to stabilize production and increase production. Under the requirement of low cost, quality improvement, efficiency enhancement and benefit development, according to the production characteristics of gas wells in Sulige gas field, a judgment model of gas well liquid accumulation is established. Sensitivity analysis and model simplification of critical liquid carrying flow method are carried out to analyze the economic applicability of various drainage gas production technologies. The research shows that the early intervention of drainage gas production technology in gas wells at the initial stage of liquid accumulation can effectively prolong the period. Gas well life cycle, improve gas well recovery.

1. Introduction
Unlike conventional gas reservoirs, Sulige gas field is a compact gas reservoir with complex geological conditions and typical characteristics of "three low" (low permeability, low pressure and low abundance). Aiming at the diagnostic method of gas well fluid accumulation in Sulige gas field, Chinese scholars have done a lot of research. Xie Yapeng and others have analyzed the factors affecting the critical fluid carrying capacity of gas wells, and compiled the diagnostic software of fluid accumulation by using the screened model and gas production curve. There is no obvious stable production period for gas wells in tight gas reservoirs. In addition to new wells, stable production is mainly implemented by drainage gas production technology, and good field application effect and economic benefits have been achieved. Yu Shuming, Liu Yongguo and Zhang Haoran introduced the application status of drainage gas production technology measures in Sulige gas field, pointed out the development direction of drainage gas production technology, but lacked deep research and understanding of economic adaptability evaluation of drainage gas production technology.[1][2][3][4]

Aiming at cost reduction, efficiency increase and benefit development, and aiming at the development status of Sulige gas field, a set of pertinent, economic and adaptable matching technology series for strong drainage and production is formed by carrying out economic adaptability evaluation research of various drainage and gas production processes, which ultimately provides effective theoretical support for field application.

2. Judgment Model of Gas Well Fluid Accumulation

2.1 Ideas for judging fluid accumulation in gas wells (Fig. 1)
Combining with the production characteristics of the liquid accumulation wells in Sulige gas field, the judgment and drainage of the liquid accumulation in gas wells are carried out, and the three-stage judgment idea of the gas well drainage-liquid accumulation judgment-liquid accumulation verification is formed to judge the liquid accumulation in gas wells, which realizes the qualitative judgment of the liquid accumulation condition and the quantitative determination of the liquid accumulation in wellbore.

2.2 Judging theoretical model of gas well fluid accumulation
According to the basic theory of IPR (inflow dynamic curve) and percolation mechanics of gas wells, the comprehensive influence of liquid accumulation on gas well production is analyzed.

2.2.1 Mechanism of liquid accumulation in gas wells [5]

Gas wells usually produce natural gas by entraining liquid in the form of fog flow. When the gas reservoir pressure is exhausted, the gas flow rate in the wellbore decreases, and the liquid carrying capacity of the gas also decreases. When the gas flow rate drops to the critical velocity, the liquid begins to accumulate in the wellbore, resulting in unstable multiphase flow. The gas flow in the wellbore also begins to change from annular mist flow to eddy flow and then to slug flow. Accumulated liquid increases bottom hole pressure and reduces gas well production, which further reduces gas flow rate and eventually converts to bubble flow. When bottom hole pressure exceeds gas
reservoir pressure, gas well stops production. As shown in Fig. 2, (1) The gas flow rate is high enough to lift all the liquid out of the wellbore. (2) As the gas flow rate decreases, the gas energy is not enough to lift all the liquid out of the wellbore. Some liquids begin to fall back and accumulate slowly. (4) When the liquid accumulates to a certain amount, the liquid enters the formation near the bottom of the well. (5) The unloading of the liquid causes the gas to unload. It can carry liquid to the ground. This process continues to circulate, resulting in intermittent accumulation of fluid in gas wells until the gas reservoir energy is exhausted and the liquid kills the gas well.

2.3 Judgment method and model for gas well fluid accumulation in Sulige gas field

2.3.1 Judgment based on pressure and daily output change

According to the production curve of gas wells (fig. 3), the change of casing pressure in gas wells is analyzed and the liquid accumulation in gas wells is judged.

