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Exploration of Safety and Energy Saving Measures in the Process of Oil and Gas Storage and Transportation

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Abstract

Under the background of continuous growth of global energy demand and intensified pressure of environmental protection, the safety risk and high energy consumption in oil and gas storage and transportation have become the key factors restricting the sustainable development of the industry. This paper systematically analyzes the safety and energy saving problems in oil and gas storage and transportation, and proposes comprehensive solutions by combining theoretical discussions and practical cases. It is found that safety risks mainly include physical (e.g., pipeline corrosion, equipment failure), chemical (e.g., fire and explosion caused by leakage), operational (human error), environmental (ecological pollution), and legal (violation of responsibility) dimensions; while energy consumption problems are focused on steam, electricity and fuel consumption, and technological lag and insufficient management are the main constraints; through the comprehensive application of safety and energy-saving technologies and the enhancement of the whole-process management, it is possible to significantly enhance the safety and energy-saving performance of oil and gas storage and transportation. Through the comprehensive application of safety and energy-saving technologies and strengthening the management of the whole process, the safety and energy efficiency of oil and gas storage and transportation can be significantly improved, taking into account the economic and environmental benefits. Future research needs to further focus on technological innovation and policy support in order to promote the sustainable development of the industry.

Keywords

Oil and Gas; Storage and Transportation; Safety and Energy Saving Measures.

1. Introduction.

With the rapid development of the global economy, the demand for oil and gas in all areas of society continues to grow, which not only promotes the expansion of the oil and gas storage and transportation system, but also triggers a high degree of concern about the safety of oil and gas storage and transportation [1]. While the global energy demand is surging, environmental problems are becoming increasingly severe, especially the frequent safety hazards and high energy consumption in the oil and gas storage and transportation process, which has become a key factor restricting the sustainable development of the industry [1]. In this context, it is particularly urgent to strengthen the safety management of oil and gas storage and transportation, reduce the risk of accidents and improve energy efficiency by combining the concept of environmental protection and energy saving [3]. This study aims to explore how to effectively implement safety and energy-saving measures in the process of oil and gas storage and transportation, with a view to proposing practical solutions through comprehensive analysis, so as to promote the healthy development of the petroleum industry, as well as to contribute to the enhancement of environmental protection and economic benefits [4]. The

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significance of the study is to clarify the importance of strengthening the safety and energy conservation management of oil and gas storage and transportation from three dimensions: economic, environmental and social. Economically, by reducing the accident rate and improving energy efficiency, it can significantly reduce the operating costs of enterprises and enhance market competitiveness; environmentally, reducing oil and gas leakage and emissions can help to mitigate the negative impact on the ecological environment and promote the green sustainable development; socially, guaranteeing the safety of oil and gas storage and transportation can effectively prevent casualties and property losses, and safeguard the stability and harmony of society [5]. In this paper, we will discuss in detail the safety and energy saving problems and their coping strategies in the process of oil and gas storage and transportation through the sections of safety and energy saving problem analysis and measures, case study, etc., with a view to providing valuable references for the research and practice in related fields.

2. Safety and Energy Conservation in Oil and Gas Storage and Transportation and its Analysis.

2.1 Safety in Oil and Gas Storage and Transportation.

2.1.1 Main Security Risks.

As a key link in the energy supply chain, oil and gas storage and transportation, its safety directly affects national energy security and social stability. In the process of oil and gas storage and transportation, great attention needs to be paid. These risks mainly include physical risks, chemical risks, operational risks, environmental risks and legal risks. Physical risk mainly refers to problems such as pipeline rupture and equipment failure. Long-distance oil and gas pipelines are usually characterized by long distance and large consumption, and are affected by many factors during construction and operation, such as management, technology and construction. The reduction of pipeline strength will directly affect operational reliability, the main reasons include material defects, corrosion, etc. [6]. These physical risks may lead to oil and gas leakage, resulting in major safety accidents and economic losses. Chemical risks are mainly related to chemical reactions after oil and gas leakage, such as explosions and fires. As the main components of oil and natural gas are hydrocarbon hydrocarbons, they are flammable, explosive and easy to gather static electricity [7]. Once the leakage occurs, it is very easy to cause fire and explosion accidents, causing serious threats to the surrounding environment and personnel safety [8]. Operational risks are mainly caused by human factors, including operational errors and improper maintenance. Operators may be negligent, fatigue, lack of skills or inadequate training, resulting in misoperation, omission or improper operation. In addition, untimely or improper maintenance of equipment may also cause safety hazards [8]. These human factors directly affect the safety and reliability of oil and gas storage and transportation.

