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The Necessity of Pipeline Integrity Management and Its Basic Methods

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Abstract

With the continuous acceleration of China's industrialization process, China's oil and gas industry is also developing rapidly. The oil and gas industry is an important part of China's national economy. The effective and safe operation of pipelines in oil and gas projects is directly related to the country's energy security and people The daily work and life of the pipeline, the integrity management of the pipeline runs through the entire process from the design to the use of the pipeline. The scientific use of the pipeline integrity management concept can effectively improve the line design level, ensure the safety of the pipeline, and ensure the safety of the pipeline. Economic Operation. Pipeline integrity management can prevent it before it occupies an important position in the entire life cycle of pipeline operations. Pipeline integrity management not only enables pipeline lines to be monitored in real time, but also enables pipeline maintenance, testing, and safe operation to be guaranteed, thereby ensuring the safe operation of pipelines. This article discusses the pipeline integrity management by analyzing the case of oil and gas pipeline accidents.

Keywords

Oil and gas pipelines; Integrity management; Accident cases; Necessity; Basic practices.

1. Introduction

The oil and natural gas industry is developing rapidly with the acceleration of industrialization. As the lifeline of the national economy, the operational safety of pipelines not only has great practical significance in the protection of national energy security, but also can maintain social stability.

As a means to ensure the safe operation of pipelines, pipeline integrity management has gradually come to people's attention under the prevailing background of modern pipeline transportation industry. It can be said that integrity management plays an irreplaceable role in the entire life cycle of newly built pipelines from design to operation. As an advanced way of managing pipeline safety, pipeline integrity management can take precautions. In turn, the safe operation of the pipeline is guaranteed. Therefore, the concept and method of integrity management can improve the level of pipeline design so as to ensure the safety of pipeline operations, and occupy an important position in the entire life cycle of pipeline operations [1].

2. Case analysis of Oil and Gas Pipeline Accidents

2.1. Chongqing Natural Gas Pipeline Accident

2.1.1. Case Analysis of Oil and Gas Pipeline Accidents

Oil and gas pipelines are highly dangerous structures. They will be affected and destroyed by various uncertain factors for a long time, and corrosion and other defects will appear to varying degrees. Once an accident occurs, it will have a serious impact on people's lives and property safety.

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There are about 57,000 kilometers of long-distance oil and gas pipelines in my country, ranking sixth in the world; there are about 200,000 kilometers of oil field gathering and transportation pipelines; about 100,000 kilometers of urban distribution pipelines; and about 2,000 kilometers of submarine pipelines. At the same time, oil and gas pipeline accidents will bring economic losses, social impacts, casualties, environmental pollution and other consequences. Figure 1 respectively show long-distance oil and gas pipelines and pipeline explosion accidents.

Figure 1. Oil and gas pipeline explosion accident

2.1.2. Accident Profile

At 3:30 am on March 14, 2008, a natural gas leakage explosion occurred in Huixing Town, Yubei District, Chongqing City [2]; the accident caused 3 deaths, 5 serious injuries, and 5 minor injuries. As well as major economic losses, the scene of the accident is shown in Figure 2.

Figure 2. Chongqing natural gas pipeline accident

2.1.3. Accident

At about 3:30 am on March 14, 2008, four co-workers were patrolling Xingke 1st Road, Huixing Town, and discovered that there was a strong peculiar smell of natural gas near Zhengwei Jizi Building #17 "Xiaojingdian Hair Salon". Wang Xiangjin, who runs a late-night snack shop next door, knocked on the door to inform the household that there might be a natural gas leak, and an explosion occurred when the shop personnel turned on the light.

2.1.4. Cause of Accident

(1) Direct cause

The PE (d110) gas pipeline along the street was torn apart, causing natural gas leakage. The leaked natural gas escaped into the room through the underground loose backfill soil layer, forming an explosive mixture of gas, which caused an explosion when encountered with sparks from switch appliances.

(2) Indirect causes

The pipeline backfill did not treat the foundation or take anti-settling measures, and the backfilled soil layer settled under the infiltration of rainwater. Under the superposition of external load stress, the pipeline will have a certain impact on the hot melt weld of the pipeline, causing the pipeline to crack.

