

# Study on the public safety protection distance of high-sulfur natural gas conditioning plant

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**Abstract.** The standards for quantitative risk assessment in China are introduced. Taking a high-sulfur natural gas conditioning plant in northeastern Sichuan as an example, Quantitative risk assessment is conducted using the national standard 《Determination method of external safety distance for hazardous chemicals production units and storage installations》 (GB/T 37243-2019) and 《Risk criteria for hazardous chemicals production unit storage installations》 (GB36894-2018). The determination basis of key parameters is explained, and the problems and suggestions in the quantitative risk assessment of high-sulfur natural gas conditioning plant in practical applications are proposed.

**Keywords:** Quantitative risk assessment, high sulfur, natural gas conditioning plant, Risk criteria, public safety protection distance.

## 1. Introduction

The Sichuan Basin contains abundant natural gas resources, and currently has the largest proven natural gas reserves in the country. However, two-thirds of the gas fields in the Sichuan Basin are high sulfur gas fields, and high sulfur natural gas accounts for 80% of the total production. For example, the Puguang gas field, the LuoJiazhai gas field, the Tieshanpo gas field, the Qilibei gas field, the Dukoupo gas field in the northeast of Sichuan are all high-sulfur natural gas fields. Natural gas conditioning plant in the Sichuan and Chongqing region are usually located in mountainous areas with complex terrain, and are often affected by stagnant winds and dense populations. In the event of an accident, a large amount of high sulfur natural gas may leak or be released into the environment, which could lead to H<sub>2</sub>S poisoning and even death of natural gas conditioning plant employees and nearby villagers. In order to protect the safety of people's lives and property, it is an effective measure to set a safety distance between the natural gas conditioning plant and the surrounding areas where people gather to reduce safety risks. Currently, both home and abroad approaches use quantitative risk assessment methods to determine the public safety protection

## 2. Quantitative Risk Assessment of High-Sulfur Gas conditioning Plant in Northeast Sichuan

Quantitative Risk Assessment (QRA) is a quantitative analysis method that quantitatively describes the system risk through quantitative analysis of failure probability and failure consequence severity [1]. This method not only qualitatively analyzes the causes and scenarios of accidents but also quantitatively calculates the frequency and consequences of accidents. By considering factors such as terrain, meteorological conditions, and population distribution, The quantitative risk

assessment results are obtained. These results are then compared with risk criteria, and measures to reduce or mitigate risks are proposed.

During the more than 10 years of development of the high-sulfur gas field in Northeast Sichuan, China, there were no relevant standards for quantitative risk assessment. Initially, the quantitative risk assessment and public safety protection distance for the conditioning plants in the Pu Guang gas field and Luo Jiazhai gas field in Northeast Sichuan were based on foreign standards or guidelines. Since 2011, the State Administration of Work Safety issued the 《Interim Provisions on Supervision and Management of Major Hazard Sources of Dangerous Chemicals 》 (State Administration of Work Safety Order [2011] No. 40), which requires quantitative risk assessment for first and second-level major hazard sources. This was the first time that the requirement for quantitative risk assessment was proposed. In 2013, the State Administration of Work Safety issued the industry standard for safety production, 《Guidelines for Quantitative Risk Assessment of Chemical Enterprises 》 (AQ/T 3046-2013), which detailed the technical requirements for conducting quantitative risk assessment in chemical enterprises. In 2014, the State Administration of Work Safety issued the "Standards for Individual Acceptable Risk and Social Acceptable Risk of Hazardous Chemical Production and Storage Facilities (Trial)" (State Administration of Work Safety Document No. 13 of 2014), which proposed personal risk and social risk standards for chemical enterprises. Following the State Administration of Work Safety, the oil and gas industry has also successively formulated industry standards and enterprise standards for quantitative risk assessment, including 《Guidelines for Risk Assessment of Oil and Gas Pipelines》 (SY/T 6859), 《Guidelines for Quantitative Risk Analysis》 (Q/SY 1646) , and 《Guidelines for Quantitative Risk Assessment of Oil and Gas Pipeline Stations》 (Q/SY 1594). However, there are differences between various regulations and industry standards, leading to ongoing disputes in the selection of parameters for quantitative risk assessment. In 2018, China issued the national standards for quantitative risk assessment, 《Determination method of external safety distance for hazardous chemicals production units and storage installations》 (GB/T 37243-2019) and 《Risk criteria for hazardous chemicals production unit storage installations 》 (GB36894-2018), which clarified key parameters such as leak scenarios, equipment leak probabilities, and acceptable risk standards, providing a basis for quantitative risk assessment of high-sulfur gas field conditioning plants in China.

