New progresses in safe, clean and efficient development technologies for high-sulfur gas reservoirs

Huang Liming

National Energy R & D Center of High-Sulfur Gas Reservoir Exploitation, Chengdu, Sichuan 610213, China

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Abstract

In China, there are a lot of high-sulfur gas reservoirs with total proved reserves of over 1 trillion m$^3$, most of which were discovered in the Sichuan Basin. Most high-sulfur gas reservoirs in China, distributed in marine carbonate zones, are characterized by great buried depths, complex geologic conditions, high temperatures, high pressures, high H$_2$S and CO$_2$ content, presenting various challenges in gas field development engineering and production safety. Since the development of Sinian high-sulfur gas reservoirs in the Weiyuan area of the Sichuan Basin started in the 1960s, Wolonghe, Zhongba and other medium to small-scale gas reservoirs with medium to low sulfur content have been developed. Ever since 2009, successful production of Longgang and Puguang in the Sichuan Basin, together with some other high-sulfur gas reservoirs highlighted the breakthroughs in development technologies for high-sulfur gas reservoirs in China. This paper reviews the progress made in gas reservoir engineering, drilling and completion engineering, gas production, pipeline transportation, corrosion control, natural gas purification, HSE and other aspects with consideration of specific requirements related to safe, clean and high-efficient development of high-sulfur gas reservoirs since the “12th Five-Year Plan” period. Finally, considering the challenges in the development of high-sulfur gas reservoirs in China, we summarized the trend in future technological development with the following goals of reducing risks, minimizing environmental damages, and enhancing the efficiency of high-sulfur gas reservoir development.

Keywords: High-sulfur gas reservoir; Gas reservoir engineering; Drilling & completion engineering; Gas recovery engineering; Ground gathering and transportation; Corrosion control technology; Natural gas purification; Safety and environmental protection technological development; Development direction

E-mail address: huanglm@petrochina.com.cn.

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1. Overview of high-sulfur gas reservoir development in China

The basic information of high-sulfur gas fields in China is shown in Table 1. In the 1960s, development started in Sinian high-sulfur gas reservoirs in the Weiyuan area of the Sichuan Basin, China. Subsequently, some medium to small scale and low-to-moderate sulfurous gas reservoirs like Wolonghe and Zhongba were successfully developed, providing more experiences in the development of sulfurous gas reservoirs. After 2000, with the successive discovery of high-sulfur gas reservoirs like Luojiazhai, Dukouhe, Tieshanpo, Longgang, Puguang and Yuanba in northeastern Sichuan Basin and Moxi-Gaoshiti in central Sichuan Basin, the exploration and development of high-sulfur gas reservoirs in China entered a stage of rapid development. The successive and successful production of Longgang and Puguang high-sulfur gas fields in the Sichuan Basin in 2009 and the successful production of Turkmenistan Amu Darya gas field—the first large high-sulfur gas reservoir of CNPC abroad marked the breakthrough of high-sulfur gas reservoir development technology in China. In recent years, the high-sulfur gas reservoir development level of China has been remarkably promoted, and CNPC has possessed the capacity and strength for developing high-sulfur gas reservoirs both at home and abroad. Currently, the development of high-sulfur gas reservoirs is undergoing in Yuanba and Moxi-Gaoshiti of the Sichuan Basin.

2. Current status of high-sulfur gas reservoir development technologies

High-sulfur gas reservoir development technologies in China are progressively developed by learning from overseas high-sulfur gas reservoir development technologies and through persistent researches and practices on the basis of technological integration and application of low/moderate-sulfurous gas field development technologies in the Sichuan Basin over the years. By far, a series of technologies (Table 2) have been available in the aspects of gas reservoir engineering, drilling and completion engineering, gas recovery engineering, ground gathering & transportation and corrosion control, natural gas purification, and safety and environmental protection, which can provide technological support for the successful development of high-sulfur gas reservoirs in China.

Table 1
Statistics of typical high-sulfur gas fields (reservoirs) in China.