A. Oil and casing differential pressure method: oil pressure drop, casing pressure rise, scissors difference, daily production decline, gas wells without packers and long shut-in casing pressure can not be balanced, it can be judged that there is fluid accumulation in the tubing.

B. The casing pressure remains unchanged and the daily production decreases, which indicates that there is fluid accumulation in both oil and casing.

C. Sheathing pressure and daily output fluctuated periodically in a zigzag manner, and both showed opposite trends. It shows that the gas well can discharge part of the wellbore fluid after its productivity is restored, but it can not discharge continuously.

Fig. 3 Gas well production curve

2.3.2 Min-Li Method (Critical Fluid-carrying Flow Method) [6]

Based on Hinze theory, Li Min, a Chinese researcher, believes that droplets will become ellipsoids rather than the spheres assumed by Turner under the action of high-speed airflow. It has been proved to be in line with the actual situation on site. Li Min gives the formula of critical velocity/flow rate.

In the formula, \( P = 1070 \text{kg/m}^3 \) (Surigh average); \( \gamma = 60 \times 10^3 \text{N/m} \) (Turner empirical value); gamma \( g = 0.55 \) (Surigh average); \( Z = 0.847 \) (Hall method iterative calculation); \( T = 293 \text{k}, P = 10 \text{MPa}; \) correction coefficient \( 950 = 0.857L^3 -3 \)

According to the sensitivity analysis of the main parameters of Li-Min formula, it will simplify the calculation results with less influence and mine conditions. Combining with computer simulation and comparative analysis of real data of 20 wells, the critical fluid carrying flow field model for Su75 block is established, and the correction coefficient is 0.857.

The revised minimum liquid-carrying flow meter is obtained (Table 1).

Table 1 Minimum Critical Fluid-carrying Flow Meter

| Tubing Diameter | Minimum Liquid-carrying Capacity (10^4 m^3/d) |
|-----------------|-----------------------------------------------|
| 73.02mm tubing  | Wellhead pressure (MPa) \( \gamma \)         |
| 60.3mm tubing   | Wellhead pressure (MPa) \( \gamma \)         |
| 48.26mm tubing  | Wellhead pressure (MPa) \( \gamma \)         |
2.3.3 Kinetic Energy Factor Method

Kinetic energy factor (at the shoe of the tubing) reflects the flow characteristics of gas-water two-phase in the tubing. Its formula is expressed as:

\[
K = V_t \sqrt{\rho_t} = 9.3 \times 10^{-7} \frac{Q}{D^2} \sqrt{\frac{\mu \cdot T_s \cdot Z_s}{P_i}}
\]

The relationship between flow velocity and critical velocity is analyzed. When the bottom hole velocity is infinitely close to ellipsoidal critical velocity, the kinetic energy factor is 5; when the bottom hole velocity is infinitely close to Turner model, the kinetic energy factor is 12. If the kinetic energy factor is less than 5, there must be fluid accumulation in wellbore. When the kinetic energy factor is greater than 5 and less than 12, there may be fluid accumulation, but when the kinetic energy factor is greater than 12, there will be no fluid accumulation. Through production practice and field measurement, kinetic energy factor 8 is taken as the judgment standard.

|   | 1   | 0.56 | 1   | 0.34 | 1   | 0.21 |
|---|-----|------|-----|------|-----|------|
| 2 | 0.80| 2    | 0.48| 2    | 0.30|
| 3 | 0.98| 3    | 0.59| 3    | 0.37|
| 4 | 1.14| 4    | 0.69| 4    | 0.43|
| 5 | 1.28| 5    | 0.77| 5    | 0.48|
| 6 | 1.41| 6    | 0.85| 6    | 0.53|
| 7 | 1.53| 7    | 0.92| 7    | 0.58|
| 8 | 1.64| 8    | 0.99| 8    | 0.62|
| 9 | 1.75| 9    | 1.05| 9    | 0.66|
| 10| 1.85|10    | 1.11| 10   | 0.69|

Fig. 4 Limin Model Discrimination Results

Fig. 5 Kinetic Energy Factor Model Discrimination Results
Fig. 6 Revised New Model Discrimination Conclusion

By synthesizing three methods of judging fluid accumulation, the critical fluid carrying capacity of 100 water producing wells measured in Su75 block is calculated. Compared with other models, the new model has a higher coincidence rate (Fig. 4, Fig. 5, Fig. 6, Table 2).