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2.1.5. Lessons Learned

(1) It is necessary to attach great importance to safety work, firmly establish the awareness of "safety is heaven", and there should be no slightest paralysis;

(2) It is necessary to vigorously carry out the investigation and remediation of hidden dangers to ensure the remediation effect and eliminate the hidden dangers in the bud;

(3) Add odor to civil gas to facilitate timely detection of natural gas leakage;

(4) Strengthen the sense of responsibility education of the majority of employees, especially the line employees, strengthen the risk prevention and identification capabilities of enterprise employees, and effectively implement pipeline inspections and equipment maintenance;

(5) It is necessary to strengthen the publicity of user safety knowledge and household safety inspection, and improve users' self-prevention awareness;

(6) Strictly monitor all aspects of construction projects to ensure project quality.

2.2. CNPC Lanchengyu Pipeline Accident

2.2.1. The Incident

The Lanzhou-Chongqing oil pipeline runs through Lanzhou, Chengdu, and Chongqing, with a total length of 1,250km and a total investment of more than 5 billion yuan. On December 19, 2003, a serious oil leak occurred at 618.8km from Shiyang Bridge, Chihua Town, Shizhong District, Guangyuan City, Sichuan Province. Fire officers and soldiers worked in concert with public security, Petroleum Pipeline Co., Ltd., Chengdu Railway Branch and other forces. After 14 hours of hard fighting, the danger was completely eliminated at 22:35 that night, ensuring that the Baocheng Railway resumed normal operation and avoided personnel. Casualties and greater property damage [3].

Figure 3. CNPC Lanchengyu pipeline accident

2.2.2. Cause of Accident

The cause of the accident was that the oil thief opened a 50mm diameter hole in the pipeline and installed a gate valve to steal the oil. Under the action of the oil delivery pressure in the pipe, the ball valve was broken and the gasoline leaked seriously.

2.2.3. Accident Rescue Experience

(1) Strengthen the mobilization of strength and rush to the scene quickly. After receiving the alarm, Guangyuan City Fire Detachment immediately mobilized 12 fire trucks directly under the squadron and 4 full-time fire brigades. More than 80 public security and full-time firefighters rushed to the scene and mobilized a large amount of personal protective equipment and foam fire extinguishing agent in time. The leaders of the Sichuan Fire Brigade immediately dispatched reinforcements from Chengdu and Mianyang. The dispatching force was rapid and accurate, and sufficient force was prepared to deal with the leakage accident.

(2) Vigilance, reconnaissance, detection, and prohibition of fire sources. After reconnaissance, there was a 10kV high-voltage line 30m west of the leak and a 110kV power line 300m north. After the accident, engineers and technicians quickly closed the valves at both ends of the

leakage point. Due to the elevation difference and other reasons, there were still 2000t gasoline in the pipeline after the valve was closed, and the injection height reached 30 m. The headquarters quickly took measures: First, use a combustible gas monitor to detect the concentration of gasoline vapor at the scene and delimit a warning area. And traffic control is implemented by public security and traffic police. Evacuate the surrounding people; the second is to cut off all power supply and fire sources in the warning area; the third is to prohibit motor vehicles and pedestrians from entering the accident site. Turn off the mobile phones of the on-site personnel; fourth, the fire officers and soldiers diluted with spray water. Reduce oil vapor concentration; Fifth, urgently mobilize 14 hand-lifted motorized pumps. Ensure normal water supply in front.

(3) Build embankments to stop the oil, and suck back the flow. Fire officers and soldiers, public security officers and local people filled sandbags and built a 17m long and 1.2m wide oil barrier around the leak to minimize the flow of gasoline into Qingyi River. At the same time, the firefighting forces conducted strict inspections and dilutions. The Guangyuan Branch of the PetroChina Pipeline Company transferred 5 gasoline transfer vehicles to continuously suck, dump, and transfer the leaked gasoline.

(4) Foam coverage, stop leaks in close combat. After the successful construction of the embankment to block the oil, the headquarters immediately deployed 3 foam guns to cover the flowing gasoline and reduce the volatilization of gasoline. At the same time, fire officers and soldiers use testing equipment to implement continuous testing. Fire officers and soldiers and oil company technicians used wooden wedges and non-sparking tools to forcibly plug the leak under the cover of spray guns. At 15:10, the leak was successfully plugged and the Baocheng Railway, which was interrupted for 7 hours, resumed normal traffic.

(5) Cover for emergency repairs and eliminate danger. After the leak was successfully plugged, 3 fire engines of the Guangyuan City Fire Detachment continued to stay behind, spraying water and foam around the leak, and using 2 fans to ventilate the oil vapor on site and detect the vapor concentration at any time. Engineers and technicians re-blocked the tubing with alloy steel cock, and covered and welded with a metal cover to plug leakage.

