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Chapter 74
Studies on Improving Drainage Gas Recovery Efficiency of Gas Wells

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74.1 Introduction

In the 13th Five-Year Plan period, Daqing Oil Field company intends to increase natural gas production. Presently, nearly forty percent of the gas wells in the oil field have been producing water, which shows a trend of aggravation [1, 2]. It is of great urgency to take reasonable measures to improve drainage gas recovery.

The whole process of drainage gas recovery method applied in Daqing Oil Field has been studied. Based on the influencing factors of the process [3–5], efficiency could be improved in three aspects, including optimizing recovery process, optimizing project design, and improving the quality of materials and equipments. An optimized drainage gas recovery process has been successfully applied in Q block of Daqing Oil Field, and good economic and social benefits have been achieved. This research will technically support the rapid and efficient gas development in Daqing Oil Field.

74.2 The Problems of Drainage Gas Recovery

Gas reservoirs in Daqing Oil Field are of low porosity and permeability with edge and bottom water. Most of produced water in gas wells is edge and bottom water, and the rest is external water. The main reason for water production in the middle and later development is unreasonable production parameters. Gas production in the beginning stage is too large, leading to the fast coning of edge and bottom water into the gas wells. It will form a “water tongue” or “water cone,” especially in the high permeability of gas production, and it is more likely to form a “water tongue” or “water cone” along the high permeability strip. When gas wells produce water, production decreases rapidly and declining period is shortened. The formation water containing salt and corrosion impurities can easily corrode the equipment and pipelines, which will also affect normal production.

In years of development practice, six sets of drainage gas recovery process have been formed, including optimizing pipe string, foam drainage, vortex, plunger lift, mechanical pumping, and electric submersible pump. Drainage gas recovery is getting

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difficult due to the decreasing wellhead pressure, the increasing water–gas ratio, and the complex situation of producing water wells. Presently, some problems exist in the drainage gas recovery process. Firstly, drainage gas recovery method is chosen according to individual experience, and well characteristics are not considered. It will lead to poor production and technical, economic effects. Some wells are shut down due to zero effect. Secondly, project plans are designed according to previous experience and no standards are formed, leading to a deviation from actual application. Finally, some material and equipment used in the process were seriously unqualified, which affect daily normal production.

74.3 Methods of Improving Drainage Gas Recovery Efficiency

In order to improve drainage gas recovery efficiency, three measures have been taken, including optimizing recovery process, optimizing project design, and improving the quality of materials and equipments.

74.3.1 Optimization of Drainage Gas Recovery Process

By general analysis well characteristics, technology performance, and economic benefit, an optimizing flowchart of drainage gas recovery process is formed. The flowchart is shown in Fig. 74.1. Firstly, general influencing parameters are analyzed, including reasons for water production, gas and water production parameters, geological and environmental factors. Then, characteristics, application scope, liquid discharge capacity, and implementation effect of drainage gas recovery technology are also analyzed. Finally, an optimized process can be chosen, including optimizing pipe string, foam drainage, vortex, plunger lift, mechanical pumping, and electric submersible pump [6, 7].

It is necessary to analyze the economic benefits in order to select the best drainage gas recovery process. The main economic indexes include gas production, water yield, lifting efficiency, process cost, the shortest operating cycle, total profit, investment recovery period, and economic limit production. The economic indexes are calculated, respectively, and the economic benefits are determined. If the economic benefit is feasible, the method will be applied in the oil field. Dynamic application effect and economic benefit will be tracked and evaluated in the process to ensure expected results. Otherwise, process will be re-optimized according to the above steps.

For water-producing wells of complex situations, a combination of multiple methods can be applied. It will achieve complementary advantages and larger application scope [5].

74.3.2 Optimization of Drainage Gas Recovery Project Design

The project design of drainage gas recovery should be based on gas reservoir engineering, drilling engineering, and ground engineering in the well area. The design