Table 2 Comparisons of coincidence rates for different models

| Model                      | Kinetic energy factor | Li Min model | Modified model |
|----------------------------|-----------------------|--------------|---------------|
| Correct Judgment of Well Number | 64                    | 84           | 91            |
| Correct judgment of proportion     | 64%                   | 84%          | 91%           |
| Misjudgement of Well Number     | 36                    | 16           | 9             |
| Misjudgement Ratio             | 36%                   | 16%          | 9%            |

2.4 Validation Method of Gas Well Fluid Accumulation

At present, the methods of verifying gas well liquid accumulation in Sulige gas field are mainly based on acoustic liquid level tester, single well gas-liquid measurement and pressure gradient test. Among them, acoustic liquid level tester and pressure gradient test can measure the height of wellbore liquid accumulation and calculate the volume of liquid accumulation. Gas-liquid metering in a single well can measure the liquid carrying capacity of the current daily production capacity, and can also verify the drainage effect of the implemented measures.

3. Applicability Analysis of Drainage Gas Production Technology

3.1 Sequence of Drainage Gas Production Technology in Sulige Gas Field

In the Sulige Gasfield, aiming at the general characteristics of "low pressure, low yield and small water quantity" in gas wells, after years of tackling key problems, a series of drainage and gas recovery technologies with the characteristics of Sulige, which are mainly composed of foam drainage, plunger gas lift and velocity pipe string, are supplemented by other drainage and gas recovery technologies (Table 3), supporting the stable production of gas fields.

Table 3 Sequence of Drainage Gas Production Technology in Sulige Gas Field

| Liquid carrying system | Reasonable allocation of production |
|------------------------|-------------------------------------|
|                        | Delivery and delivery               |
| Drainage technology    | Foam drainage gas recovery          |
|                        | Plunger gas lift drainage gas recovery |
### 3.2 Economic applicability analysis

#### 3.2.1 Foam drainage gas recovery

Well selection conditions: daily gas production is less than 0.3 *10⁴ m³, casing pressure > 8 MPa, liquid level is less than 1500 meters; daily gas production is 0.3-0.8 *10⁴ m³, casing pressure > 5 MPa, liquid level is less than 1000 meters; daily gas production is > 0.8 *10⁴ m³, casing pressure rises 10% in 10 days (starting liquid accumulation), or casing pressure is stable, daily gas production decreases by more than 10%, bubble drainage is implemented to maintain stable production of gas wells.

Process applicability: It has strong applicability, quick effect, does not affect the normal production of gas wells, and is suitable for any liquid accumulation stage of gas well production.

Technical advantages and disadvantages: advantages: simple process, low cost and quick effect; Disadvantages: High cumulative cost, heavy filling workload, need defoaming, demulsification, water treatment.

Table 4 Statistics on the economic benefits of foam drainage and gas recovery over the past 75 years in block Su

| Bubble discharge risk operation | Number of wells (wells) | Annual cumulative gas increment (10⁴m³) | Increasing gas revenue (10,000 yuan) | Cost Consumption (RMB 10,000 yuan) | Net profit (10,000 yuan) | Cost (yuan/party) |
|--------------------------------|-------------------------|----------------------------------------|-------------------------------------|-------------------------------------|-----------------------|-----------------|
| 2012 year                      | 53                      | 1193.14                                | 897.24                              | 373.75                              | 523.49                | 0.31            |
| 2013 year                      | 65                      | 1764.63                                | 1327                                | 472.11                              | 854.86                | 0.27            |
| 2014 year                      | 86                      | 1819                                   | 1367.9                              | 527.8                               | 840.1                 | 0.29            |
| 2015 year                      | 91                      | 2352.5164                              | 1606.55                             | 401.3293                            | 1205.2173             | 0.17            |
| 2016 year                      | 123                     | 4252.0848                              | 2903.77                             | 641.488                             | 2262.2845             | 0.15            |
| 2017 year                      | 119                     | 5280.1166                              | 3605.82                             | 923.0858                            | 2682.7354             | 0.17            |
| 2018 year                      | 133                     | 6798.1697                              | 4642.51                             | 1136                                | 3506.5082             | 0.17            |
| Total                          | 670                     | 23459.6575                             | 16350.79                            | 4475.563                            | 11875.195             | 0.19            |

