Research on Protective Measures for 360QS/825 Bimetallic Composite Pipes in High Sulfur Gas Fields

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Abstract

High-sulfur natural gas accounts for a relatively high proportion of natural gas resources and is an important development direction for the natural gas industry in China. However, in the process of high-sulfur natural gas extraction and transportation, H_2S and CO2 in the pipeline are highly corrosive, which will lead to serious safety accidents in case of pipeline leakage, so reasonable and effective protection measures must be taken for the pipeline. Bimetallic composite pipe has good corrosion resistance and comprehensive economic benefits, and has been widely used in the production of high sulfur gas fields in recent years. Although the corrosion resistance of bimetallic composite pipes is better than that of conventional pipes, factors such as geological changes outside the pipe, hydrate and sulfur deposit blockage inside the pipe are very likely to lead to the failure of the pipeline transmission system. Therefore, in this paper, we have studied the external monitoring/inspection measures and internal anti-clogging measures of 360QS/825 bimetallic composite pipes, and proposed reasonable solutions to provide guidance to ensure the safe operation of high sulfur-bearing pipelines.

Keywords

High Sulfur Natural Gas; Pipeline Protection; 360QS/825 Composite Pipe; Hydrate; Sulfur Deposition.

1. Introduction

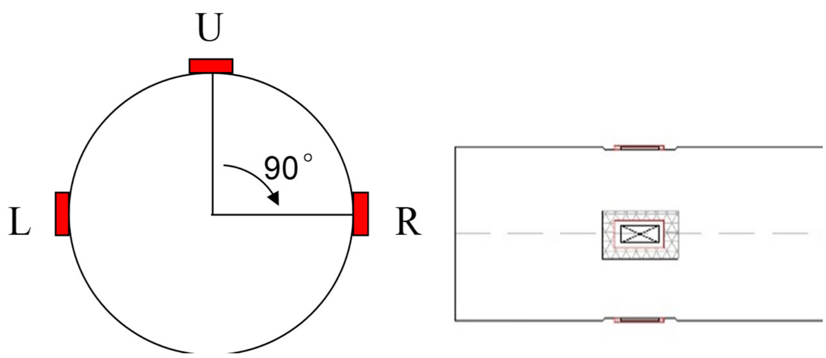
With the development of high sulfur-bearing gas reservoirs, the oil and gas industry has seen a surge in demand for pipeline transportation of sulfur-bearing gases. If the pipeline production operation is unreasonable and the safety protection measures are not in place, it is easy to cause the leakage of the transported gas. H_2S in sulfur-containing natural gas is a highly toxic gas, and its leakage is very likely to cause casualties. Therefore, scientific and reasonable maintenance of high sulfur-containing natural gas pipelines is one of the necessary conditions to ensure the safe development of the whole gas field and the normal transmission of the subsequent pipeline network[1-3]. In the pipeline transmission process of high sulfur gas, the pipeline is affected by geological changes, temperature differences and pH changes, which are likely to cause adverse consequences such as deformation, distortion and cracking of the pipeline body. During the pipeline transmission of high sulfur-bearing gas, natural gas hydrates are easily formed internally, which can lead to blockage of pipelines or equipment along the way, and effective control measures should be taken to inhibit hydrate generation[4]. Prevention of sulfur deposition is also the key to protect high-sulfur gas pipelines as the problem of sulfur deposition is becoming increasingly common due to the generally high transmission pressure of high-sulfur-bearing gas reservoirs, which are prone to the formation of elemental sulfur. Therefore, reasonable and effective protective measures inside and outside the pipeline are needed to ensure efficient operation of the pipeline.