### **3. Quantitative Risk Assessment of Conditioning Plant**

#### **3.1 Overview of Conditioning Plant**

Taking a high-sulfur gas conditioning plant in the northeast of Sichuan as an example, the public safety protection distance is determined using a quantitative risk assessment method. The designed processing capacity of the conditioning plant is  $400 \times 10^4 \text{ m}^3/\text{d}$ , with an operating pressure of 6.0~7.2 MPa. According to the production plan, the H<sub>2</sub>S content in the raw gas is 15.9%. The plant is equipped with two sets of  $200 \times 10^4 \text{ m}^3/\text{d}$  desulfurization absorption towers, one set of dehydration unit, sulfur recovery unit, tail gas treatment unit, and supporting utilities. The process flow of the conditioning plant is shown in Figure 1.

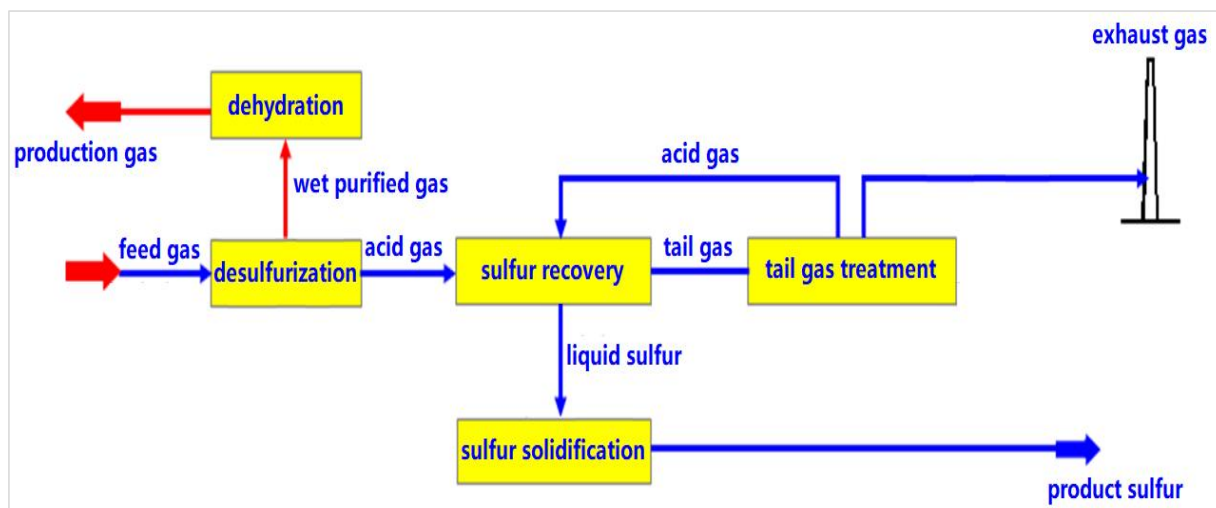


Fig. 1 Process system diagram of the conditioning plant

### 3.2 Key parameters for quantitative risk assessment calculation

The calculation parameters for quantitative risk assessment of the conditioning plant are mainly based on the national industry standard 《Determination method of external safety distance for hazardous chemicals production units and storage installations》 (GB/T 37243-2019), The key parameters such as leak aperture, leak time, and leak probability determined based on engineering practice.

#### (1) Meteorological parameters

When calculating dispersion, the local wind speed, wind direction, and stability joint frequency should be considered, and sixteen wind directions should be selected. The weather condition data calculated based on the joint frequency table of wind speed and wind direction for the past ten years at the location of the conditioning plant are shown in Table 1.

Table 1 Weather Condition Data

Wind Speed and Stability	N	NN E	NE	EN E	E	ES E	SE	SS E	S	SS W	SW	WS W	W	WN W	N W	NN W
1.5m/s, F	0.0913	0.0807	0.2829	0.0887	0.0317	0.0161	0.0118	0.0063	0.017	0.0167	0.0501	0.115	0.0824	0.0239	0.0104	0.0106
3.0m/s, D	0.0023	0.0081	0.0256	0.0156	0.0043	0.0012	0.0003	0.0009	0.0006	0.0012	0.0006	0.0002	0.0014	0.0003	0	0

#### (2) Leak Aperture

According to the provisions of Article 6.4.4 of the 《Determination method of external safety distance for hazardous chemicals production units and storage installations》 (GB/T 37243-2019) leakage scenarios can be divided into complete rupture and orifice leakage according to the size of the leak aperture, and the range of values and representative values are shown in Table 2. The leakage direction is horizontal release.