#### 3.2.2 Plunger gas lift drainage gas recovery

Well selection conditions: casing pressure is 5-15 MPa, daily gas production is 3000-5000 m³/d, water production is less than 20 m³/d, pipe diameter is more than 47 mm, inner diameter is 62.0 mm or 50.7 mm, pipe string is unobstructed, there is a certain pressure recovery rate, pressure recovery rate after shutdown is more than 3 MPa/24h.
Technological applicability: According to the effect of plunger gas lift implementation, dynamic classification of type II wells has quick recovery of shut-in pressure and good effect of measures; load factor should be less than 50% when plunger is put into operation, and medium liquid accumulation stage should be selected when plunger is put into operation; dynamic tracking analysis should be carried out in time to optimize operation system, load coefficient of field plunger wells is 10%-35%, and pressure difference of gas wells is 3-5 MPa, which is solid. The application effect is better.

Technical advantages and disadvantages: advantages: high degree of automation, low production and strong adaptability; disadvantages: Need external electricity or gas source, high input and operation cost, great damage to formation.

Table 5 Statistical Table of Economic Benefits of Plunger Gas-lift Drainage Gas Production in Su75 Block

| Plunger gas lift drainage gas recovery | Number of wells (wells) | Annual cumulative gas increment (104m3) | Increasing gas revenue (10,000 yuan) | Cost depletion (10000 yuan) | Net profit (10,000 yuan) | Cost (yuan/party) |
|--------------------------------------|------------------------|----------------------------------------|------------------------------------|---------------------------|-------------------------|------------------|
| 2012 year                            | 5                      | 235.52                                 | 160.84                             | 42                        | 118.84                  | 0.18             |
| 2013 year                            | 0                      | 164.98                                 | 112.67                             | 41.3                      | 71.37                   | 0.25             |
| 2014 year                            | 0                      | 39.00                                  | 26.63                              | 6.83                      | 19.80                   | 0.18             |
| 2015 year                            | 15                     | 1011.10                                | 690.49                             | 86.45                     | 604.04                  | 0.09             |
| 2016 year                            | 6                      | 1247.20                                | 851.72                             | 111.23                    | 740.48                  | 0.09             |
| 2017 year                            | 0                      | 1041.75                                | 711.42                             | 53.34                     | 658.08                  | 0.05             |
| 2018 year                            | 4                      | 1249.27                                | 853.13                             | 93.85                     | 759.29                  | 0.08             |
| Total                                | 30                     | 4988.82                                | 3406.89                            | 435                       | 2971.89                 | 0.13             |

3.2.3 Gas-lift drainage gas recovery

Well selection conditions: casing pressure (> 6MPa), with a certain formation energy, serious fluid accumulation and oil-lined gas wells; after the shutdown of compressor, casing pressure rises and production decreases substantially in liquid accumulation wells or blowout shutdown wells.

Process applicability: Gas lift has a good effect on gas lift of water flooded liquid accumulation wells with better productivity, assistant bubble drainage and interruption after resumption of production can achieve the effect of resuming continuous production of gas wells, and gas lift has a good effect on increasing production of gas wells without throttles. It is suggested that gas lift wells should try their best to salvage the wellbore throttle; through multiple gas lift or optimization process control, the accumulation of fluid in wellbore and formation can be effectively eliminated, and the effect of gas lift can be significantly improved; gas lift has no obvious effect on gas lift of gas wells with large water output and low productivity; gas lift of wellbore fluid is returned to formation by gas lift pressure to damage formation; and it is suggested that formation damage be reduced by combining wellbore pressure reduction.

Technical Advantages and Disadvantages: Advantages: Large Drainage
Disadvantage: Need external electricity or gas source, high input and operation cost, great damage to formation.