Environmental risk mainly refers to the pollution of the natural environment such as water and soil by oil and gas leakage, as well as the long-term impact on the ecosystem. Today's society is facing serious resource and environmental problems, over-exploitation and irrational use of energy may cause environmental pollution [7]. Oil and gas leakage not only causes waste of resources, but also causes serious damage to the surrounding ecological environment. Legal risks are mainly related to the possible legal liabilities resulting from the violation of relevant laws and regulations. With the increase in safety and environmental protection requirements, oil and gas storage and transportation enterprises are facing stricter legal regulations. Non-compliance with laws and regulations may result in fines, suspensions and other penalties, which may affect the normal operation of the company. In summary, clarifying the main safety risks in the process of oil and gas storage and transportation not only helps to improve the level of safety management, but also provides a theoretical basis for the design and implementation of subsequent safety measures. In conclusion, the safety risk in the process of oil and gas storage and transportation involves many aspects, which requires the joint efforts of enterprises, government and all sectors of the society and the adoption of comprehensive measures in

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order to effectively reduce the risk and ensure the safety and sustainability of oil and gas storage and transportation.

2.1.2 Case Studies of Security Incidents.

In the process of oil and gas storage and transportation, safety has always been an important factor restricting the development of the industry. The common safety risks in the process of oil and gas storage and transportation, such as pipeline leakage, explosion, etc., are then discussed in depth the specific manifestations of these risks and the causes behind them through a few representative cases. In 2010, a serious natural gas pipeline explosion occurred in California, USA, resulting in eight deaths, dozens of injuries, and the destruction of several homes [9]. The accident occurred on a high-pressure natural gas pipeline with a diameter of 30 inches, and the explosion was so powerful that it created a crater about 20 meters wide. The main cause of the accident was investigated to be the failure to detect and repair the corrosion of the pipeline in a timely manner due to the aging of the pipeline material and improper maintenance. In addition, the safety monitoring equipment at the accident site failed to provide effective early warning, further exacerbating the extent of the accident. This case not only caused huge casualties and property losses, but also had a long-term impact on the local environment, highlighting the importance of safety management during oil and gas storage and transportation [10].

Another typical case is a crude oil leakage accident somewhere in China, which occurred on November 22, 2013, when the Sinopec Donghuang pipeline in Qingdao ruptured, resulting in a large amount of crude oil leaking into the sea, which ultimately triggered a serious explosion, resulting in 62 deaths and 136 injuries [11]. The causes of this accident mainly include pipeline design defects, poor construction quality and inadequate routine maintenance. After the accident, the relevant departments carried out a comprehensive investigation of the accident and found that the anti-corrosion layer of the pipeline had serious defects and failed to operate in strict accordance with the standards during the construction process, which led to cracks in the pipeline after years of operation. This accident not only brought serious impact to the life of local residents, but also caused irreversible damage to the marine ecosystem [12]. Through the analysis of the above cases, it can be seen that the safety risks in the process of oil and gas storage and transportation are mainly focused on the aging of pipeline materials, improper maintenance, design defects, construction quality problems and the failure of safety monitoring systems. Once these risks occur, they will not only lead to serious casualties and property losses, but also cause long-term negative impacts on the environment. Therefore, strengthening the safety management in the process of oil and gas storage and transportation, improving the reliability of equipment and the professional quality of operators, and establishing a sound safety monitoring and early warning mechanism are effective ways to prevent such accidents from occurring [13].

