

Exploration of Safety Management and Maintenance Techniques for Special Chemical Equipment

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Abstract: This article explores the importance of safety management and maintenance techniques for special chemical equipment and analyzes the current shortcomings. Safety management provides the prerequisite for maintenance, while maintenance is an integral part of safety management. Through regular inspections and repairs of equipment, it ensures the safety and reliability of the equipment, reducing the occurrence of accidents. Timely identification and resolution of safety issues ensure that the equipment operates in a safe state. The article proposes a series of improvement measures, which can enhance the safety and reliability of special chemical equipment and provide better assurance for chemical production.

Keywords: special chemical equipment; safety management; maintenance

1. Introduction

Safety management is a crucial means of preventing accidents and reducing production risks in the operation of special chemical equipment. By establishing a comprehensive safety management system and operating procedures, it can ensure that operators follow standard operating procedures, reducing operational errors and accidents caused by human factors. Regular equipment maintenance ensures its proper working condition. Regular replacement of vulnerable parts and lubricants prevents wear and failures due to prolonged use of the equipment. Effective implementation of maintenance techniques can reduce equipment failure rates, minimize production interruptions, improve production efficiency, and also reduce maintenance costs, saving company resources.

2. The Importance of Safety Management and Maintenance Techniques in Special Chemical Equipment for Chemical Industry

Special chemical equipment operates in environments involving high temperature, high pressure, and flammable and explosive substances, making them prone to high operational risks. Any accidents in these devices can lead to severe casualties and environmental pollution. Effective safety management measures are crucial to ensuring the safe operation of special chemical equipment. It is essential to establish a robust safety management system, delineate responsibilities, and clarify work procedures to ensure that personnel strictly adhere to safety operating procedures in high-risk work environments. Training employees to be aware of safety risks and equipping them with emergency response measures is also indispensable. Conducting regular safety drills to enhance employees' ability to handle emergency situations is an effective means of accident prevention. Regularly inspecting the operational status of equipment, identifying potential issues, and promptly addressing them can reduce equipment failure rates and ensure normal equipment operation. Furthermore, routine replacement of vulnerable components and critical parts extends equipment lifespan, lowers the risk of equipment failure, and optimizes equipment performance, thus improving production efficiency and reducing resource consumption in line with the principles of sustainability^[1].

3. Current Shortcomings in Safety Management and Maintenance Techniques for Special Chemical Equipment

3.1 Lack of Awareness Among Personnel

Some management personnel in chemical enterprises may perceive safety management and maintenance as secondary tasks, prioritizing them lower than production efficiency. Consequently,

these enterprises allocate insufficient resources to safety and lack long-term safety planning and preventive measures. Moreover, some chemical companies do not place enough emphasis on safety, leading to inadequate awareness and attention to safety among their staff. This phenomenon may result in negligence, carelessness, or improper behavior during equipment operation and maintenance, posing safety hazards and accident risks^[2]. Insufficient safety awareness and a lack of urgency may lead some employees to not strictly adhere to safety regulations, neglect safety operating procedures, or exhibit inadequate vigilance regarding equipment operation status. Such negligence and improper behavior undoubtedly increase the likelihood of accidents, potentially having a severe impact on the company's production and employees' well-being^[3].

3.2 Lack of Comprehensive Maintenance Plans

In many chemical enterprises, although equipment maintenance is considered important, there is often a lack of comprehensive maintenance plans. These companies typically only take emergency maintenance measures when equipment malfunctions or serious failures occur. The absence of regular inspections and preventive maintenance leads to a gradual decline in equipment performance, which may result in severe breakdowns or accidents. Some enterprises may view maintenance as a cost rather than an investment, and they are reluctant to allocate significant resources to it. However, this short-sighted approach may lead to frequent equipment failures, higher maintenance costs, production losses, and even jeopardize employee safety in the long run^[4]. Furthermore, some companies may lack an understanding of preventive maintenance. They may believe that maintenance is only necessary when equipment fails, overlooking the gradual aging and wear of equipment during operation. Regular inspections and maintenance can detect and address potential equipment issues promptly, ensuring equipment remains in good working condition, enhancing its stability and reliability^[5].