2. Classification of Pipeline Protection Measures

High-sulfur natural gas gathering pipeline is a high-risk pipeline, which will lead to serious safety accidents in case of leakage. Therefore, necessary protective measures must be taken for the pipeline. Protection measures are divided into conventional pipeline protection and the use of bimetallic composite pipes. Conventional pipeline protection measures include external coating protection, corrosion inhibitor protection and cathodic protection[5]. External coating protection is a layer of corrosion protection applied to the outer wall of the pipeline to isolate the natural gas pipeline from the soil and space, which can greatly reduce the probability of corrosion on the outer wall of the pipeline[6]. Corrosion inhibitor protection is the addition of a quantitative amount of corrosion inhibitor to the pipeline, which can effectively mitigate pipeline corrosion[7]. Cathodic protection is the use of a generator to provide current so that the active material does not lose electrons and is oxidized, maintaining its original properties to protect the pipeline[8]. Conventional pipeline protection measures are difficult to balance in terms of reliability, economy and other indicators. In order to enhance the reliability of protection measures and reduce the cost of protection, bimetallic composite pipes came into being. Due to its excellent mechanical properties, good corrosion resistance and relatively low price, it is widely used in oil and gas field production and development. Bimetallic composite pipe is made of two different metals through various processing processes, divided into an outer layer and a liner layer. The outer layer is the base material of the composite pipe, and the inner layer is a thin layer of corrosion-resistant alloy, which gives the bimetallic pipe good strength and corrosion resistance[9]. Commonly used corrosion-resistant alloys include 316L, 22Cr and 360QS/825 alloy, and 360QS/825 bimetallic composite steel pipe is a pipe made of 360QS/825 alloy and steel pipe. Although the corrosion resistance of bimetallic composite pipes is better than that of conventional pipes, factors such as geological changes outside the pipe, hydrate blockage and sulfur deposition inside the pipe can also lead to the failure of the pipeline system. Therefore, this paper investigates the external monitoring/detection measures and internal anti/unclogging measures of 360QS/825 bimetallic composite pipes and proposes reasonable solutions.

3. 360QS/825 Bimetallic Composite Pipe Outside the Pipe Monitoring and Testing Measures

3.1 Stress-strain Monitoring System



(a) Schematic diagram of the installation position of the sensor

(b) Field detection pile for pipeline geological hazards

Figure 1. Sensor installation locations and detection stakes

The gas gathering trunk line and gas gathering branch line studied in this paper are both high sulfur pipelines, and the pipelines are located in mountainous areas. The pipeline bodies are susceptible to geological conditions and temperature changes, which can easily cause undesirable consequences such as pipeline twisting, deformation and stress increase, and even cause cracks to sprout and expand, leading to fractures, which eventually damage the pipelines or reduce the service life of the pipelines, resulting in incalculable economic losses and social impacts. Therefore, this study sets up stress-strain monitoring measures for special locations, monitors the stress state of the pipeline body, and transmits the monitoring data to the server through wireless transmission, which can realize risk monitoring and early warning. In this study, stress-strain monitoring points were set up for two sections that may induce landslides, as well as the sections crossing rivers and highways. After subsequent multiple site reviews, the number of settings was finally determined, and the sensor installation locations and detection stakes are shown in Figure 1.

3.2 Geohazard Monitoring System

According to the requirements of pipeline integrity management, the risk of hazardous factors to pipelines needs to be reduced so that pipelines can be prevented and controlled. At the same time, as the pipeline passes through mountainous areas, the terrain is undulating and the possibility of geological hazards is high. Therefore, a geohazard monitoring system is used to monitor the areas where the pipeline may have geological risks.

Combined with the engineering geology along the pipeline, a geohazard monitoring system is set up for two sections where landslides may be induced.

(1) Between No. 4 valve chamber ~ No. 5 valve chamber, at a distance of 0.83km from No. 5 valve chamber, which has a horizontal length of 203m and a height difference of 132m, and this section is the steepest slope section of the whole line.

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(2) Between valve room No. 6 ~ clearing station, 120m from valve room No. 6, located near a company's pipeline crossing section, 180m from the pipeline, and the gas gathering trunk line interval 1 ridge beyond the collapse phenomenon.

The workload of the monitoring system is shown in Table 1.