<table>
<thead>
<tr>
<th>Gas field</th>
<th>Gas reserves/10⁹ m³</th>
<th>H₂S content</th>
<th>CO₂ content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhongba</td>
<td>186.30</td>
<td>6.75%–13.30%</td>
<td>2.90%–10.00%</td>
</tr>
<tr>
<td>Wolonghe</td>
<td>408.86</td>
<td>5.00%–7.80%</td>
<td>1.30%–1.50%</td>
</tr>
<tr>
<td>Dukouhe</td>
<td>359.00</td>
<td>9.79%–17.10%</td>
<td>6.40%–8.30%</td>
</tr>
<tr>
<td>Tieshanpo</td>
<td>373.97</td>
<td>14.37%</td>
<td>/</td>
</tr>
<tr>
<td>Luojiazhai</td>
<td>797.36</td>
<td>6.70%–16.65%</td>
<td>5.80%–9.10%</td>
</tr>
<tr>
<td>Longgang</td>
<td>720.33</td>
<td>1.67%–8.60%</td>
<td>2.46%–5.10%</td>
</tr>
<tr>
<td>Puguang</td>
<td>3812.59</td>
<td>15.20%</td>
<td>8.60%</td>
</tr>
<tr>
<td>Yuanba</td>
<td>1834.20</td>
<td>2.51%–6.65%</td>
<td>1.63%–11.31%</td>
</tr>
<tr>
<td>Moxi-Gaoshiti</td>
<td>/</td>
<td>92.00%</td>
<td>/</td>
</tr>
</tbody>
</table>

Table 2
Series of technologies for high-sulfur gas reservoir development in China.

<table>
<thead>
<tr>
<th>Series of technologies</th>
<th>Key technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas reservoir engineering</td>
<td>Fine description of strong heterogeneous high-sulfur reservoirs</td>
</tr>
<tr>
<td>Drilling and completion engineering</td>
<td>Drilling fluid and lost circulation prevention and control of high-sulfur gas wells</td>
</tr>
<tr>
<td>Ground gathering &amp; transportation and corrosion control engineering</td>
<td>Assessment on material selection and gathering line welding performance</td>
</tr>
<tr>
<td>Natural gas purification engineering</td>
<td>Total corrosion control of high-sulfur gas fields</td>
</tr>
<tr>
<td>Safety and environmental protection engineering</td>
<td>Emergency response technology in gas field development</td>
</tr>
<tr>
<td>Safety and environmental protection engineering</td>
<td>Quantitative risk evaluation by 3D diffusion simulation</td>
</tr>
</tbody>
</table>

3. New progresses in development technologies for high-sulfur gas reservoirs

To solve key technological problems restricting the safe, clean and efficient recovery of high-sulfur gas reservoirs, the National Energy R&D Center of High-Sulfur Gas Reservoir Exploitation has conducted many researches and field applications. New progress has been made in gas reservoir engineering, drilling and completion engineering, gas recovery engineering, ground gathering & transportation and corrosion control engineering, natural gas purification engineering, safety and environmental protection engineering and other aspects.

3.1. Gas reservoir engineering technologies

Breakthroughs have been made in such technologies as fine description of complex strong heterogeneous high-sulfur reservoirs, fine description of fluid distribution in complex reef shoal gas reservoirs, and water influx performance analysis on strong heterogeneous carbonate high-sulfur hydrous gas reservoirs.

3.1.1. Fine description of complex strong heterogeneous high-sulfur reservoirs

For complex strong heterogeneous reservoirs, there are limited discrimination means and reservoir parameters which cannot be quantitatively described. Accordingly, the technologies including seismic reflection pattern, digital core and imaging logging were combined to form the fine description technology for strong heterogeneous reservoirs. This technology can be used to quantitatively describe the development, matching and spatial structure of fractures, caverns, and pores, and provides a technological support for the selection of prospective areas, allocation of development wells and adjustment of development modes.