3.3 Outdated Technological Means

In current chemical enterprises, the use of traditional methods for equipment safety management and maintenance is still prevalent. These traditional methods often include periodic inspections and manual observations, lacking advanced monitoring technologies and maintenance approaches. This practice results in several issues. Due to the limitations of time and human resources, manual inspections cannot achieve round-the-clock monitoring of equipment, making it difficult for enterprises to have real-time insights into equipment operational status. Additionally, traditional methods often rely on personnel experience and perception, which may overlook subtle but potentially risky signs of malfunction. This situation is particularly pronounced in special chemical equipment since these devices typically operate under extreme conditions such as high temperature, high pressure, and corrosive environments, making them prone to concealed faults^[6]. Ultimately, the absence of advanced monitoring technologies and maintenance approaches limits enterprises' comprehensive understanding of equipment and their ability to intervene effectively, hindering the overall enhancement of equipment safety and reliability.

4. Chemical Special Equipment Safety Management and Maintenance Techniques

4.1 Strengthening Personnel Training

Organizing specialized training is a crucial approach to improving safety management and maintenance techniques for chemical special equipment. During training, comprehensive and systematic knowledge and skill training should be conducted for employees in different positions. Training content should encompass safety operating procedures to ensure that operators are familiar with the correct operating processes. Emphasizing emergency response methods for different emergency situations is essential as emergency plans are a vital safeguard for the safety of chemical special equipment. Training should also cover equipment maintenance knowledge, including skills for daily maintenance, regular inspections, and troubleshooting. Through training, employees acquire maintenance and repair skills, enabling them to promptly identify equipment abnormalities and carry out necessary repairs and maintenance to ensure equipment is in good working condition. By analyzing case studies of safety incidents and providing safety awareness education, employees gain a deep understanding of the importance of safety management and the potential consequences it carries. Simulation exercises during training allow employees to experience real-life emergency situations and improve their emergency response capabilities. It is imperative that the management of chemical enterprises correctly recognizes the importance of safety management and maintenance, prioritizing them above production efficiency and taking practical measures to ensure employee safety. Only when employees fully understand the significance of safety management and maintenance, adopt the correct

safety mindset, and possess a sense of responsibility and urgency, can equipment safety be guaranteed.

4.2 Regular Equipment Maintenance

Establishing a comprehensive equipment maintenance plan is a key measure to ensure the safe and reliable operation of chemical special equipment. This plan should encompass various aspects, with regular inspections being a crucial component. Regular inspections involve meticulous examination of all equipment components to ensure their integrity. Through regular inspections, potential faults and hazards in the equipment can be detected, and measures can be taken promptly to repair and adjust, preventing the accumulation of risks caused by minor issues. Beyond equipment inspections, regular maintenance and cleaning of the equipment are necessary. This not only ensures the equipment remains in good working condition but also extends its service life. Lubrication is a vital aspect of maintaining normal equipment operation. Regular lubrication reduces operational resistance, decreases frictional wear and tear, and lowers the equipment failure rate. Furthermore, the regular replacement of vulnerable components should not be overlooked in the equipment maintenance plan. Vulnerable components such as seals, rubber parts, and filters often experience significant wear and tear during equipment operation. If not replaced promptly, they can lead to decreased equipment performance or even failure. Therefore, regular replacement of vulnerable components ensures stable equipment operation, reduces maintenance costs, and mitigates the risks of production interruptions and safety hazards caused by vulnerable component failures. Thus, the establishment of a comprehensive equipment maintenance plan is the cornerstone of safety management for chemical special equipment, effectively ensuring that the equipment remains in good working condition and providing robust support for production safety and environmental protection.