Table 6 Statistical Table of Economic Benefits of Gas-lift Drainage and Gas Production in Su75 Block

| Gas-lift drainage gas recovery | Number of wells (wells) | Annual cumulative gas increment (104m3) | Increasing gas revenue (10,000 yuan) | Cost Consumption (RMB 10,000) | Net profit (10,000 yuan) | Cost (yuan/party) |
|-----------------------------|------------------------|----------------------------------------|------------------------------------|---------------------------|-------------------------|------------------|
| 2012 year                   | 19                     | 917.1526                                | 689.7                              | 80.8                      | 608.9                   | 0.09             |
| 2013 year                   | 50                     | 1947.8195                               | 1464.76                            | 241.72                    | 1223.04                 | 0.12             |
2014 year    75  1589.9437  1190.55  274.56  915.99  0.17  
2015 year    44  829.1196  578.71  154.28  424.43  0.19  
2016 year    16  754.9169  564.5571  94.62  469.9371  0.13  
2017 year    32  605.9602  413.81  108.46  305.35  0.18  
2018 year    17  261.8906  148.12  64.6271  83.4929  0.25  
Total        253  6906.8031  5050.207  1019.067  4031.14  0.16  

3.2.4 Speed Pipe Drainage and Gas Production
Well selection conditions: daily gas production > 0.2 *104 m3/d, casing pressure: between 5 and 15 MPa, casing pressure difference: <6 MPa, remaining recoverable reserves prediction greater than 500 *104 m3, water volume less than 10 m3/d.

Technological applicability: Well selection of velocity string must be done well, assistant foam drainage and intermittent production should be done in the later stage of production to prolong the production period of gas wells.

Technical advantages and disadvantages: advantages: continuous gas and water production, small management workload;
Disadvantage: High primary cost and low output need to cooperate with other measures.

Table 7 Statistical Table of Economic Benefits of Speed Pipe Drainage and Gas Production in Su75 Block in 2012 (Cost of Auxiliary Measures Not Calculated)

| Particular year | Execution well (mouth) | Average Daily Gas Increase in Single Well (104m3/d) | Annual Accumulative Gas Increase (104m3) | Gas gain (10000 yuan) | Cost depletion (10000 yuan) | Net profit (10,000 yuan) | Cost (yuan/party) |
|-----------------|------------------------|-----------------------------------------------------|------------------------------------------|-----------------------|-----------------------------|--------------------------|------------------|
| 2012            | 5                      | 0.12                                                | 157.31                                   | 107.43                | 563.53                       | 0.11                     |                  |
| 2013            | 5                      | 0.21                                                | 175.12                                   | 119.59                |                             |                          |                  |
| 2014            | 5                      | 0.1                                                 | 493                                      | 336.67                |                             |                          |                  |
| 2015            | 5                      | 0.28                                                | 70.9804                                  | 48.47                 |                             |                          |                  |
| 2016            | 5                      | 0.55                                                | 85.9102                                  | 58.67                 |                             |                          |                  |
| Total           | 5                      | 0.92                                                | 982.3206                                 | 670.83                | 170.3                       | 563.53                   | 0.11             |

3.2.5 Gas recovery by eddy current drainage
The eddy current drainage gas production technology has the characteristics of reducing critical liquid carrying capacity, increasing liquid carrying rate and reducing wellbore pressure loss.

Well selection principles: serious fluid accumulation well, water-gas ratio < 100 square/10000 square; formation pressure coefficient > 0.6; gas production is less than the minimum critical fluid carrying flow, and pipe diameter is unimpeded.

Technological applicability: In the absence of downhole throttle, it is more conducive to drainage if the eddy current tool goes down to the position close to the gas reservoir; in the case of throttle, it is more conducive to drainage if the eddy current tool goes down to the position close to the throttle; whether the next stage or the second stage of the eddy current tool, at least one stage should go down to the liquid level to ensure the effect of downhole eddy current tool drainage; Gas production technology is suitable for gas wells with certain productivity and can carry liquid continuously and steadily; from the field application, gas production is greater than 0.4 *104 m3/d, casing pressure is greater than 6 MPa, and the application of eddy current technology in block gas wells shows that it can increase production and prolong the self-blowout gas production time of gas wells when well
selection is accurate. Some gas wells with little effect need to be combined with other combined drainage and gas production processes.