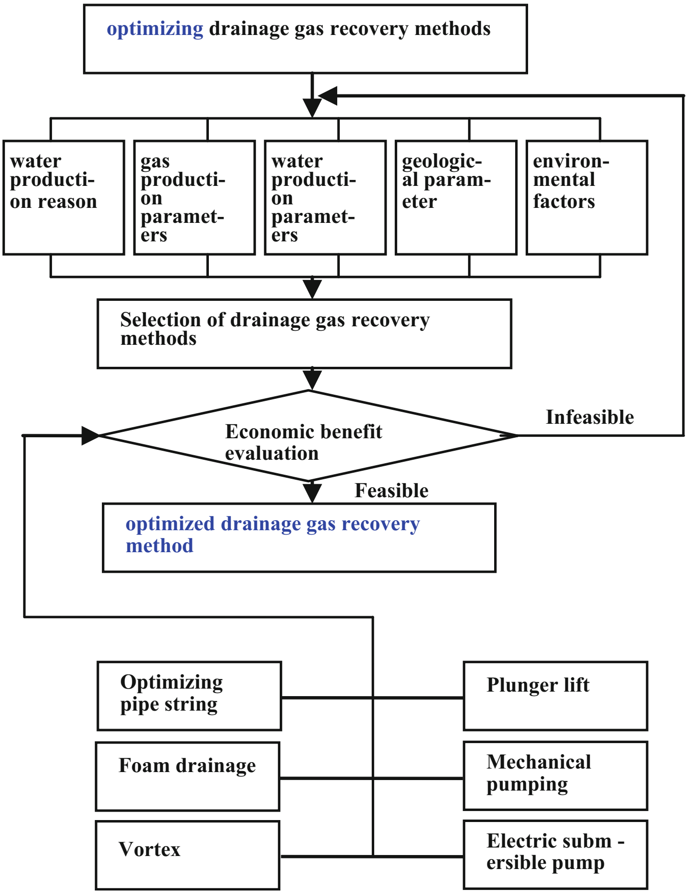

Fig. 74.1. Optimizing flowchart for drainage gas recovery method

should meet the needs of gas production. The final project design should be of high performance, safety, and economy, in order to improve the development and economic benefit of gas production [7].

Taking the foam drainage gas recovery for an example, the design process will be detailed. The foam drainage gas recovery technology is optimized and subdivided, including effusion diagnosis, best time, effusion degree, agent type, injection parameter, and injection process. The monitoring method of annulus liquid level is added in the judgment and analysis of effusion, which could visually and accurately judge liquid level. The parameters database of foaming agent is updated through process design, and the critical flow model is also improved. An injection process for low-temperature environment is established too. Through the above improvements, an integrated design foam drainage process is set up, which can significantly improve the implementation effect and technical level of the foam drainage gas recovery technology.

The optimized project design of foam drainage gas recovery technology in Daqing Oil Field is shown in Fig. 74.2. With the optimized foam project design, gas production of five wells is improved. The average daily gas increment is 9.2×10^3 m^3. Water production is also increased, and the average daily water increment is 2.3 m^3. The cumulative gas increment is 5.76×10^6 m^3.

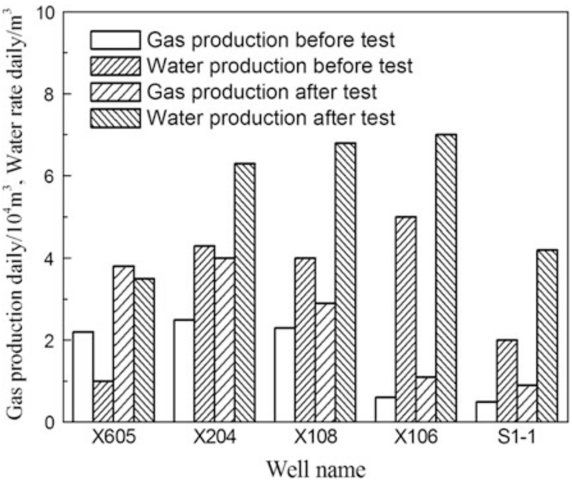

Fig. 74.2. Results of field test of foam drainage gas recovery technology

74.3.3 Quality of Materials and Equipments

The quality of materials and equipment is the key factor in drainage gas recovery. Unqualified materials or equipment might lead to failure of drainage gas recovery technology.

The foaming agents of foam drainage gas recovery technology are illustrated in detail. Foam is a thermodynamically unstable system. Temperature has a great influence on foam properties. The foaming properties and foam stability of the foaming agent decreased significantly at high temperature above 100 °C [8]. To improve the heat resistance of foaming agent, molecules of foaming agent need to be connected with poly oxygen alkyl group or connected with cationic hydrophilic group. Stability agent can also be added to improve heat resistance. Salinity of formation water influences foaming property and stability. Especially, calcium and magnesium ions precipitate with anionic surfactant. Therefore, foaming agent should be salt resistant [9, 10]. The foaming agent should use surfactant, which is not affected by electrolyte in solution. The decisive factor of foam drainage gas recovery is liquid volume with foam of foaming agent. Foam stabilizer can improve foam stability and liquid volume with foam. Therefore, foam stabilizer is added to improve foam properties. Foam stabilizer includes polymer, cellulose, and starch.

Foam properties and liquid volume with foam of the optimized foaming agent are shown in Fig. 74.3. Foam properties and liquid volume with foam of the optimized foaming agent DQG1 and DQG2 are much better than those of DQA1. The foam height and liquid volume with foam of DQG1 and DQG2 are one time higher than those of DQA1. Foaming agents DQG1 and DQG2 have been used in foam drainage gas recovery in Daqing Oil Field.