(6) Cross-region reinforcements and coordinated operations. This rescue is a successful case of Sichuan Fire Force's cross-regional combined operations. After the leaders of the Sichuan Fire Brigade arrived on the scene, they set up a headquarters in a timely manner, set up teams for rescue, alert, pipeline repair, and logistics support. Commanders at all levels conducted scientific commands to ensure the personal safety of the soldiers.

3. Pipeline Integrity Management

3.1. Pipeline Integrity Management Concept

Pipeline Integrity Management (Pipeline Integrity Management, abbreviated as "PIM") is usually defined as: In order to ensure the safe operation of pipelines and prevent pipeline accidents, pipeline operators face the potential risks of pipeline operations based on endless pipeline factors To control the risk level of pipeline operation through the use of corresponding risk control methods, and control the pipeline operation risk within a reasonable and acceptable range, and conduct pipeline adaptability through monitoring, testing, and inspection methods. Assessment and continuous improvement of pipeline integrity and factors that threaten pipeline failure to prevent pipeline accidents. Pipeline integrity management is a cyclical and comprehensive process, and the entire process is particularly important from the beginning of pipeline design and planning until the pipeline is put into use and scrapped.

Pipeline integrity management is an integrated and comprehensive management, which requires continuous analysis and research on related factors affecting pipeline integrity. Effective and scientific assessment of pipeline risks is required, so as to assess potential risks

and accidents of pipelines. To understand the consequences, analyze the causes and locations of frequent pipeline accidents by regularly inspecting and evaluating the integrity of the pipeline, and at the same time, make targeted improvements and continuously train pipeline managers.

3.2. Pipeline Integrity Management Composition

Pipeline integrity management is mainly divided into pipeline integrity objectives, pipeline integrity management system and physical technology system, quality control, management audit, pipeline integrity management information platform, pipeline data management platform and pipeline integrity geography Information support platform [7].

The first is to set pipeline integrity management objectives based on multiple requirements such as finance, safety and environmental protection. The systematic integrity management system ensures that the safe operation of the pipeline complies with PDCA continuous improvement, and ensures that the system management procedures, systems and technical systems enable the orderly operation of integrity management , And then the quality control and management guarantee of the system can provide guarantee for pipeline integrity management efficiency, and finally digital management provides support for pipeline integrity management efficiency and intelligent decision analysis.

3.3. Pipeline Integrity Management Support Technology

Integrity management requires a lot of technical analysis and evaluation, including two major parts, 4 levels, and 8 series. The two major parts mainly include the line part and the station part. The 8 series mainly include hazard identification, risk assessment, and integrity. Inspection and evaluation, pipeline monitoring and monitoring, pipeline repairs, station risk assessment, equipment monitoring and monitoring, station pipeline inspection and evaluation, and instrumentation system integrity.

3.4. Pipeline Integrity Management Operation Mode

The operation mode of pipeline integrity management complies with the Deming Model (PDCA): “Plan-Implement-Inspect-Improve”. First, the management system policy is formulated, the integrity management system documents are established and implemented, and then internal and external Check and evaluate the effectiveness and rationality of the system, and finally realize the continuous cycle and continuous improvement of the management system.

4. Application and Necessity of Pipeline Integrity Management

4.1. The Need for Integrity Management

Ensuring the safety of pipeline operation is a prerequisite for ensuring the stability of my country's energy supply system. The main function of pipeline integrity is to ensure that the working state of the pipeline is always safe and reliable, and to effectively control the state of the pipeline, and at the same time to ensure that the physical and functional integrity of the pipeline should take timely targeted measures for the occurrence of pipeline accidents Because the pipeline is a process of contact and update, it requires effective integrity management of the pipeline. Not only that, the life cycle of the pipeline is also closely related to integrity management. The time dependence of pipeline failure is very strong. The design, construction and operation of the pipeline system, etc. The concept and practice of pipeline integrity management need to be integrated [8].

4.2. Pipeline Route Planning and Design

Pipeline planning and management has many obstacles, including a wide area, high media risk, continuous production, high operating pressure, etc. Once problems occur, it will affect the

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entire system. So this requires us to plan and design pipeline routes first. It is necessary to strictly abide by the relevant national pipeline laws and regulations. Secondly, the pipeline integrity management method should be effectively introduced, and the pipeline design line should be optimized, so as to ensure the later operation safety of the pipeline and the rationality of the pipeline route planning.