3.1.2. Fine description of fluid distribution in complex reef shoal gas reservoirs

For complex reef shoal gas reserves, the fluid distribution in vertical multi-phase reef shoal bodies is complicated. The comprehensive discrimination accuracy of fluid in reef shoal bodies is low, and there is no pertinent depiction method for fine description of fluid distribution. Accordingly, the logging fluid identification method was optimized, and fine description of gas and water was conducted by strata series and blocks, in order to recognize the vertical and lateral distribution of fluid in reef shoal gas reservoirs. Then, well-seismic data and dynamic and static data were combined to finely describe the gas-bearing boundary and gas—water relation of each development unit, laying a foundation for the selection of potential areas, rational water control and definition of development countermeasures.

3.1.3. Water influx performance analysis on strong heterogeneous carbonate high-sulfur hydrous gas reservoirs

The water influx rules of strong heterogeneous carbonate high-sulfur hydrous gas reservoirs are complicated. To solve this problem, on the basis of fine description of reservoir and of gas and water distribution, dynamic and static data, together with qualitative identification and quantitative calculation, were combined to generate the technology of water influx performance analysis on strong heterogeneous carbonate high-sulfur hydrous gas reservoirs. This technology can provide important support for rational water control and enhancing gas reservoir recovery and development benefit of strong heterogeneous carbonate high-sulfur hydrous gas reservoirs.

3.2. Drilling and completion engineering technologies

Drilling and completion of high-sulfur gas wells may suffer high well control risks and complex formation conditions, in addition to extremely difficult operations. In this circumstance, technological researches mainly focus on drilling pressure control, cementing technique, integrity assessment, well test technology, uncontrolled blowout emergency rescue and other aspects. Accordingly, three series of technologies, i.e. drilling & completion, accident prevention, and emergency rescue, have been formed for high-sulfur gas wells.

3.2.1. Safe drilling and well control of high-sulfur gas wells

To ensure downhole safety during the drilling of high-sulfur gas wells, properly treat sulfurous drilling fluid above ground, and address well control risks, numerous efforts have been taken. Firstly, “three models and one method” (rheological parameter prediction model for drilling fluid, equivalent static density (ESD) prediction model, equivalent circulating density (ECD) prediction model, and drilling fluid property and hydraulic parameter design method) were established; on this basis, the drilling fluid property and hydraulic parameter simulator was developed and applied as an important tool for ensuring the safety in high-sulfur drilling. Secondly, four-phase separator and hydrogen sulfide removal facility were innovated to effectively separate oil, gas, fluid and solid, and control and process hydrogen sulfide in the returned drilling fluid. Thirdly, an on-site air-tight detection system was developed for internal packer and tubing/casing thread, which ensures the well control safety in tubing/casing running operation of high-sulfur gas wells.

3.2.2. Completion commissioning and integrity assessment of high-sulfur gas wells

Through hole stability analysis on high-temperature, high-pressure and large-output gas wells, check on mechanical strength of completion string under different conditions, study on corrosion prevention techniques for downhole string, analysis on erosion of completion string and wellhead, optimization of liner parameters and cause analysis on wellhead uplift, a set of comprehensive completion commissioning technologies for high-sulfur gas wells has been developed. Moreover, such detection devices as phased array defectoscope, corrosion monitor and ultrasonic leak hunting instrument were equipped to evaluate two types of integrity, i.e. the corrosive integrity of gas recovery wellhead and downhole tubular goods, and the mechanical integrity of annular
pressure of permanent packer completion. In this way, an integrity assessment and management technology system for high-temperature, high-pressure and high-sulfur gas wells was further improved, contributing to the integrity of high-sulfur gas wells in their life cycles.

3.2.3. Accident prevention and rescue in drilling and completion of high-sulfur gas wells

Some key technological problems exist in high-sulfur gas wells, such as poor performance in real-time and reliable overflow monitoring and outdated emergency rescue technologies and equipment. To solve these problems, overflow indication on-line monitoring & warning system and emergency rescue testing system were developed, as supplement to technologies in accident prevention and rescue in drilling and completion of high-sulfur gas wells. The overflow induction on-line monitoring & warning system can acquire data of site operations in a real-time manner and analyze such data in a real-time manner with the discrimination model, thereby helping to achieve much earlier warning in case of overflow. The emergency rescue testing system, with the model test well and rig as carriers, is capable of rescue in case of uncontrolled blowout, in conjunction with equipment like obstacle cutting, wellhead reset, cooling shielding and emergency communication.