Table 8 Statistical Table of Economic Benefits of Eddy Current Drainage Gas Production in Su75 Block

| Gas recovery by eddy current drainage | Number of wells (wells) | Annual cumulative gas increment (10^4m³) | Increasing gas revenue (10,000 yuan) | Cost Consumption (RMB 10,000) | Net profit (10,000 yuan) | Cost (yuan/party) |
|--------------------------------------|-------------------------|------------------------------------------|-------------------------------------|-------------------|------------------------|-------------------|
| 2014 year                            | 8                       | 117.9506                                 | 201.79                              | 38                | 163.79                 | 0.32              |

3.2.6 Gas recovery by eddy current drainage

Synchronized rotary compressor drainage and gas recovery: It is a dynamic pressurized drainage and gas recovery technology which integrates compressor, mixing pump and vacuum pump. Features: No fixed compression ratio, gas-liquid mixed transportation, strong sediment resistance. The implementation of one mouthpiece in Su75 block is not effective.

3.2.7 Mechanical Drainage and Drainage for Gas Production

In Su75 block, the technology has not been implemented. In other blocks, the effect of the technology is better. Outside electricity is 400,000 yuan + 1 million yuan (equipment and pipe string, workover) + 200,000 yuan / year (two pump checks) + 60,000 yuan / year (electricity fee and maintenance).

Technical advantages and disadvantages: advantages: low cost, mature technology;
Disadvantages: external electricity, short cycle of deep well pump inspection, large workload of operation and maintenance.

3.2.8 esp

In Su75 block, the construction cost of this technology is high in other blocks. The external electricity is 400,000 yuan + 4,000,000 yuan (equipment, workover) + 100,000 yuan per year (once pump inspection) + 900,000 yuan per year (electricity fee and maintenance); and the factors such as wellbore scaling and sand production have great influence on it.

Advantages and disadvantages of the process: advantages: large drainage;
Disadvantage: External power demand, one-time input and high operating cost, need to check the pump.

3.2.9 Summary

Table 9 Comparison Table of Economic Applicability of Drainage and Gas Production Technologies

| Serial number | Measures | type | Unilateral Gas Consumption Cost (RMB) | Technological limitations |
|---------------|----------|------|-------------------------------------|--------------------------|
| 1             | Bubble row | Short-term | 0.19 | The effect of serious liquid accumulation well is poor, which may cause wellbore blockage. The whole pharmaceutical system needs to be optimized. |
| 2             | Plunger | stage | 0.13 | The application scope is relatively small, and the effect is poor for class III wells with serious fluid accumulation. |
| 3             | gas lift | Short-term | 0.16 | The effusion is pressed back to the bottom, and the effective time is short. |
| 4             | Velocity tube | lifelong | 0.11/0.84 | It is ineffective and easier to be flooded when the flow rate is lower than the critical carrying capacity. |
| 5             | vortex | stage | 0.32 | High cost, no pertinence, the effect of increasing |
Through the analysis of applicability of various drainage and gas recovery technologies, it is shown that the cost of foam drainage gas recovery, plunger gas lift drainage and gas recovery, gas lift drainage gas recovery and velocity pipe drainage and gas recovery process is relatively high, and the implementation effect in Sulige gas field is good, and it is recommended to be popularized and applied.

4. Drainage Gas Production Process Selection Strategy Flow and Application Effect

4.1 Drainage Gas Production Process Selection Strategy Flow

Based on the analysis of the effect of drainage gas production over the years, the process selection area is divided by combining the daily gas production capacity of gas wells with the water-gas ratio (Fig. 7).

Fig. 7 Water-gas ratio and selection of drainage gas production technology

According to casing pressure and daily production, the gas wells put into production are divided into eight categories (Fig 8). Targeted measures are taken for different types of gas wells to achieve fine management of gas wells, improve the management level of gas wells drainage and gas recovery, and enhance the efficiency of measures.
Finally, the overall process of drainage gas production technology implementation is determined: liquid accumulation judgment - gas well classification management optimization measures technology - real-time tracking effect analysis - measure parameter optimization - adjustment process type - real-time tracking effect analysis.

