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Methods and Measures for Leak Detection of Heating Pipe Networks

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Abstract: As a crucial component of urban infrastructure, heating pipe networks are responsible for providing safe and stable heating services to residents. With the acceleration of urbanization and the continuous growth of heating demand, the heating pipe network system has expanded significantly. However, the expansion of the heating system and its scope make it difficult to ensure the safety and stability of the heating pipe network. Therefore, it is of practical significance to explore methods and measures for leak detection of heating pipe networks.

Keywords: Detection technology; Faults; Energy; Heating pipe networks; Temperature

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1. Introduction

In the context of accelerated urbanization and the improvement of people's living standards, the safety and stability of the heating pipe network system, which serves as the cornerstone for maintaining and supporting the safe and harmonious development of cities, have received extensive attention from society and the public. Facing multiple challenges such as pipeline damage, heat source alternation, and natural aging, traditional leak detection methods can no longer meet the more precise and targeted requirements. At the same time, they also increase the consumption of a large amount of energy to a certain extent and pose potential safety hazards. In this context, regular inspection of heating pipe networks can help detect and resolve potential problems in a timely manner, ensuring the stable operation of the heating system. In addition, an intelligent monitoring system can be used to monitor various parameters of the pipe network in real-time, improving management efficiency and enabling timely detection and handling of problems.

2. Causes of leakage faults in heating pipe networks

2.1. Material problems of heating pipe networks

The materials selected during the construction of heating pipe networks are closely related to the degree of

network aging and service life. In order to save costs, some heating pipe networks often use low-quality iron, steel, and other materials. These materials, which are prone to chemical reactions, are likely to be affected by the environment during long-term use and become corroded, further accelerating the aging of the pipe network [1]. For example, the internal corrosion of heating pipe networks is mainly caused by the quality of the water inside the pipes. When there is a high content of oxygen or carbon dioxide in the environment, these chemical substances will react with the pipe materials, leading to metal corrosion. Low-quality iron and steel pipes have poor corrosion resistance and are more vulnerable to external corrosion, thus affecting the bearing capacity and service life of the pipes. In addition, the environment inside the heating pipes is too humid, which accelerates the corrosion rate of the internal materials. In a humid environment, with the large-scale generation of chemical substances, moisture, and oxygen, the pipe network materials react with them, resulting in a corroded state. Low-quality iron and steel pipes that have not undergone pre-treatment are more vulnerable to corrosion and form rust layers. This not only affects the appearance of the pipes but also weakens their structural strength, increasing the risk of pipe rupture and leakage [2].

2.2. Difficulty in determining temperature and pressure

During the operation process, the changes in temperature and pressure in heating pipes affect the heating pipe network to a certain extent, leading to various faults. Under the action of high temperatures, the internal structure of the pipe network materials changes, causing the materials to react chemically with substances in the air, including thermal expansion, softening, and embrittlement of the materials [3]. For example, as the temperature rises, the pipe network materials will expand thermally, causing changes in the pipe dimensions and resulting in loosening or rupture. At the same time, in a high-pressure environment, both the inner and outer walls of the heating pipes are subjected to greater stress. Long-term operation under high pressure will cause fatigue damage to the pipe materials, making the pipes more fragile and greatly increasing the probability of rupture.

3. Methods for leak detection of heating pipe networks

3.1. Infrared thermal leak detection method

Infrared thermal imaging technology is a technique that uses an infrared detector and an optical imaging lens to receive and convert the infrared radiation energy distribution pattern emitted by an object. Infrared thermal imaging technology can generate visible thermal images and effectively display the infrared energy emitted by the object. Infrared thermal imaging technology can work in a non-lighted environment. It can not only accurately capture the shape and direction of an object in the dark but also determine the actual radiation temperature of the infrared image object through temperature calibration and calibration equipment, enabling the rapid mapping of the temperature distribution [4].

On the one hand, the leakage of heating pipes can change the temperature of the surrounding soil. Specifically, as the leakage time and leakage volume increase, the temperature range of the affected soil will gradually expand. Infrared thermal imaging technology can effectively monitor the changes in soil temperature, accurately capture the thermal images of the heated areas, timely detect the location of pipe leaks, and monitor the operation status of the pipes.

On the other hand, when the pipe network is operating normally, the infrared thermal imager can directly monitor and detect the temperature of the soil around the pipes, thus timely reflecting the operation status of

the pipes. If signs of heating pipe leakage are detected, measures can be taken immediately to reduce the risk of potential major accidents.