3.3. Gas recovery engineering technologies

In order to reduce the exploitation risks, enhance the recovery factor and realize beneficial development of high-sulfur gas reservoirs, some supporting technologies have been developed, including reservoir stimulation of high-temperature, high-pressure and high-sulfur gas reservoirs, water drainage and gas recovery of high-sulfur deep wells, and downhole throttling of high-sulfur gas wells.

3.3.1. Reservoir stimulation of high-temperature, high-pressure and high-sulfur gas reservoirs

New mechanical packer, degradable temporary blocking ball, fibrous diverting agent and 160 °C temperature-resistant acidizing fluid system were developed, and physical and chemical combined uniform acidizing technology was formed, which meet the requirements for deep acidizing of high-temperature, high-pressure and high-sulfur gas reservoirs. Based on experimental evaluations on acid-rock reaction mechanism, a set of parameter optimization methods for carbonate reservoir acidizing was established, making the acidizing design more pertinent and effective.

3.3.2. Water drainage and gas recovery of high-sulfur and high-temperature deep wells

A high-temperature gas lift valve testing device was developed. This unique device in China can be used to simulate downhole temperature environment in the course of calibration of gas lift valve in high-temperature deep wells. Moreover, the high sulfur-resistant gas lift valve and supporting tools with nitrogen charge of 25 MPa and external pressure resistance of 90 MPa were developed. They have been successfully applied in Longgang 001-31 and Huanglong 001-X1wells.

3.3.3. Downhole throttling of high-sulfur gas wells

For simplifying the ground process flow and expediting the construction of high-sulfur gas wells, the downhole throttling tool with throttling pressure differential reaching 35 MPa and H2S content reaching 225 g/m³ was developed independently.

3.4. Ground gathering & transportation and corrosion control engineering technologies

In the aspect of ground gathering & transportation, some technologies for high-sulfur gasfields have been developed, such as gas gathering technology, gasfield water transportation technology, gas hydrate control technology and associated material selection, and the highly integrated and modularized skid-mounted ground gathering and transportation process for sulfurous gasfield was realized for the first time in China. In the aspect of corrosion control, some overall corrosion prevention technologies were developed in terms of material, inhibitor and surface coating, and a comprehensive corrosion detection (monitoring) system was built.

3.4.1. Gas—liquid multiphase flow and integrative skid-mounted production process

The ground gathering & transportation technologies for high-sulfur gasfields, inclusive of gas gathering technology, gasfield water transportation technology, gas hydrate control technology and associated material selection, can help to realize zero discharge of gasfield water and hydrogen sulfide in the whole process. The integrative skid-mounted production process and equipment integrating gas heating, gas—liquid separation, agent adding, corrosion monitoring, on-site sampling and blowdown system were developed, and they can be manufactured and quickly installed in factory-style batch.

3.4.2. Total corrosion control of high-sulfur gas fields

Due to the harsh corrosive environment of high-sulfur gas reservoirs, the total corrosion control technology inclusive of material optimization, corrosion prevention by inhibitor and supporting corrosion detection (monitoring) system was formed. Tubings made of corrosion-resistant alloy materials like 2830, 2532 and G3 were adopted in wellbore, and annular inhibitor protection fluid was added in the annulus. L360NCS and L360QCS sulfur/corrosion-resistant steel pipelines were universally adopted for ground gathering and transportation, together with inhibitors for corrosion prevention. 1Cr18Ni9Ti material was adopted in the harsh corrosive environment of natural gas purification plants, and coating plus sacrificial anode were adopted for corrosion prevention inside the devices like separators and flash drums. Inhibitor, anti-precipitant and bactericide were jointly used for the water-circulating system, in order to ensure stable water quality. The total corrosion control technology has been intensively applied in the development of Longgang high-sulfur gas field,
revealing that the total corrosion rate of metallic materials used in the ground system is controlled below 0.1 mm/a.