2.2 Energy Conservation in Oil and Gas Storage and Transportation.

2.2.1 Status of Energy Consumption.

The current situation of energy consumption in the oil and gas storage and transportation process is the result of a combination of factors. In the crude oil storage and transportation system, energy consumption mainly focuses on steam, electricity, and fuel, with steam consumption accounting for more than 80% of the total, making it the most important source of energy consumption.3 This not only reflects the high demand for energy utilization in the current oil and gas storage and transportation system, but also reveals the deficiencies in its energy efficiency management. A research on a tank farm found that the region has achieved a year-on-year decrease in steam consumption through a series of measures, such as optimizing the tank supply method, reducing the number of inversions, and establishing a mechanism for counting steam usage, showing the important role of technical optimization in the control of energy consumption [14]. However, despite a series of energy-saving measures, the problem of energy consumption is still serious due to factors such as aging equipment, lagging technological updates, and poor management. For example, the efficiency of long-running equipment decreases due to wear and tear, coupled with frequent start-stop operations,

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further exacerbating energy waste [11]. In addition, the lack of tank insulation measures is also one of the important reasons for high energy consumption, especially in the season of lower temperatures, the heat loss problem of tanks is particularly prominent [13]. From the international perspective, there is still a certain gap between China's oil and gas storage and transportation energy consumption control and developed countries, especially in technological innovation and management refinement needs to be strengthened. In summary, the current situation of energy consumption in oil and gas storage and transportation is not optimistic, and there is an urgent need to improve energy efficiency and reduce energy waste through technological innovation and management optimization, so as to contribute to the realization of the goal of sustainable development.

2.2.2 Analysis of Energy Saving Potential.

In the process of oil and gas storage and transportation, energy consumption is an important factor that cannot be ignored. Currently, the energy consumption of oil and gas storage and transportation systems mainly focuses on steam consumption, electricity consumption and fuel consumption [12]. These energy consumptions not only increase the operation cost, but also have a negative impact on the environment. Therefore, clarifying the current status of energy consumption in the oil and gas storage and transportation process is of great significance in exploring the potential space for energy saving. By analyzing the energy consumption of the existing storage and transportation system, it can be found that tank heating and machine pump operation are the main energy consumption links. For example, in a tank farm, steam consumption was significantly reduced by optimizing the tank supply method and establishing a statistical mechanism for steam usage [14]. In addition, the continuous operation of machine pumps is also one of the main sources of power consumption.

There are many factors affecting energy consumption in the oil and gas storage and transportation process, mainly including technical limitations, management problems and external environment. On the technical side, the high energy consumption and low efficiency of old equipment is one of the main reasons for energy waste. On the management side, the lack of effective energy consumption management and monitoring mechanism makes energy utilization inefficient. External environmental factors, such as climate change and geographical conditions, also affect energy consumption during storage and transportation. For example, extreme weather conditions often require an increase in the frequency of heating equipment in order to ensure the safe operation of pipelines, thus increasing energy consumption [15]. Therefore, it is particularly necessary to take appropriate energy saving measures to address these factors.

Based on the above analysis, assessing the energy-saving potential of each link of oil and gas storage and transportation can provide a theoretical basis for proposing effective energy-saving measures. For example, energy consumption can be significantly reduced by improving equipment and facilities through technological innovation. A study established an energy consumption prediction model for crude oil gathering and transportation system through BP neural network , which optimized the energy utilization efficiency and reduced the annual cost of gas and electricity [16]. In addition, optimizing the storage and transportation plan and improving the management level are also effective ways to reduce energy consumption. Through the application of optimization methods, unnecessary energy waste can be reduced while ensuring storage and transportation efficiency [14]. These measures not only help reduce operating costs, but also promote environmental protection and realize sustainable development.