3.2. Traditional leak detection methods

Basic principles such as acoustics, optics, and heat are the main methods relied on by hardware detection technologies for monitoring heating pipe networks. Based on this, workers can collect and analyze the parameter changes of the pipe walls and the surrounding environment to check for leaks. Manual leak detection, infrared detection, and radioactive tracer leak detection are all commonly used methods. In traditional methods for diagnosing leakage faults in heating pipe networks, hardware leak detection technologies are widely applied [5]. With the assistance of these technologies, workers can analyze the relevant environmental parameters of the heating pipe network walls and their surroundings through monitoring or equipment monitoring to achieve the effect of fault diagnosis.

Hardware-based diagnostic methods are flexible, portable, and highly adaptable, with relatively low costs and simple installation processes. However, they also have disadvantages such as weak anti-interference ability and inaccurate diagnostic results. Especially in complex and changeable pipeline environments, hardware methods may be affected by various interference factors, leading to deviations in diagnostic results.

Supported by computer technology and information technology, automated detection technologies have developed rapidly in the detection of heating pipe networks. Software-based detection methods rely on this technology. Based on this, a computer data acquisition system is used to collect the real-time operation parameters of the heating network, and algorithms are used for analysis and calculation to identify leaks, accurately locate fault points, and analyze the causes of faults [6]. In software-based detection technologies, diagnostic methods based on mathematical models and signal processing are commonly used by workers in detection work. These methods have a certain degree of accuracy and reliability and are helpful for accurately judging leakage faults in heating pipe networks.

3.3. Artificial intelligence detection methods

The rapid development of science and technology and information technology has brought changes to various fields. Artificial intelligence technology, with its powerful information-processing capabilities, provides new solutions for the fault diagnosis of heating pipe leaks and has gradually become the main research direction for the fault diagnosis and detection of heating pipe networks.

The expert system was the first artificial intelligence method used for the fault diagnosis of heating pipe network leaks [7]. The expert system is based on a sample database composed of a large amount of expert experience. It can simulate the decision-making process and fault-diagnosis reasoning process of human experts to effectively diagnose leakage faults in heating pipe networks. Based on this, the expert system based on artificial intelligence technology has gradually become an innovative means for the fault diagnosis of heating pipe network leaks. However, the expert system also has certain limitations in the process of fault diagnosis. Specifically, the expert system relies on a complete expert knowledge base and has a high degree of subjectivity. In complex heating pipe networks and changeable heating operation states, it is difficult for the expert system to construct an extremely complete expert knowledge base, making it difficult to play its expected role. Judging from the current situation of leakage fault diagnosis and detection in heating pipe networks, relevant enterprises rarely use the expert system method to diagnose leakage faults in heating pipe networks.

4. Analysis of measures for maintaining heating pipe networks

4.1. Regularly inspecting heating pipe networks to prevent aging

To better prevent the aging of heating pipe networks, technicians need to regularly inspect the heating pipe networks, which can effectively prevent network aging and the occurrence of fault points. Key equipment and parts, such as pipelines, valves, pump rooms, and heat exchange stations, are the key points that technicians need to focus on during inspection. Technicians need to carefully check the overall condition of the pipelines, including whether there are problems such as damage, aging, and leakage [8]. Special attention should be paid to vulnerable parts such as pipeline connections, elbows, and tees, as these locations are more likely to have problems. At the same time, observe the operation status of valves and pump rooms; check whether the heat exchange efficiency, working pressure, temperature, and other parameters of the heat exchange stations meet the standards, and pay special attention to potential hazard areas around the pipes. Technicians need to check whether there are flammable, explosive materials, or heavy objects stacked around to avoid causing pressure or damage to the pipe network.

Enterprises should be aware of the importance of regular inspections for maintaining the normal operation of heating pipe networks, and promptly urge technicians to conduct inspections to identify potential safety hazards in the pipe network and prevent accidents. The aging of heating pipe networks is a phenomenon in which the original performance of pipeline materials is gradually consumed during long-term operation, while corrosion is caused by a series of chemical reactions in the pipes. Under the influence of the environment, harmful substances are generated, which damage the pipes [9]. To better maintain the pipes, technicians also need to take a series of maintenance measures. For example, clean the inside of the pipes to remove dirt, corrosion products, and other impurities, keep the pipes unobstructed, and improve the heat exchange efficiency. Another example is that anti-corrosion treatment of the pipe surface is an effective means to prevent external environmental erosion. Methods such as painting anti-corrosion paint and wrapping with anti-corrosion materials can be used to improve the corrosion resistance of the pipes.