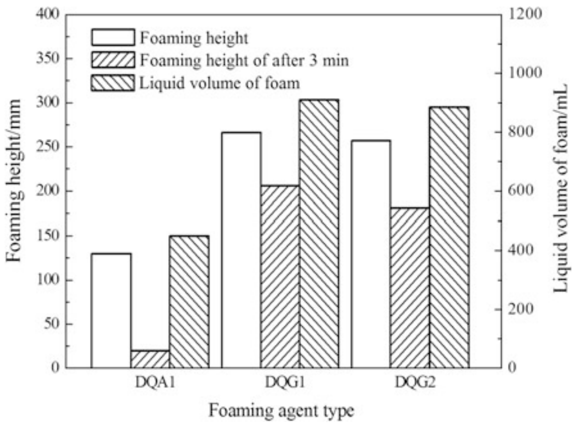

Fig. 74.3. Foam properties of different foaming agent

74.4 Applications

Researches and field tests of drainage gas recovery have been carried out since 2008 in Daqing Oil Field. Based on underground reservoir properties, fluid properties, and gas well parameters, a set of technology has been established, including down-hole choking, foam, and vortex drainage gas recovery technology. And better field application performance is achieved.

Results of field test for foam drainage gas recovery are shown in Fig. 74.4. The average single well increasing gas volume is 0.7×10^4 m^3 per day. The average single well increasing the amount of water is 3.0 m^3 per day. The cumulative gas increment is 5.76×10^6 m^3.

Vortex drainage gas recovery technology is applied in low production wells. Field test result of vortex drainage gas recovery technology is shown in Fig. 74.5. Results show that the average single well increasing gas volume is 0.8×10^4 m^3 per day. The average single well increasing the amount of water is 2.5 m^3 per day. The cumulative gas increment is 1.702×10^7 m^3. Vortex technology is closely connected with well, process parameters, and design. Therefore, vortex project is highly individual and targeted.

Statistical analysis of field test shows that cumulative gas increment is 2.2×10^7 m^3. The economic benefit is 22 million RMB, and the input–output ratio is 1:5.

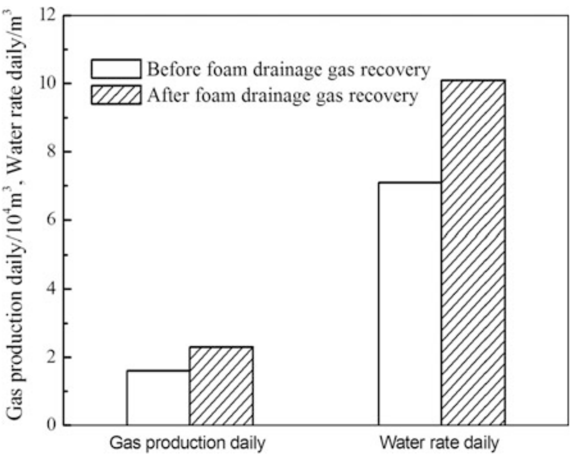

Fig. 74.4. Results of field test for foam drainage gas recovery

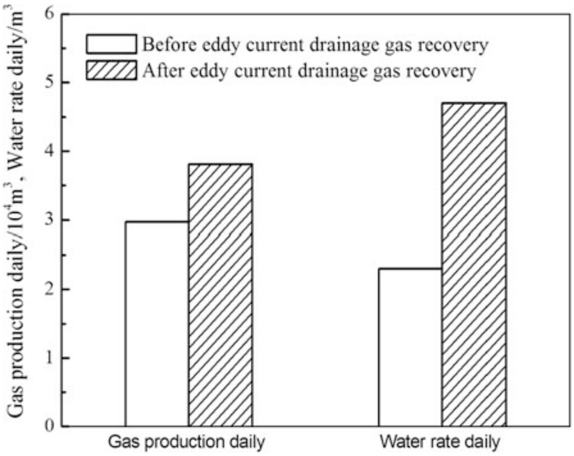

Fig. 74.5. Field test results of vortex drainage gas recovery technology

Nearly forty percent of gas wells in Daqing Oil Field produce water. The number of effusion wells increases year by year. Foam drainage gas recovery technology is of good adaptability, low input, and high output. However, the long-term benefits of vortex technology are higher than that of foam technology. Vortex technology needs no maintenance, and it can effectively make up for the shortage of foam technology. A combination of foam and vortex technologies is formed in Daqing Oil Field.

74.5 Conclusion

Gas recovery process is optimized by general analysis of process characteristics, well parameters, and economic benefits. Projects are individually designed to ensure high performance, safety, and economy. The material and equipments are tested and checked to improve drainage gas recovery efficiency.

Better pilot test results in Q block of Daqing Oil Field are obtained. Gas production increment is 2.2×10^7 m^3, economic benefit is 22 million RMB, and the input–output ratio is 1:5. The combination of foam and vortex technology will form the main drainage gas recovery method in Daqing Oil Field.

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