3. Safety and Energy Conservation Measures in Oil and Gas Storage and Transportation.

3.1 Do a Good Job in the Pre-design of the Safety and Energy Saving Work.

Environmental factor analysis should be strengthened in the safety and energy saving work in the early stage of the oil and gas storage and transportation process. In the engineering design, a comprehensive investigation of the oil transmission line of the nature reserve, drinking water zone, the environment of the pollution medium for scientific analysis. When the oil and gas storage and

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transportation engineering construction line construction, the line direction should be determined according to the environmental characteristics. In the related design and planning work, the ecological and soil and water protection concepts are used to carry out the design, so that the project and the environment can get along harmoniously and the surrounding environment can not be damaged due to the storage and transportation construction. At the end of the design process, the construction environmental assessment work should be strengthened to minimize the impact on the surrounding environment.

3.2 Designing Safe and Energy-efficient Technical Solutions.

In the process of oil and gas storage and transportation, the design of technical solutions is the key to realizing the goals of safety and energy saving. First of all, technology selection needs to be based on various considerations such as safety, economy and operability. For example, when selecting energy-saving technologies, not only should we consider their energy-saving effect, but also need to evaluate their impact on system safety and economic costs. Specific technical solutions include, but are not limited to, intelligent monitoring systems, high-efficiency oil transfer pumps and energy recovery devices. Intelligent monitoring system can monitor the parameters in the storage and transportation process in real time, detect and deal with abnormal situations in time, and effectively prevent safety accidents; high-efficiency oil transfer pumps can reduce energy consumption and improve the efficiency of oil transfer by optimizing the design and operation status of the pumps; and the energy recovery device can use the residual heat in the system or the difference in pressure to generate additional energy, which further reduces the energy consumption. According to the characteristics of the process to choose a good corrosion, high temperature and pressure resistant materials, the design to strengthen the fire isolation, explosion relief and ventilation work, the explosion and fire performance of the device and equipment to strictly check [17]. According to the current situation of oil and gas storage and transportation, internal and external floating roof storage tanks should be used instead of fixed roof storage tanks in order to reduce the pollution of the environment and strengthen its safety. The steel pipe material of the oil pipeline must be qualified, and the pipeline inclusions should be controlled so that the hydrogen and sulfur content in the pipe can be reduced.

3.3 Enhanced Level of Maintenance and Management of Storage and Transportation Equipment.

In the oil and gas storage and transportation, the management and maintenance of related transportation pipeline equipment is also very important, we must take the principle of prevention and cure as the principle of the safety hazards of the transportation equipment to carry out in-depth inspection. The storage and transportation enterprises should be based on the special characteristics of the storage and transportation equipment, develop a detailed and scientific maintenance program plan, improve the equipment maintenance management responsibility system. And equipment maintenance personnel should regularly check the equipment to ensure that each index of the storage and transportation equipment and the relevant safety indicators are consistent. Especially to do a good job of pipeline anti-corrosion. The use of coating anti-corrosion, cathodic protection joint protection technology to ensure the quality of the pipeline, so that the transportation pipeline all-weather accident-free safe operation.

4. Case Studies and Effectiveness in Practice.

This case study is selected from a large-scale oil and gas storage and transportation project located in Shandong Province, China, which began in 2018 and is being implemented by Sinopec Group with the aim of improving the efficiency and safety of oil and gas transportation in the region. With a total investment of more than RMB 1 billion, the project covers the construction of a full oil pipeline from the oilfield to the refinery, which is about 300 kilometers long and passes through several cities and regions along the way. The implementation environment of this case is somewhat complex, geographically spanning a variety of terrains, including plains, hills, and some mountainous areas, while facing strict environmental requirements and policy restrictions [18]. The government of the

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project site attaches great importance to environmental protection and has introduced a series of relevant policies to ensure that the project construction and operation will not cause negative impacts on the local ecological environment. In terms of technology, the project adopts a number of advanced safety and energy-saving measures and technologies, including but not limited to supercritical CO2 pipeline transportation technology [19], intelligent monitoring systems, and the application of high-efficiency heat-insulating materials. These technologies were selected not only based on their advantages in improving energy utilization efficiency, but also in consideration of their safety and reliability in safeguarding the oil and gas storage and transportation process. For example, supercritical CO2 pipeline transportation technology was prioritized due to its significant effect in reducing energy consumption and improving transmission efficiency [19]; the introduction of intelligent monitoring systems effectively enhanced the early warning capability of potential safety hazards and ensured the smooth progress of the project.