4.2. Paying attention to heating pipe network testing to ensure normal equipment operation

During the process of maintaining heating pipe networks, technicians need to pay attention to heating pipe network testing to timely understand various leakage problems. First, workers need to test the water quality in the heating pipe network to check whether there are substances prone to reactions, reduce problems such as pipeline corrosion, scaling, and blockage, extend the heating effect, and reduce the occurrence of safety risks. During the water quality testing process, workers need to focus on the hardness, pH value, oxygen content, impurity content, etc., of the water quality to determine whether there are potential risks. If abnormal water quality is found, workers can immediately take measures such as installing water treatment equipment and observing water supply parameters to solve the problem [10]. To ensure that the water quality meets the standards, workers can install water treatment equipment. Using the automatic functions of the water treatment equipment, impurities in the water can be removed in a timely manner, the hardness can be reduced, and the pH value can be adjusted, further improving the water quality. In addition, during the inspection process, workers need to protect and maintain the water treatment equipment through methods such as cleaning and replacing the filter elements to ensure its normal operation and high-efficiency treatment effect.

4.3. Adjusting the temperature of heating pipe networks to improve the stability of the heating system

During the process of maintaining heating pipe networks, workers need to adjust the temperature of the pipe networks according to the seasons and temperature changes to improve the stability of the heating system. For example, in winter, the external environmental temperature is low, and the demand for heating in buildings increases significantly. To ensure that heat can be fully transmitted indoors to meet the heating needs of users, the water supply temperature should be appropriately increased. When adjusting the temperature of the heating pipe network, workers need to ensure the working efficiency of the heating system and the heat recovery effect. In summer, the outdoor environmental temperature is high, and the heating demand of buildings will decrease accordingly. If the temperature of the heating pipe network is too high, it may lead to heat waste, while if the return water temperature is too low, it may affect the circulation efficiency and heat recovery effect of the heating system [11]. In addition to seasonal changes, when the weather changes, such as during the cold-hot alternation period, workers need to adjust the temperature in a timely manner. For example, during the day, the temperature difference between morning and evening is large, and users' requirements for temperature change rapidly. To ensure a suitable indoor temperature, the water supply temperature can be appropriately increased, and the return water temperature can be finely adjusted to maintain the stable operation of the heating system and efficient heat recovery. At noon, when the indoor temperature is relatively high, the water supply temperature can be appropriately reduced.

4.4. Discharging the gas in heating pipe networks to maintain the balance of the heating system

The accumulation of gas in the pipe network mainly comes from the gas dissolved in the water during system water replenishment and the external air entering the system when a vacuum is formed locally in the system. The presence of external gas has an adverse impact on the heating of the pipe network. Therefore, during the inspection process, workers need to regularly discharge the gas in the heating pipe network to reduce gas accumulation. The accumulation of a large amount of gas will occupy the narrow space of the pipes, reducing the flow channel of the heat medium and affecting the heat transfer efficiency. If the gas accumulates for a long time, bubbles or gas masses will form. The increase in their volume will limit the normal flow of the heat medium, hinder the heat transfer, and prevent the heat from being evenly and quickly transmitted to each heating area [12]. Long-term gas accumulation may also cause corrosion and damage to pipes and equipment, shortening their service life. In addition, the gas is closely related to the pressure balance of the heating system. During the heating process, the normal circulation of the heat medium requires the pipe network to maintain a certain pressure. Once gas is present, the pressure balance of the pipe network will be disrupted, causing the temperature and pressure in the area to be too high or too low, affecting the heating effect of the heating pipe network. Therefore, during the maintenance process, workers can use the discharge method to remove the gas in the pipes, open the normal flow channel of the heat medium, improve the heating effect, maintain the pressure balance, and prevent corrosion and damage to pipes and equipment. When performing the discharge operation, the following points need to be noted: First, select a suitable discharge location. Usually, the discharge point should be set at the high point of the pipe network or the position where gas is likely to accumulate. Second, reasonably control the discharge speed and time to avoid excessive fluctuations in the system pressure. Excessive discharge speed may lead to a sharp drop in system pressure, affecting the heating effect, while too slow discharge may not effectively remove the gas. Third,

workers should regularly check whether the discharge device is operating normally and discharging effectively to ensure its normal operation and effective discharge.

Disclosure statement

The author declares no conflict of interest.

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