3.4.3. Corrosion monitoring/detection and internal corrosion direct assessment

In view of corrosion control plan adjustment and basic data acquisition for safety assessment, a technology in corrosion monitoring/inspection and internal corrosion direct assessment was formed. FSM and hydrogen probe were innovatively used to realize assessment on inhibitor pre-filming effect. Internal corrosion direct assessment technology based on corrosion mechanism analysis, critical liquid loading analysis, multi-phase flow modeling analysis and corrosion probability analysis was innovatively formed. Moreover, corrosion monitoring/inspection database was established for data query, input, evaluation and prediction.

3.5. Natural gas purification engineering technologies

Desulfuration and decarbonization solvent, sulfur recovery and tail gas treatment technologies for high-sulfur gas were improved, and can be applicable in a wider range of gas quality. The gas—solid SO₂ adsorption technology was developed to replace the traditional SCOT technology. Moreover, a series of technologies were developed to maintain smooth operation of natural gas purification facility and realize supergravity desulfuration and process simulation.

3.5.1. Desulfuration and decarbonization by the solvent method

On the basis of original formula-type desulfuration and decarbonization system, study was conducted on special high-sulfur gas with both H₂S and CO₂ content (volume fraction) exceeding 20% and organic sulfur content exceeding 1000 mg/m³. The developed solvent helps to reduce the regenerated energy consumption by 10% while meeting the national class II commercial gas standard, i.e., in the purified gas, H₂S ≤ 20 mg/m³, and organic sulfur content ≤ 200 mg/m³.

3.5.2. Purification of amine fluid for natural gas desulfurization

After amine fluid for desulfurization was used for a long period, many problems have occurred due to the reduction of active components, such as poorer desulfurization performance and challenging storage and treatment of waste solvents. To solve these problems, two kinds of foam-inducing remover were developed independently, with removal rate exceeding 99%. Additionally, these removers can help to maintain the hydrogen sulfide selective absorption capability of activated solvent, and make the solvent restore to a fresh one.

3.5.3. Treatment of tail gas in sulfur recovery

As per new standards, tail gas in sulfur recovery of the natural gas purification plants may be unqualified. In this regard, a series of new technologies were developed to treat such tail gas. Gas—solid adsorption was used to remove SO₂. New SO₂ removal catalyst and associated technology were developed to control the SO₃ content in Claus tail gas to be below 300 mg/m³. New recyclable amine process SO₂ solvent and associated removal technology were developed, with acid gas loading almost doubled compared with the SCOT technology, which can remove SO₂ in Claus tail gas to be lower than 200 mg/m³.

3.6. Safety and environmental protection engineering technologies

The areas where high-sulfur gas reservoirs are developed are characterized by complex topography, dense population, high production of gas well and high safety risks. Accordingly, a series of safe and clean production technologies were developed in the development of high-sulfur gas fields, which mainly involve environmental impact assessment, safety assessment, risk prevention and control and emergency security, as well as pollutant disposal and cyclic utilization and energy saving and emission reduction. These technologies provide great support for the safe, efficient and clean development of high-sulfur gas fields.

3.6.1. Quantitative risk evaluation on sulfurous gas leakage by 3D diffusion simulation

Under complex topography and local weather conditions, high-sulfur gas development may suffer severe accidents, which can hardly be predicted and assessed accurately. In this regard, 3D diffusion simulation technology and quantitative risk evaluation method and software based on computational fluid dynamics (CFD) were innovatively formed, which can enhance the evaluation precision by 50% or more for hills and moderate-low mountain zones, and shorten the evaluation cycle by more than 90%.

3.6.2. Emergency security for the regions of high-sulfur gas fields

Currently, there are numerous high-sulfur gas fields held by different owners, and emergency security systems of local authorities and enterprises are relatively independent. In this circumstance, a regional emergency resource optimization and allocation plan inclusive of fire fighting, medical treatment and transportation was proposed, and a regional emergency management system framework (Fig. 1) was established, which help to improve the interaction between enterprises and between enterprise and local authority, and realize scientific regional risk precaution and emergency management. These achievements have been promoted in the working-out of emergency plan for natural gas project in the northeastern Sichuan Basin and the safety assessment in the Amu Darya gas recovery plant.

