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# Research progress of optimized operation technology of natural gas pipelines

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**Abstract.** In recent years, the large application of natural gas has led to a severe shortage of the operation efficiency of its pipelines, which has been unable to meet the rapid growth demand. Therefore, the study of natural gas pipeline transportation optimization plays a very important role in maintaining the steady economic development of our country. In this paper, through the empirical analysis, the natural gas pipeline optimization operation technology was studied, the existing problems of natural gas pipeline transportation were analyzed first, and the scheme and countermeasure of natural gas pipeline operation optimization design were obtained; then through the experimental analysis, the optimization design scheme of natural gas pipeline was verified. It can be concluded that the scheme can effectively improve the optimal operation level of natural gas pipeline.

**Key words.** Natural gas pipeline, optimal operation, technical research.

## 1. Introduction

After the reform and opening up, China's economic development speed is obvious to all, so the rapidly rising energy consumption of the industries is particularly prominent [1]. In China's energy consumption structure, Oil consumption accounts for a large proportion, the proportion of natural gas consumption is also great, which has reached more than 30 % [2]. Therefore, natural gas has become an important part of China's energy consumption [3]. Not only that, in recent years, the use of natural gas in China has been increasing, which has increased the burden of natural gas pipeline and put forward higher demands on the operation efficiency of natural gas pipeline [4]. Therefore, how to improve the efficiency of natural gas transportation pipeline operation and maintain the construction and optimization of natural gas pipeline has become one of the more difficult problems in the chemical industry [5].

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At present, more and more researchers have been involved in the study of the optimization design of natural gas pipelines, and have had some research experience on the current situation and existing problems of natural gas pipeline operation [6]. The state has invested a lot of money and resources to develop a number of natural gas delivery projects to meet the growing demand for natural gas use [7]. However, for the optimal design of natural gas pipeline operation, our research is still in a relatively weak stage, so for the researchers concerned, this is a major problem that needs to be overcome [8].

## 2. State of the art

Because of the lack of experience in the design of natural gas pipelines in China, the current design is still based on the mathematical approach that has been consistently used in the past, which relies on the construction of a mathematical model to design natural gas pipelines [9].

Since the 1970s, the development of natural gas pipeline projects has become an important part of economic construction in the world [10]. And because of the uneven distribution of natural gas resources between countries, a large amount of natural gas trade has been needed between countries, which has greatly increased the distance and demand of natural gas transportation As a result, many countries have had the need to build long-distance, large-diameter natural gas pipelines Before the 90 s of last century, the Soviet Union had already owned a 2698-kilometer natural gas pipeline. By the time of the 1990s, large diameter natural gas pipelines built by Russia have exceeded 60 % of the total natural gas pipeline Compared with the 1219 mm diameter of Western European countries, Russia's 1420 mm pipeline caliber has a great advantage.

In the past more than 20 years, on the basis of absorbing the advanced experience of foreign natural gas transportation technology, China's natural gas transportation technology has also developed rapidly. In order to realize the rapid development of China's western region economy, the "West-East Gas Pipeline Project" in China has promoted the improvement of the technical level of natural gas pipeline and provided technical guarantee for the rapid economic development.

### *2.1. Methodology*

### *2.2. Problems in operation of natural gas long-distance pipeline*

In terms of technology, natural gas pipelines are generally laid along the road. Therefore, when they passes through some larger buildings and bridges and other ground environment, it is necessary to use some methods to solve, which puts forward high requirements for the construction technology. In the process of building natural gas pipelines, some people who steal natural gas tend to appear due to economic interests. These personnel will drill some of the pipes and then use some means to steal natural gas for sale, which makes the natural gas transmission process

suffer greater losses, and is also likely to cause major safety incidents, such as leaking pipelines. In addition to man-made destruction, natural gas pipelines are also vulnerable to natural disasters. Natural gas pipelines are often conduits with very long distances, so they passes through a lot of areas, and the natural environment is also complex, which usually has a lot of natural factors that cannot be controlled. As a result, natural gas pipelines often encounter a variety of ground subsidence, debris flow, earthquakes and other harsh natural environment, which threatens natural gas pipelines. The following figure shows the actual operation and transmission of natural gas pipeline, which is the actual laying of natural gas pipeline.