4.3 Introduction of Advanced Equipment and Technologies

Modern equipment monitoring technologies and maintenance methods have greatly enhanced the safety and maintainability of chemical special equipment. The introduction of advanced technological means can effectively monitor equipment operational status, provide real-time data on equipment parameters, promptly detect anomalies, and take corresponding measures, thus reducing the probability of accidents. The implementation of an online monitoring system is a significant step that allows real-time monitoring of equipment operational status. This system utilizes sensors and data collection devices to monitor critical parameters of chemical special equipment, including temperature, pressure, flow rate, vibration, and more. Real-time monitoring assists personnel in promptly identifying potential anomalies, such as excessive temperature, pressure fluctuations, abnormal vibrations, and taking actions to prevent equipment failures. The application of online monitoring systems significantly enhances the understanding and control of equipment status, effectively preventing potential hazards. Automation technology, which delegates certain equipment operations and control processes to computer systems, can help avoid human errors and negligence. Automated control systems provide precise control and adjustment of equipment operational parameters, improving equipment stability and reliability. Additionally, automated control systems can perform maintenance and repair operations automatically based on preset conditions and requirements, reducing the need for human intervention and, consequently, lowering maintenance costs and risks.

4.4 Establishment of Robust Safety Management Systems and Operating Procedures

Establishing scientifically sound safety management systems and operating procedures is fundamental to ensuring the safety of chemical special equipment. Through the creation of a comprehensive safety management system, including safety operating procedures, emergency plans, accident handling procedures, and more, employee behavior can be effectively regulated, reducing potential risks. During the development of regulations and procedures, the unique characteristics and conditions of the equipment, as well as the potential hazards involved, must be fully considered to ensure the regulations' scientific and practical nature. Clearly delineating responsibilities and management processes is crucial for safety management. Safety management systems should specify the responsibilities and obligations of personnel in different positions and clarify the authority and duties of relevant individuals to ensure that each step has a dedicated person responsible. Furthermore, well-defined management processes ensure smooth communication and accountability, facilitating swift responses to emergencies. To ensure the effective implementation of safety management systems and procedures, personnel training is essential. Tailored training for employees in different positions ensures that they are familiar with and proficient in relevant regulations and operating procedures, enhancing their safety awareness and risk prevention capabilities. Periodic safety training and drills should also be organized to improve employees' emergency response abilities, ensuring they can respond swiftly and appropriately in emergency situations. By establishing scientifically sound safety

management systems and operating procedures, clarifying responsibilities and management processes, and strengthening employee training, it is possible to effectively reduce accidents caused by human error and enhance the safety and stability of chemical special equipment.

5. Future Development Strategies for Safety Management and Maintenance Techniques of Chemical Special Equipment

5.1 Online Monitoring Systems

By installing various sensors on equipment, real-time monitoring of critical parameters such as temperature, pressure, and liquid levels during equipment operation can be achieved. The collected data is then transmitted to a central monitoring system for processing. Through real-time data analysis and anomaly detection capabilities, the monitoring system can accurately assess the equipment's operational status, promptly identify anomalies, and potential faults. In the event of issues, the system immediately issues warning signals, notifying relevant personnel to take appropriate emergency measures. The application of real-time monitoring technology will significantly enhance the monitoring and responsiveness to chemical special equipment. Continuous data collection and analysis of equipment operation data can establish a dynamic assessment of equipment health, aiding in the formulation of more scientifically rational maintenance plans. Furthermore, the monitoring system possesses data storage and analysis capabilities, allowing it to record historical operational data, providing robust evidence for subsequent equipment failure analysis and root cause investigation. As sensor technology and data processing algorithms continue to advance, the performance of equipment monitoring systems will improve, expanding the range of monitored parameters. This will provide chemical enterprises with more comprehensive and accurate information about equipment operational status, facilitating full lifecycle management of equipment, and maximizing equipment safety and reliability. Additionally, with the application of artificial intelligence (AI) technology, systems can conduct deeper data mining and analysis, predict potential equipment failures, achieve intelligent preventive maintenance, and further enhance equipment operational efficiency and lifecycle cost management.