In terms of implementation steps, from the preliminary preparation to the final implementation, the whole process is divided into four phases: preliminary research, program design, equipment installation and commissioning, and later operation and maintenance. In the pre-study phase, the existing storage and transportation system needs to be comprehensively assessed to identify the existence of safety hazards and energy waste points, in order to provide a basis for the subsequent design of technical solutions. In the program design stage, based on the results of the preliminary research, combined with the actual needs, design both economic and efficient solutions. In the equipment installation and commissioning phase, the construction is carried out in strict accordance with the design program to ensure that each link achieves the expected results. Finally, in the later operation and maintenance stage, establish a perfect maintenance system, regularly check and maintain the equipment to ensure the long-term stable operation of the system [17]. With regard to the operation process, in order to ensure the standardization and normalization of each step of the operation, a detailed operation manual has been formulated, which specifies the specific processes and standards of each work. For example, in the installation process of the automation control system, the pre-installation test of the system is carried out first to ensure the normal functioning of each component before formal installation; after the installation is completed, system intermodulation is also required to ensure the coordinated operation of the various sub-systems. In addition, special emphasis is placed on the professional training of operators to ensure that they can master the operating skills and avoid safety accidents caused by improper operation [19].

This case was chosen for study because of its typicality and innovation in the field of oil and gas storage and transportation. Firstly, the project successfully incorporates the latest environmental protection and energy saving concepts, demonstrating the possibilities of green development under existing technologies and conditions. Secondly, the scale and complexity of the project makes it an ideal object of analysis to comprehensively reflect the various challenges and their solutions that may be encountered in oil and gas storage and transportation. In addition, the successful implementation of the project provides valuable experience and lessons for other similar projects, and is highly replicable [19]. Through the implementation of the above safety and energy conservation measures, the project is expected to significantly reduce energy consumption and environmental pollution during oil and gas storage and transportation, while improving the overall level of operational safety. Specific targets include reducing energy consumption by more than 10%, lowering carbon emissions by 20%, and ensuring that no major safety accidents occur throughout the project's life cycle. These targets are set not only based on technical feasibility considerations, but also in response to the national strategic plan on energy conservation and emission reduction and the development of a green economy. In summary, this case study not only contributes to an in-depth understanding of safety and energy saving measures in oil and gas storage and transportation, but also provides a useful reference for future research and practice in related fields.

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5. Conclusion and Outlook.

This paper discusses safety and energy saving measures in the oil and gas storage and transportation process, aiming to solve the main safety risks and energy consumption problems existing in this field. It is found that the safety risks in the oil and gas storage and transportation process mainly include pipeline leakage, tank leakage, loading and unloading process leakage and transmission equipment leakage, etc. These accidents may not only lead to serious economic losses, but also cause catastrophic consequences such as fires, explosions and environmental pollution. At the same time, the energy consumption of oil and gas storage and transportation should not be ignored, and the high energy consumption not only increases the operation cost of enterprises, but also has a negative impact on the environment. To address the above problems, this paper proposes a number of technical solutions, including strengthening the management of the construction process, adopting environmentally friendly and energy-saving measures to ensure the scientific rationality of the construction; improving the safety and efficiency of oil and gas storage and transportation through the application of automation technology to reduce the risks caused by human errors; and optimizing the oil and gas storage and transportation process to improve the efficiency of energy use and reduce energy consumption. Comprehensive evaluation results show that these measures have demonstrated significant advantages in improving the safety performance and energy saving effect of oil and gas storage and transportation. Future research should focus on further innovation and optimization of technologies and strengthen policy support to promote the sustainable development of the oil and gas storage and transportation industry. In addition, attention should be paid to the challenges that new technologies may face in practical application, such as technical costs and operational complexity, to ensure the effective implementation of safety and energy-saving measures.

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