Fig. 1. The actual laying of natural gas transmission pipelines

In the whole natural gas pipeline project development process, the construction of oil and gas pipeline is a very important part, which will greatly affect the stability and reliability of natural gas transportation. So this step is a very important step. In the case of oil and gas pipelines, it is necessary to understand the natural and weather conditions of the installation area before the installation, and to make full technical preparations, so as to strictly control the entire construction process in the construction process and perform a test of performance after completion. Once there is a problem in any of these links, it will affect the operation efficiency and operation safety of the whole natural gas transmission pipeline. When welding the pipe, it is necessary to check the safety and integrity of the device material, and to make a timely remedy for the damaged pipe, so as to avoid mistakes from construction personnel at any time and prevent the emergence of various construction defects and other issues, thus ensuring the efficient and safe operation of natural gas pipeline.

Today, natural gas has entered the people's lives, and has become an indispensable part of people's lives, so the use of the natural gas is gradually increased. However, although the number of people who use natural gas is very large, there is no effective protection measure, the people are less aware of the precautions and knowledge in the use of natural gas, but also lack security awareness. Therefore, in the process of using, people's safety cannot be fully guaranteed.

### *2.3. Measures for optimizing design of natural gas pipeline operation*

Based on the analysis of the problems that are easy to occur in the construction of the above natural gas pipeline, the corresponding effective measures for the optimization of the operation of the long-distance natural gas pipeline can be explored. Figure 2 below shows the design of the natural gas transmission pipeline, in which the specific values and the standard of the pipeline have been designed and marked in detail, so as to ensure that the natural gas transmission pipeline can guarantee a more precise size when building.

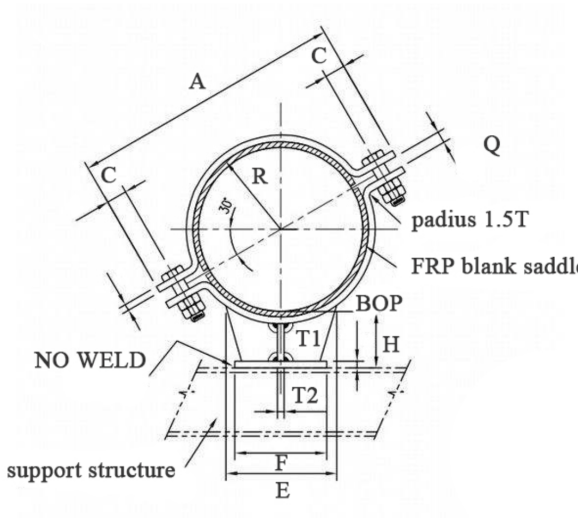


Fig. 2. Design diagram of a natural gas transmission pipeline

In the optimization of the design of flat lots of pipelines, it is necessary to take full account of various special circumstances encountered when laying the natural gas pipelines, different pipe elevation determines the safety of different pipe, which puts forward higher requirements for the design of natural gas pipeline. Therefore, the design must take full account of the natural environment of the natural gas pipeline during the laying, and allow the natural gas pipelines to be fully safe at the time of operation and have effective measures to minimize losses after its emergence of a security incident. For the environment and conditions, it is necessary to take into account the various important large buildings that pass through the pipeline and to understand the special natural environment of the area. In the optimization of the construction of natural gas pipeline in the river crossing phase, it is necessary to take full account the situation when the pipe passes through the river. Because natural gas pipelines are vulnerable to water erosion, it is necessary to avoid these problems as much as possible during design. In order to avoid all kinds of damage to the natural gas pipeline, casing and other methods can be used to protect the safety of the pipeline. In order to prevent the occurrence of rotations in the pipeline, the outside of the natural gas pipeline can be coated with a cathodic protection sub-

stance. In the optimization of mountain and other stages of the natural gas pipeline, it is necessary to fully take into account all sorts of circumstances that appear when suffering landscape scour. Because the laying distance of natural gas pipelines is very long, pipelines often go through many countries and regions. Therefore, it is necessary to fully understand the standards and specifications of the natural gas industry in these countries and regions, so as to strictly implement these standards and specifications at the time of design. The laying of natural gas pipeline will be carried out along the ridge, because the amount of water collected in the ridge area is relatively small, which will not cause extensive erosion of the pipeline, and can greatly improve the safety of the pipeline.

### *2.4. Empirical analysis of optimized design of natural gas pipeline operation*

Firstly, the emptying time and volume of gas in the pipeline are calculated by reasoning, and the formula is derived. Combined with the company's current diameter specifications and pressure condition, the formula is applied, and the evacuation of the chamber between two valves is calculated separately. Through the formula analysis, some conclusions can be drawn, so as to provide the scientific basis for our production scheduling decision, the dispatching of the gas volume and the reasonable organization of the accident repair, which has the practical guiding significance to ensure the stable supply of the pipeline. The figure below shows the pipeline pressure setting in the natural gas pipeline design. The air pressure setting of the natural gas pipeline can adequately ensure the safety of the pipeline and can determine the speed and efficiency of the natural gas in the transmission process. Therefore, the pressure control of the pipeline is a very important part.