Table 2 Leak Aperture Values

Leak Aperture Classification	Aperture Range (mm)	Representative Aperture (mm)
Small Aperture	0 ~ 5	5
Medium Aperture	5 ~ 50	25
Large hole	50 ~ 150	100
Complete rupture	> 150	1) Equipment completely ruptured or aperture > 150 2) Instantaneous release of all inventory

Note: The diameter of the largest pipeline connected to the equipment is selected for the complete rupture of the process unit.

(3) Leakage time

According to the requirements of the 《Determination method of external safety distance for hazardous chemicals production units and storage installations》 (GB/T 37243-2019), the leakage time is determined based on the detection and interlocking shutdown system level.

Table 3 Leakage time parameters

Detection system level	Shutdown system level	Leakage aperture (mm)	Leakage time (min)
A	A	5	20
		25	10
		100	5

(4) Leakage probability

According to the leakage probability data in Appendix C of GB/T 37243-2019, the typical leakage probabilities of conditioning plant equipment are shown in Table 4.

Table 4 Leakage probabilities of similar equipment in natural gas conditioning plants

Equipment name		5mm	25mm	100mm	Complete rupture
Gas gathering device	Feed gas gravity separator	$4 \times 10^{-5}$	$1 \times 10^{-4}$	$1 \times 10^{-5}$	$6 \times 10^{-6}$
Desulfurization device	Desulfurization tower	$8 \times 10^{-5}$	$2 \times 10^{-4}$	$2 \times 10^{-5}$	$6 \times 10^{-6}$
	Feed gas gravity separator	$4 \times 10^{-5}$	$1 \times 10^{-4}$	$1 \times 10^{-5}$	$6 \times 10^{-6}$
	Feed gas filter separator	$9 \times 10^{-4}$	$1 \times 10^{-4}$	$5 \times 10^{-5}$	$1 \times 10^{-5}$
Dehydration device	Dehydration tower	$8 \times 10^{-5}$	$2 \times 10^{-4}$	$2 \times 10^{-5}$	$6 \times 10^{-6}$
	Product gas separator	$4 \times 10^{-5}$	$1 \times 10^{-4}$	$1 \times 10^{-5}$	$6 \times 10^{-6}$
Sulfur recovery device	Acid gas separator	$4 \times 10^{-5}$	$1 \times 10^{-4}$	$1 \times 10^{-5}$	$6 \times 10^{-6}$

### 3.3 Quantitative risk assessment results

The acceptable risk benchmark for personal and societal risks in the conditioning plant is based on the 《 Risk criteria for hazardous chemicals production unit storage installations 》 (GB36894-2018).

#### (1) Personal risk

Personal risk is usually represented by personal risk contours. The contour map of personal risk caused by the leakage of the conditioning plant is obtained by integrating the calculation parameters and accident scenario settings, as shown in Figure 2.

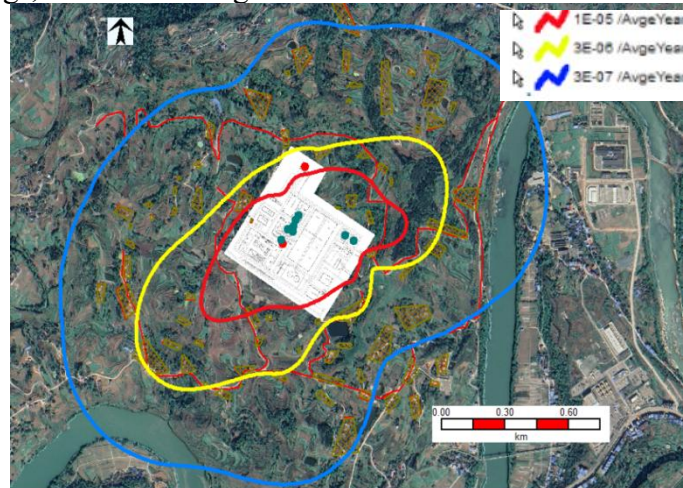


Fig. 2 Contour map of personal risk in the conditioning plant

From the above figure, it can be seen that:

① The risk contour of  $1 \times 10^{-5}$ /year is mostly beyond the boundary of the facility, and the farthest distance of the contour line of personal risk is 494m. Within this range, three types of protective targets need to be relocated;

② The risk contour of  $3 \times 10^{-6}$ /year is completely beyond the facility area, and the farthest distance of the contour line of personal risk is 782m. Within this range, two types of protective targets need to be relocated;

③ The range of the annual risk contour of  $3 \times 10^{-7}$  continues to increase, and there are no protective targets within this range that need to be relocated.

Therefore, based on the risk calculation method, the individual risk of  $1 \times 10^{-5}$  per year and the individual risk of  $3 \times 10^{-6}$  per year do not meet the requirements of GB36894. It is necessary to demolish the houses within the impact range of the  $3 \times 10^{-6}$  per year individual risk contour. The farthest distance of the  $3 \times 10^{-6}$  per year individual risk contour is 782m, so it is recommended to relocate the conditioning plant at a distance of 800m from its surroundings.

#### (2) Social risk

Based on individual risk, combined with the population distribution around the conditioning plant, social risk is calculated. Social risk is represented by the FN curve, and the social risk of the conditioning plant can be seen in Figure 3.

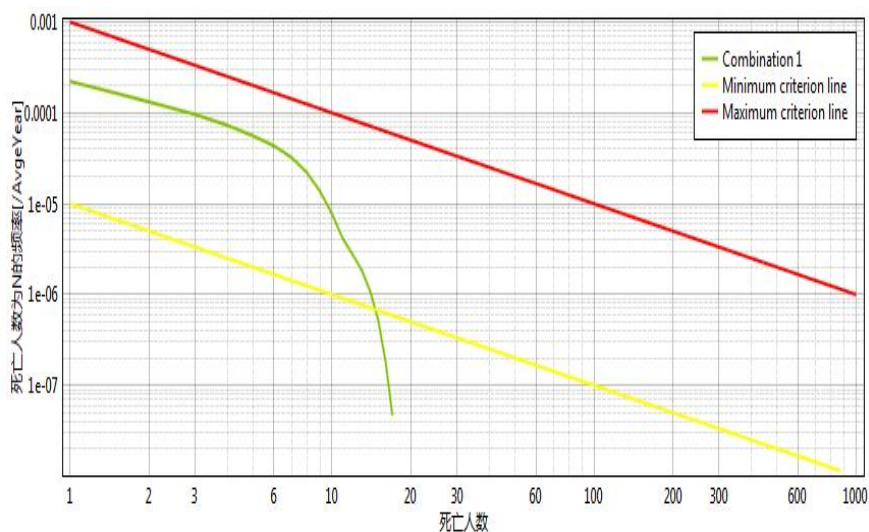


Fig.3 Contour map of social risk at the conditioning plant

In the above figure, the red line represents the unacceptable risk line, the yellow line represents the widely acceptable risk line, and the green line represents the calculated social risk FN curve. From the figure, it can be seen that under the current population distribution around the conditioning plant, the social risk FN curve does not exceed the red unacceptable area and half of it is in the "risk reduction as much as possible" area. With the implementation of safety measures and emergency measures, the social risk of the conditioning plant is controllable.

#### 4. Conclusions and Recommendations

Conducting quantitative risk assessment before site selection and design of conditioning plants can effectively support comparative analysis of site selection schemes and provide technical support for setting process parameters, ensuring the inherent safety of plant safety production. Although China has formulated relevant standards and risk benchmarks for quantitative risk assessment, there are many uncertainties in the setting of key parameters due to different calculation software, resulting in significant disputes over quantitative risk calculation results. Therefore, conducting quantitative risk assessment needs to combine the actual production of the project to determine key calculation parameters and reduce the differences in risk results.

Currently, the standards for conditioning plants in high-sulfur gas fields in China only provide relocation distances for specific operating conditions with an average volume percentage of hydrogen sulfide between 13% and 15%. It does not cover all production conditions of high-sulfur conditioning plants, and there is incompleteness in the formulation of standards. Therefore, it is recommended to develop relocation distance standards for high-sulfur gas field conditioning plants in a graded manner.

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