4.3. Risks of Pipeline Routes

Through the analysis and research of pipeline accidents, it is concluded that the common causes of pipeline accidents are usually basically due to the corrosive operation of the pipeline. The occurrence of any of the problems, such as incorrect construction or material damage, will seriously affect the pipeline line and cause casualties. Third-party damage, equipment failure, etc. will threaten the personal safety of the staff. In order to more accurately understand the impact of each risk factor, you can calculate the correlation degree of various accident risk factors in the pipeline according to the correlation degree of each factor. Factors carry out risk ranking so as to scientifically prevent pipeline risks.

4.4. Inspection of Pipeline Operation

Pipeline inspection is a complex process, which includes many aspects of inspection such as external inspection, internal inspection, wall thickness and non-destructive inspection, etc. The normal operation of the pipeline depends on the operating status of the line. Pipeline integrity management can realize the pipeline line Real-time monitoring of operation, so it is of great significance to promote the normal operation of pipelines through pipeline integrity management.

4.5. Realization of Safe Pipeline Operation

Natural gas pipeline is a system of fluid medium transportation. The external conditions have certain pressure and temperature conditions. How to ensure the long-term stable operation of the pipeline requires comprehensive control in many aspects. First of all, for long-distance natural gas pipelines, my country has promulgated some macro-management regulations, and companies must strictly abide by the regulations, from materials, design, and construction. The use of strict control in many aspects, in addition, the company itself must formulate safety management operating procedures according to specific enterprise conditions and urge employees to comply with it and standardize operations [9].

5. Basic Practices of Integrity Management

The objects of integrity management are tube body, anti-corrosion layer and cathodic protection, which are interrelated and have their own characteristics.

5.1. Data Collection

The data runs through the entire life cycle of the pipeline (design → construction → operation), including basic pipeline data, environmental data, operation and maintenance data, inspection and evaluation data, etc. Develop pipeline data standards, collection templates, and review mechanisms to ensure that the source data is true and effective and the format is standardized [10]. Establish pipeline database and information management platform to realize unified and efficient data management. Pipeline data should be continuously updated and archived in time according to daily business activities,

5.2. High Consequence Area Identification

The high-consequence area is a key section for the implementation of integrity management. According to the changes in the social and natural environment information around the pipeline, the high-consequence area identification is carried out regularly. High-consequence areas are

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divided into three categories: dense population, important facilities, and environmentally sensitive according to the types of consequences, and three levels of severity: III (high), II (medium), and I (low). The identification and classification results of high-consequence areas can be used to guide line design, risk assessment, and maintenance.

5.3. Risk Assessment

Risk is a comprehensive measurement of failure probability and failure consequences, and risk evaluation is an important basis for complete decision-making. Therefore, it is necessary to fully identify the pipeline hazards such as excavation damage, corrosion, design and construction, operation and maintenance, geological disasters, and deliberate damage, analyze and evaluate the failure probability and potential hazard consequences, and scientifically evaluate the pipeline risk status. Determine risk sensitive factors based on the evaluation results, and formulate targeted mitigation measures to provide guidance for daily protection, hidden danger management, inspection and evaluation, repair and maintenance, etc.

5.4. Completeness Evaluation

Integrity inspection and evaluation is an important means to fully grasp the integrity of the pipeline itself and its auxiliary facilities. Therefore, it is necessary to reasonably choose internal inspection and evaluation, direct evaluation, pressure test or other technical methods to determine or estimate the type of pipeline defects, and accurately evaluate its safety and applicability, and scientifically formulate maintenance and maintenance plans

5.5. Repair and Maintenance

Repair and maintenance is based on the results of high-consequence area identification, risk assessment and integrity assessment, to formulate repair and maintenance plans for pipelines with greater safety hazards, determine the response level, and implement them as planned. For pipelines that do not need to be repaired temporarily, maintenance preventive measures shall be formulated and implemented based on the evaluation results.

Figure 3. Field maintenance

5.6. Effectiveness Evaluation

(1) Establish an efficiency evaluation index system

The first is to investigate and understand the current status of the integrity management business of the pipeline enterprise and key implementation elements. Then conduct theoretical analysis and questionnaires to determine the sensitive factors of integrity management efficiency and establish an evaluation index system.

(2) Establish an effectiveness evaluation model

First, statistically analyze historical accidents, determine efficiency evaluation requirements, and establish efficiency evaluation goals. Then combined with the actual demand for theoretical analysis, establish an evaluation mathematical model based on process management and effect evaluation.

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(3) Develop effectiveness evaluation methods

Advanced comprehensive evaluation technology determines a multi-index comprehensive evaluation method. Then the fuzzy mathematics theory establishes a quantitative and qualitative evaluation method.

5.7. Basic Approach

The current mainstream approach of integrity management is system construction + technology development + platform construction [11], and finally form corporate standards

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