5.2 Automated Control Systems

By introducing automated control systems, the risks associated with human-operated equipment can be effectively reduced, enabling automated control and intelligent operation of equipment. Automated control systems utilize advanced sensor technology and data collection systems to monitor equipment operational status and parameters in real-time. Once anomalies are detected, the system makes immediate adjustments and responses to prevent potential safety risks and faults. Moreover, automated control systems can achieve automated equipment operation based on preset control strategies. During equipment operation, the system can automatically adjust parameters such as flow rate, temperature, and pressure to maintain the equipment in its optimal working condition. This not only improves equipment operational efficiency and production stability but also reduces production failures and downtime caused by human errors. The application of automatic control technology allows chemical special equipment to operate with minimal human intervention, reducing the risks associated with human errors and enhancing overall equipment safety. Furthermore, automated control systems can provide continuous monitoring of equipment, ensuring that the equipment operates in its optimal state at all times. Therefore, the application of automatic control technology to safety management and maintenance of chemical special equipment not only enhances equipment safety and stability but also effectively reduces potential risks associated with human operation.

5.3 Application of Artificial Intelligence

Utilizing artificial intelligence (AI) technology to perform deep learning and analysis of equipment operation data can achieve intelligent maintenance and preventive maintenance goals. First, through the collection and processing of equipment operation data, AI systems can establish a real-time monitoring and analysis of equipment operational status. This real-time monitoring capability enables the system to promptly detect anomalies during equipment operation, such as abnormal fluctuations in parameters like temperature, pressure, and vibration, thus predicting potential equipment faults. Early warnings can prevent production downtime and interruptions caused by equipment failures, ensuring continuous and stable industrial production. Secondly, AI systems can identify potential patterns for equipment faults and maintenance needs by conducting deep learning on historical data. By learning the characteristics and patterns of past equipment failures, the system can more accurately predict potential future faults. This predictive maintenance approach allows maintenance personnel to take targeted maintenance measures before equipment failures occur or mitigate the resulting losses. Additionally, the system can

provide maintenance recommendations tailored to equipment operational conditions and maintenance history, assisting maintenance personnel in performing more efficient equipment maintenance and upkeep. The utilization of AI technology to perform deep learning and analysis of equipment operation data not only achieves intelligent maintenance but also fundamentally improves equipment reliability and safety.

5.4 Strengthening International Cooperation

In the current era of globalization, safety management and maintenance techniques for chemical special equipment face increasingly common and interconnected challenges. Collaborating and exchanging experiences with other countries and regions can facilitate the sharing of successful experiences and advanced technologies in safety management and maintenance. This cross-border cooperation not only helps fill gaps in domestic technology but also promotes the standardization and regularization of global safety management for chemical special equipment. By establishing close cooperative relationships with other countries and regions, a platform for technical exchange can be created, organizing experts and scholars to engage in academic exchanges, technical discussions, and experience sharing. Moreover, visits, inspections, and training activities can be organized, enabling domestic technical personnel to gain in-depth insights into advanced practices and technological methods in safety management and maintenance from other countries. Such cooperation and exchanges not only contribute to addressing current technical challenges but also elevate the overall qualifications and technical competence of domestic technical personnel. In a globalized context, the market for chemical special equipment is gradually becoming internationalized. Through cooperation and exchanges with other countries and regions, it is possible to understand the safety management and maintenance standards and requirements in international markets, which can then be adjusted and improved to meet international market demands. This alignment and standardization can enhance the competitiveness and international influence of chemical special equipment, further expanding international market share and promoting the development of domestic industries.

6. Conclusion

Safety management and maintenance techniques are the foundation and guarantee for ensuring the safe and stable operation of chemical special equipment. Within a scientifically rational safety management system, coupled with effective maintenance measures, chemical special equipment can maximize its role in industrial production while ensuring production safety, improving production efficiency, and conserving enterprise resources. Enterprises should attach great importance to the application and implementation of these technologies, creating favorable conditions for the safety of equipment, stable production, and sustainable development. Utilizing artificial intelligence technology for intelligent maintenance and strengthening cooperation and exchanges with other countries and regions to absorb advanced safety management and maintenance experiences are essential steps towards standardizing and regulating the globalization of safety management for chemical special equipment.

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