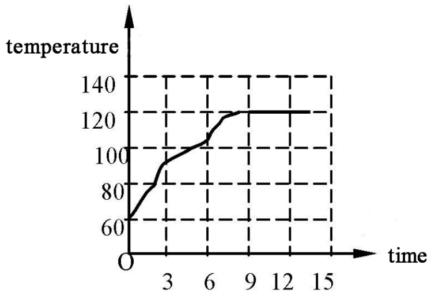


Fig. 3. Gas pressure setting of natural gas transportation pipeline

Assume that the length of a pipeline is $L$, the pipe diameter is 9Dx, and the average line pressure is $P_1$ (absolute pressure). The pipeline is emptied by the air release valve, and $P_2$ is the venting time and volume required when the pressure drops. Assuming that the pipeline temperature $T$ remains the same the process is described by equations listed according to the conservation of mass:

$$V\,\mathrm{d}p = G\,\mathrm{d}t\,, \tag{1}$$

where $G$ is the mass flow and $V$ is the volume of the empty tube, $p$ is the valve opening (abscissa) and $t$ is the venting time. Because

$$p = \frac{PM}{RT}\,, \tag{2}$$

where $M$ represents the relative molecular mass of the vent gas, $T$ is the pipe temperature, $P$ is the absolute pressure before and after venting and $R = 848\,\mathrm{kg}$, we can write

$$V\,\mathrm{d}\left(\frac{PM}{RT}\right) = G\,\mathrm{d}t\,. \tag{3}$$

As the mass flow rate $G$ of the gas in the critical state is

$$G = FP\sqrt{\frac{KMg}{ZRT}\left(\frac{2}{K+1}\right)^{\frac{K+1}{K-1}}}\,, \tag{4}$$

where $F$ represents the cross-sectional area when the vent valve is fully open, $K$ represents the adiabatic index, $g = 9.81$ and $Z$ represents the natural gas compression factor.

Then

$$V\mathrm{d}\left(\frac{PM}{RT}\right) = \left(FP\sqrt{\frac{KMg}{ZRT}\left(\frac{2}{K+1}\right)^{\frac{K+1}{K-1}}}\right)\,\mathrm{d}t\,, \tag{5}$$

and, hence

$$t = \frac{V}{F}\sqrt{\frac{\frac{M}{ZRT}}{Kg\left(\frac{2}{K+1}\right)^{\frac{K+1}{K-1}}}\ln\frac{P_1}{P_2}}\,. \tag{6}$$

It is necessary to conduct a certain instance of the calculation, and the gas between the two valves is vented, pipeline specifications is $426\times7\,\mathrm{mm}$, the length is $30\,\mathrm{km}$, and tube pressure is $3.5\,\mathrm{MPa}$ (gauge pressure), the temperature is $17\,^{\circ}\mathrm{C}$, vent tube specifications is $9108\times6\,\mathrm{mm}$, and the valve opening height and diameter ratio is: $h/d = 1.0$. It is now calculated that, firstly, the emptying time and volume required when the natural gas in the pipeline is vented is equal to the atmospheric pressure; secondly, the emptying time and volume required when the natural gas in the pipeline is vented until the pipe pressure is $1.5\,\mathrm{MPa}$

By using the formula above, the calculation can be obtained:

When the natural gas in the pipe is completely emptied to the atmospheric pressure, the venting time is 128 minutes, and the discharge volume is $140724.5\,\mathrm{m}^3$.

The emptying time is 50 minutes when the pressure is $1.5\,\mathrm{MPa}$, and the vent volume is $80446\,\mathrm{m}^3$.

## 3. Result analysis and discussion

After analyzing the optimization design of the natural gas pipeline, the author also made an empirical analysis of the pipeline to construct the overall structure of the natural gas pipeline design. Before the construction and operation of the above design plan, the integrity and safety of its natural gas pipeline design must be tested to ensure the safety and efficiency of the gas pipeline when it is running. The figure below shows the overall structure of the natural gas pipeline design. Through the interconnection between the various hardware facilities, the basic system of the operation and management of the natural gas pipeline can be established, which can manage the operation of the whole natural gas pipeline in an orderly way and ensure the efficiency of its natural gas transmission.