3.6.3. Water reinjection risk prevention and control in sulfurous gas fields

By means of risk system identification in respect of ground and wellbore integrity and reinjection wells/layers, the ground reinjection water processing system optimization, wellbore leakage monitoring and reinjection water channeling
preventive measures were proposed. As a result, a technology for water reinjection risk prevention and control for sulfurous gas field (Fig. 2) was formed, which provides technical support for the risk assessment and management of reinjection wells in the Longgang reef shoal gas reservoir.

4. Typical application cases of associated development technologies

In China, the associated development technologies and standard and specification systems for high-sulfur gas
reservoirs were developed through researches with close consideration to the demands in development engineering of high-sulfur gas reservoirs and improved in practical application. They provide strong support in the development of high-sulfur gas fields in China.

4.1. Development of Longgang large-scale high-sulfur reef shoal gas reservoir

Discovered in October 2006, the Longgang reef shoal gas reservoir consists of two sets of reservoirs (Feixianguan Formation oolite shoal and Changxing Formation organic reef), with the output of high-yield well exceeding $100 \times 10^6$ m$^3$/d. The H$_2$S content of Feixianguan Formation and Changxing Formation exceeds 30 g/m$^3$ or even reaches 130.3 g/m$^3$. Many technological challenges exist in the development of the gas reservoir. For example, as the first ultra-deep (6000 m) large-scale high-sulfur gas reservoir in China, it has no technology and experience that could be referred; it was hard to predict the reservoir and fluid distribution of strong heterogeneous lithologic carbonate gas reservoir; the requirements are high for drilling, completion and gas recovery technologies of high-temperature (150 °C) deep wells with multiple pay zones under the condition of water producing; due to water production in the gas field, high requirements are raised in the gathering and corrosion prevention technology; comprehensive HSE security measures should be taken for development of high-sulfur gas field in densely populated mountainous areas. Considering these challenges, CNPC used the available development technologies for high-sulfur gas reservoirs (e.g., description and geologic modeling for complex reef shoal gas reservoirs with multiple pressure systems, experimental evaluation on special filtration mechanism of high-sulfur gas reservoirs, and non-steady test analysis on deliverability of gas wells) jointly to complete the $20 \times 10^8$ m$^3$/a production test project only within 18 months, which set a successful antecedence in large-scale high-sulfur gas field development in China. As of October 2014, the Longgang reef shoal gas reservoir had been in safe and smooth production for 1905 days, with cumulative gas production exceeding $62 \times 10^9$ m$^3$.

4.2. Development of Samandepe large high-sulfur gas field at the right bank of Amu Darya River, Turkmenistan

Located in the west of Block A at the right bank of Amu Darya River, with H$_2$S content of 35–45 g/m$^3$, the Samandepe gas field was put into production in December 1986. After breakup of the former Soviet Union in 1993, all the wells were shut in. CNPC took over the project in July 2007. Many problems exist in the gas field, such as difficult wellbore integrity evaluation and production restoration of old high-sulfur wells that had been shut in for years, high single well output, complicated pressure systems, high well control risks during drilling, large processing scale of natural gas purification facility (designed daily processing capacity of $4 \times 450 \times 10^4$ m$^3$), short construction period, higher technological requirements for design, construction, and operation, and serious emulsification in multiphase transportation of gas, oil and water via pipeline. In such a case, CNPC combined the available associated technologies like optimization of development mode of complex high-sulfur gas reservoirs, quick well intervention and completion, joint corrosion prevention and monitoring by both material and inhibitor, and large-scale desulfurization and sulfur recovery, to efficiently complete the $60 \times 10^8$ m$^3$/a productivity engineering project in less than 18 months, which was successfully commissioned in December 2009. By far, this project has been in safe and smooth operation for 1800 days, and has delivered totally $242.18 \times 10^8$ m$^3$ commercial gas to the Trans-Asia Gas Pipeline, helping to alleviate the stress in natural gas supply in China to some extent.