Table 1. Main engineering quantities of the earth disaster monitoring system

Serial number	Name	Number
1	BeiDou communication transmission equipment	5
2	Soil moisture content, soil moisture content station	2
3	Integrated soil pressure/tilt monitoring station	8
4	Sensors	6

4. 360QS/825 Bimetallic Composite Pipe Control and Unblock Measures

4.1 Hydrate Control Measures

4.1.1 Formation of Hydrates

In natural gas fields, in addition to components such as hydrocarbons like methane and ethane, carbon dioxide, and hydrogen sulfide, there is also water, which is usually present in the natural gas in liquid or gaseous form. Under certain conditions, water can form ice-like, non-chemically measured, cage-like crystalline solid mixtures with certain components of natural gas, called hydrates. Hydrate formation is related to the temperature, pressure, and hydrocarbon content of the natural gas gathering system[10-13], with hydrate generation temperatures of 24 ~ 28°C. Hydrate control measures are required at well sites and lines, the hydrate generation curve is shown in Figure 2.

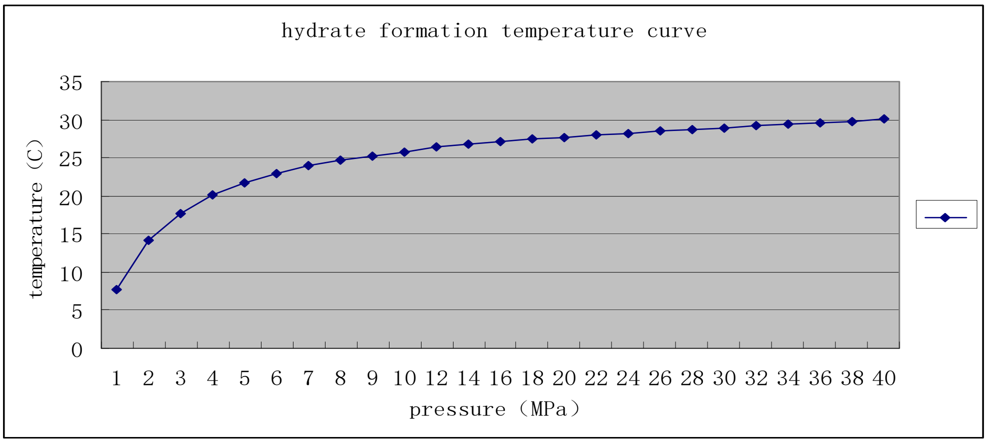

Figure 2. Hydrate formation curve

4.1.2 Hydrate Inhibition Scheme

High sulfur gas-liquid blending pipelines are highly susceptible to hydrate formation during the transportation process. The accumulation of hydrates can block pipelines and pose a great threat to the safe operation of pipelines, and the oil and gas industry has been studying how to prevent hydrate generation in pipelines, and keeping the pressure and temperature of operating systems outside the hydrate generation region is the basis for hydrate inhibition[14-15]. Common anti-freeze measures are:

(1) Well station antifreeze: Single well without heating and throttling to outside pressure will form hydrate. The heating furnace should be set up in the station for hydrate prevention under normal

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working conditions, and hydrate prevention by adding inhibitors during accidents, start-ups and shutdowns.

(2) Line antifreeze: After comparison, the gas collection branch adopts insulation technology, and the alcohol injection port is reserved in the well station exit pipeline. Special line antifreeze process and thermal calculation of the gathering system are shown in Table 2 and Table 3.

Table 2. Comparison and selection of antifreeze technology for lines

Projects	Option 1: Station heating + line insulation	Option 2: Station heating + outbound filling with antifreeze
Program Description	Well station heating (out station 34°C), line pipe insulation	The well station is heated to 44°C to ensure that no hydrates are formed in the station and the line is filled with methanol
Advantages	Save investment, low running cost	Good effect
Disadvantages	The construction and daily maintenance monitoring management of the insulation layer should be strengthened	1) Higher operating costs and the need to consider methanol recovery. 2) Poor adaptability to water content and temperature change of upstream medium

Table 3. Thermal calculation table of gathering and transportation system

Well Station	Wellhead flow pressure /MPa	Wellhead flow temperature /°C	Outbound pressure /MPa	Outbound temperature /°C	Hydrate formation temperature at outgoing pressure /°C	Heating furnace power /kW	Into the dewatering station pressure /MPa	Inbound temperature /°C	Hydrate formation temperature at inlet pressure /°C
Well Station No.1 Platform A	14.21	40	10.3	34.3	25.4	608	9.5	30.1	25.1
Well Station No.1 Platform B	14.64	41	10.3	34	25.4	570			
No. 2 well station	17.69	40	9.97	34.1	25.2	279			