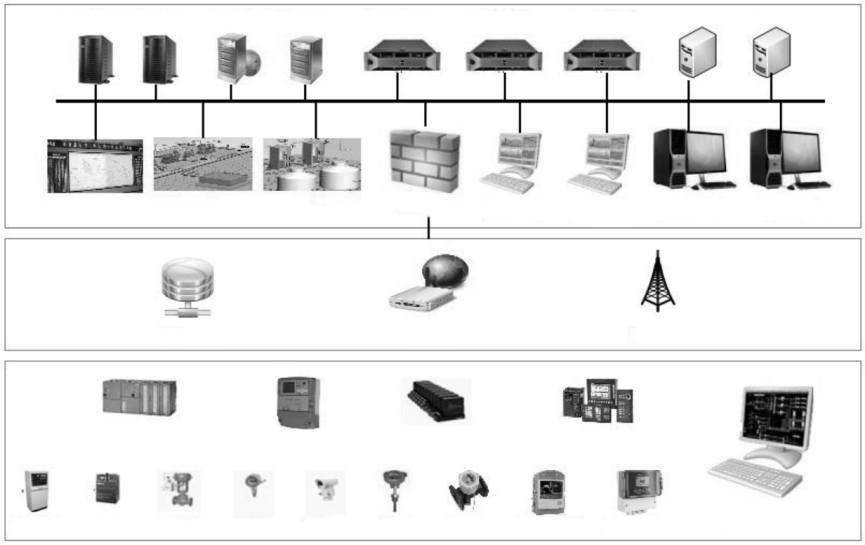

Fig. 4. The overall structure of the natural gas pipeline design

The integrity and safety of gas pipeline design must be analyzed on the basis of a large amount of experimental data collected. Therefore, at the time of this test, the author collected some of the actual operation data, and collated and analyzed the data, and obtained a certain analysis results from the data analysis. Table 1 shows the experimental data for the operation of natural gas pipelines, including pipeline integrity data, safety data, barometric data, operational efficiency data, and operating speed data.

Evaluation of pipeline integrity: pipeline integrity management refers to that risk and integrity evaluation is carried out through the collection and classification and analysis of potential risk factors for pipeline, and the evaluation results are processed to ensure the integrity and safety of pipeline operations, which mainly adopts GIS and database, risk assessment, risk detection, applicability evaluation, pipeline geological hazard assessment, pipeline maintenance decision and emergency

response and other key technologies. The corresponding safety risk control measures are developed and the identified adverse factors are continuously improved, so that the safety risk level of the pipeline operation is controlled within a reasonable and acceptable range, so as to reduce the occurrence of pipeline accidents and ensure the safe operation of the pipeline.

Table 1. Natural gas pipeline operation experimental data

| | Integrity | safety | Air pressure | Operating efficiency | Running speed |
|---|---|---|---|---|---|
| P1 | 0.56 | 1.11 | 0.97 | 0.24 | 1.45 |
| P2 | 0.83 | 1.13 | 0.06 | 0.45 | 1.22 |
| P3 | 0.59 | 1.15 | 0.04 | 0.77 | 1.13 |
| P4 | 0.76 | 1.43 | 0.34 | 0.46 | 1.13 |
| P5 | 0.88 | 1.26 | 0.13 | 0.33 | 1.14 |
| P6 | 0.90 | 1.21 | 0.46 | 0.57 | 1.46 |
| P7 | 0.34 | 1.14 | 0.31 | 0.24 | 1.25 |
| P8 | 0.34 | 1.45 | 0.62 | 0.34 | 1.09 |
| P9 | 0.56 | 1.62 | 0.72 | 0.32 | 1.05 |
| P10 | 0.28 | 1.09 | 0.53 | 0.14 | 1.04 |

Optimized detection technology: in order to ensure the safety of gas pipelines, domestic and foreign advanced technology can be actively absorbed and introduced to ensure the safe operation of the pipeline, the safety supervision and prevention of gas pipelines in the area where natural conditions are harsh and social environment is complex can be strengthened. Through field investigation, safety management can be carried out. At the same time, corrosion tests of pipeline and production base equipment can be continuously strengthened to improve safety management levels.

## 4. Conclusion

Because research experience of natural gas pipeline design technology of our country is less, and the research starts late, so it is still in a relatively primary stage, technical level is not high. The design of natural gas pipelines can affect the safety and efficiency of pipeline operation. Therefore, the optimization of pipeline design technology is very necessary. In this paper, through the analysis of the problems in the operation of long-distance natural gas pipeline, measures of natural gas pipeline operation optimization design were designed; then from the three perspectives of optimizing the flat pipelines, optimizing river pipelines, and optimizing mountainous pipelines, the description was carried out; finally, through the empirical analysis, the natural gas pipeline optimization scheme was designed, and the experimental data of the safety and operation efficiency of the gas pipeline were collected and the experimental results were analyzed, so as to show the effectiveness of the natural gas pipeline optimization design in this paper and promote the development of China's natural gas pipeline optimization design technology.

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