5. Trend in development technologies for high-sulfur gas reservoirs

5.1. Challenges

Through technological researches and practical applications in more than half a century, great breakthroughs and progress have been made in the development technologies for high-sulfur gas reservoirs in China. However, many challenges still exist for these technologies in terms of deeper understanding, configuration, improvement, environmental protection, development cost and development benefits.

1) The high-sulfur gas reservoirs newly discovered are characterized by greater burial depth, higher temperature and pressure, diverse reservoir types, complicated gas–water relation and more difficult development, and they set higher demands for controlling drilling trajectory, increasing ROP, controlling safety risk, completion material and technology as well as reservoir stimulation fluid, tool and technology.

2) The high-sulfur gas reservoirs developed are confronting a series of problems like universal water production and wellbore or formation plugging. Accordingly, it is required that fine description of gas reservoir be further strengthened and the associated technologies for water drainage, water control and plugging removal be improved.

3) The new safe production law and environmental protection law of China are increasingly strict, which further stress the treatment of drilling fluid waste of high-sulfur gas reservoirs, sulfurous gas test unloading, water treatment of sulfurous gas fields, SO$_2$ emission control of purification desulfuration tail gas and other aspects.

5.2. Trend of technological development

Safety, cleanliness and high efficiency are always focal points in the development of high-sulfur gas reservoirs. In the future, more efforts will also be made to work out technologies
for maintaining safe, clean and efficient development of high-sulfur gas reservoirs.

1) Safety risks should be reduced. Associated technologies will be maintained to keep the integrity of wellbore and ground system for high-sulfur gas wells. Failure database and detection (monitoring) system will be established and improved for high-sulfur gas field facilities, and quantitative risk evaluation method for wellbore integrity and gathering pipelines will be prepared, in order to ensure safe production in the life cycle of high-sulfur gas wells. Regional emergency system framework and emergency resource optimization allocation plan for high-sulfur gas fields will be improved, and effective interaction between enterprises and between enterprise and local authority will be promoted, so as to upgrade emergency control level.

2) Environmental hazards should be mitigated. Ecological monitoring technology for vegetation will be developed, and ecological environment quality will be traced, aiming to minimize the impacts on ecological environment in the regions of high-sulfur gas field. Water reinjection risk control standards will be improved, and technical researches will be conducted to ensure the drainage of qualified water, in order to continuously promote clean production level. Large-scale desulfurization, high-sulfur natural gas purification and tail gas SO₂ processing technologies will be further improved to enhance desulfurization efficiency, reduce the discharge concentration and volume of SO₂ in the desulfurized tail gas and mitigate pollution to the atmosphere. New processing technologies like drilling fluid waste processing by microorganism will be developed to realize cleaner drilling.

3) Development benefits of high-sulfur gas reservoirs should be increased. The contradiction between safety and economy will be effectively balanced, the tracing evaluation and perfection of existing development technologies will be strengthened, and the development cost will be reduced, in order to enhance the gas field development level and benefit. Firstly, the theory and technology for enhancing the recovery of gas reservoirs will be deepened, including the coexisting system fluid phase theory of highly acidic gas reservoir, experimental evaluation and dynamic analysis of elemental sulfur deposition and damage mechanism of reservoir, and overall water control optimization of complicated strong heterogeneous high-sulfur hydrous gas reservoirs. Secondly, the safe, quick and excellent drilling and completion technologies will be developed, including the drilling fluid system and cementing slurry system of high-temperature, high-pressure and high-sulfur gas wells, and the tools and fluid techniques for reservoir stimulation will also be considered. Thirdly, the development cost will be lowered, the selection of downhole tubular goods and tools will be optimized, the application technology of ground inhibitor corrosion prevention will be promoted, the formula solvent and associated technology will be upgraded, and the treatment efficiency of used amine fluid will be increased.

References