4.2 Sulfur Deposition Unblocking Measures

4.2.1 Principle of Sulfur Deposition

When the volume content of H_2S in natural gas is higher than 5 %, sulfur deposition and plugging may occur in the formation. Statistics show that sulfur deposition occurs in most gas reservoirs with H_2S content higher than 30 %, which increases the seepage resistance of the formation, and the production of gas wells decreases sharply or even stops. Sulfur deposition is mainly controlled by temperature and pressure changes. In the case of sudden changes in pressure and flow, sulfur deposition is very likely, that is, sulfur deposition may occur at the bottom of the wellbore, throttle valve and separator[16].

(1) Chemical deposition

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In a stratigraphic environment, sulfur and hydrogen sulfide produce polysulfides with the equation $H_2S + S_x \rightleftharpoons H_2S_{x+1}$. The reaction process is a reversible chemical equilibrium process. From left to right, the reaction is a heat-absorbing reaction. When the temperature or pressure increases, the equilibrium shifts toward hydrogen sulfide, causing the monomeric sulfur content in the formation to decrease and the sulfur content in the natural gas to increase. When the H_2S content in natural gas is higher, a more efficient way of dissolving monomeric sulfur is available and the gas is more capable of dissolving sulfur[17].

(2) Physical deposition

In addition to the above-mentioned equilibrium reactions that can cause sulfur deposition, the physical dissolution and desorption of sulfur in the dense fluid phase should not be ignored. When natural gas is dense and in a highly compressed state, its flow will cause changes in the surrounding sulfur particles, which will flow together under the action of the gas. When the temperature and pressure values are certain, the gas acts on the sulfur element, breaking its internal chemical bonds and creating an open state of the molecule, which eventually lowers the melting point of the singlet sulfur further, resulting in sulfur deposition[18-19].

4.2.2 Status of Sulfur Deposition in High Sulfur-bearing Gas Fields and Treatment Measures

Sulfur deposits exist in the ground process of A gas field, which are mainly located at the separator, elbow and check valve. At present, the main treatment measures are to manually clean up sulfur deposits during shutdown and to set up sulfur solvent refilling ports at the station. Sulfur deposits exist in the entire system of wellbores, valves, separators and gathering pipelines in the B gas field. On the one hand, blockage occurs to take corresponding unblocking measures, and on the other hand, the station and pipelines are overhauled for three years and cleaned with sulfur solvents.

(1) Gas field sulfur deposition treatment scheme

Referring to the practices of A and B gas fields, this study selects the sulfur solvent immersion unblocking scheme, setting up a reserved sulfur solvent filling port on the ground, setting up one set of sulfur solvent filling system at each station, adopting intermittent filling process, and collecting the discharge in the unblocking process and handing it over to a third party for disposal.

(2) Gas field sulfur deposition prevention measures

In the subsequent design stage, the measures taken to optimize the process flow and reduce the occurrence of sulfur deposition are.

1) Avoiding the use of check valves, necked ball valves, target flow meters, corrosion probes and other insertion fittings for the main raw gas process.

2) Liquid phase as far as possible to use volume counting method, reduce the use of fluid area too small flowmeter, such as mass flowmeter.

3) Gravity separator is not recommended to use in-screen components that can easily lead to the deposition of elemental sulfur.

5. Conclusion

This paper analyzes the classification of pipeline protection measures, and studies the protection measures of bimetallic composite pipes among them. According to the geographical environment outside the pipe, a reasonable solution is proposed for 360QS/825 composite supervision/testing means. In addition, the formation of natural gas hydrate seriously affects the development and formation of gas fields. Through the study of natural gas hydrate prevention and control measures, the production difficulties of high sulfur gas fields are solved and the formation of hydrate is prevented to meet the production needs. Finally, the study analyzed the mechanism of sulfur deposition blockage, revealed the chemical and physical conditions of sulfur deposition, and explored the treatment methods of sulfur deposition. Different measures to solve the sulfur plugging problem in the surface gathering system are analyzed and compared, and the best treatment plan and preventive measures are selected to provide guidance for the protection of high sulfur-bearing gas pipelines.

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