4.2 Analysis of Application Effect of Drainage Gas Production Technology

Fig. 8 Technical Route of Fine Classification Management for Gas Wells

Fig 9 Gas well production performance lazie curve (yearly) of Sulige gas field

Fig 10 Production performance prediction of Sulige gas well after drainage gas recovery
According to the development effect analysis of Sulige gas field over the years, drainage gas production is a necessary stage in the whole life cycle of gas wells (Fig. 9, Fig. 10). Sulige gas field is a typical tight gas reservoir. The production characteristics of tight gas reservoirs determine the situation faced by drainage gas production.

In Sulige tight gas reservoir, the initial production of a single well is low, the pressure production decreases rapidly, and it quickly enters the low pressure and low production stage. At the same time, it decreases gradually in the low pressure and low production stage, and the production time is long (Fig. 11, Fig. 12).

![Fig. 11 Daily production curve of straight/inclined wells in Sulige gas field self-operated area.](image)

![Fig. 12 Change characteristics of production decline law in Sulige gas field](image)

![Fig 13 Twenty-eight wells pressure and production change chart](image)
The long-term production of Twenty-eight wells in Sulige (put into operation in 2002-2003) shows that gas production at low pressure and low production stage occupies a large proportion at present. Over 60% of the total gas production, gas wells have been in low pressure and low production stage for a long time (Fig. 13 and 14).

The average production of a single well is about 3 years, so it is impossible to carry liquid continuously. Measures need to be taken. After 4 years of production, all wells are drainage and gas production measures. More than 80% of the production time of gas wells requires drainage and gas recovery.

There is no obvious stable production period for gas wells in tight gas reservoirs. The stable production mainly depends on the replacement of new wells. Gas wells enter the liquid accumulation stage quickly. Generally, drainage and gas production work is needed in 1-4 years. At present, Sulige adopts the technology of stage drainage and gas production (Fig. 15).

Research and analysis show that early intervention of drainage gas recovery measures in the initial stage of liquid accumulation in gas wells can prolong the life cycle of gas wells, improve the final cumulative production of gas wells and enhance recovery factor.

For example, the daily gas production of Su 75-64-3X well dropped to 0.5 million square meters on July 8, 2016, and the bubble drainage measures were implemented for three consecutive years. After the measures, the annual decline rate decreased by 7.77%, the final cumulative gas production increased by 8.52 million square meters, and the gas production per unit pressure drop increased from 2.84 million square meters/MPa to 3.4579 million square meters/MPa.
For example, the well Su75-89-23X was put into operation in December 2010, with an initial output of 20,000 square meters per day and a reduction of 11,000 square meters in 2015. After the implementation of the plunger gas lift process, gas production has recovered to 10,000 square meters per day. At present, production has remained stable at 0.3 million square meters per day, with a cumulative increase of 3.0601.18 million square meters in four years. Cost input: 228,800 yuan, the cost of unilateral gas increase is only 0.07 yuan.

5. Conclusions
(1) The main methods for judging liquid accumulation in gas wells in Sulige gas field are production curve judgment method, critical fluid carrying flow method and kinetic energy factor method. The critical fluid carrying flow method needs to be revised according to the actual production situation of gas wells in different blocks, and the revised comprehensive model has a higher coincidence rate of liquid accumulation judgment.
(2) through the analysis of the economic applicability of various drainage and gas recovery technologies, it can be seen that the four drainage gas recovery processes, such as foam drainage production, plunger gas lift drainage, gas drainage, gas drainage and gas recovery, are suitable for the Sulige tight gas reservoir with "three low" characteristics, regardless of economic applicability or technical applicability.

(3) Through the analysis of the implementation effect of drainage gas production over the years, it can be seen that early intervention of drainage gas production measures in the early stage of liquid accumulation in gas wells can prolong the life cycle of gas wells, improve the final cumulative production of gas wells and enhance recovery factor.

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