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Design and Application of An Intelligent Detection Defrosting Device

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Abstract: To improve the defrosting process of cold storage, a defrosting device with an intelligent detection function is proposed. Through the setting of the lifting mechanism, the up and down movement of the mobile shell can be realized, and then the use height of the ventilation pipe can be adjusted according to the actual situation, making the use more flexible. Through the cooperation among the mobile shell, opening, fan, ventilation pipe, water-passing ring, heat-conducting water pipe, water tank, pump body, water suction pipe, water outlet pipe, water return pipe and heating rod, the air in the ventilation pipe can be better heated, with good heating efficiency and excellent defrosting effect. Among them, the wind pressure sensor and temperature sensor can monitor the temperature and wind pressure in the ventilation pipe in real time. When the temperature is too high or the wind pressure is too large, the controller can adjust the heating temperature and air intake, thus ensuring the defrosting effect, saving electricity costs and improving the intelligent control level of the cold storage.

Keywords: Intellectualization; Intelligent wind pressure sensing detection; Intelligent temperature sensor; Lifting control

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1. Introduction

In recent years, with the rapid development of China's manufacturing industry, the refrigeration industry, as an important branch, has been widely applied in various fields such as refrigerators, air conditioners, and cold storage facilities. Refrigeration products are diverse, and many of them involve defrosting technology. During long-term use, these refrigeration devices are prone to frost accumulation, which can have a series of negative impacts on their normal operation. Taking cold storage as an example, the frost layer on the surface of evaporators hinders the conduction and dissipation of cold energy in the refrigeration evaporator (pipes), thereby affecting refrigeration efficiency. When the thickness of the frost (or ice) layer reaches a certain level, the refrigeration efficiency may drop to below 30%, leading to energy waste and shortening the service life of the refrigeration system. Therefore, it is particularly important to perform defrosting operations in cold storage at appropriate intervals. Currently, cold air blowers typically rely on defrosting control devices for assistance during operation. However, existing defrosting control devices are inconvenient to adjust in terms of usage height, lack flexibility, and have low air heating efficiency, resulting in unsatisfactory defrosting effects. There are still many shortcomings in the current defrosting technology that need urgent improvement. Traditional frost detection methods mainly rely on physical measurements, such as monitoring the frost layer on the surface of finned tube heat exchangers with the naked eye or microscopic cameras to dynamically track changes in frost thickness [1]. This method is intuitive and easy to understand, but involves complex operations, cumbersome data processing, and low efficiency. With the development of artificial intelligence technology, frost detection methods based on machine learning have gradually become a research hotspot. For example, a study proposed a frost detection method for cold chain refrigerators based on spiking neural networks. This method uses image processing technology and machine learning algorithms to automatically detect dynamic changes in the frosted area of evaporators, exhibiting strong adaptability and stability [2]. Although this method has improved accuracy, its high cost, due to reliance on high-precision sensors and complex algorithms, makes it a heavy burden for small enterprises or ordinary consumers. Despite certain progress in modern technology regarding frost detection and defrosting control, there remain technical bottlenecks and cost challenges.

How to ensure detection accuracy while reducing costs and improving the popularity of the technology is still an urgent issue to be addressed. Given the development of intelligent technology and the shortcomings of existing detection methods, this paper studies and optimizes defrosting detection methods. Compared with existing technologies, the innovation of this utility model lies in realizing the up-and-down movement of the mobile shell through a lifting mechanism, which allows adjusting the usage height of the ventilation pipe according to actual needs and improves operational flexibility. Through the effective cooperation of the mobile shell, openings, fans, ventilation pipes, water-passing rings, heat-conducting water pipes, water tanks, pumps, water suction pipes, water outlet pipes, return pipes, and heating rods, the air in the ventilation pipes can be heated more effectively, enhancing heating efficiency and defrosting effects. In addition, the installation of wind pressure sensors and temperature sensors enables real-time monitoring of temperature and wind pressure inside the ventilation pipes. When the temperature is too high or the wind pressure is too strong, the controller will automatically adjust the heating temperature and air intake volume, ensuring defrosting effectiveness while saving energy and improving the intelligent control level of cold storage. This optimized solution not only enhances equipment performance but also improves the efficiency and energy efficiency of cold storage management.

2. Working principle and design of intelligent defrosting equipment

Defrosting methods mainly include electric heating defrosting and hot gas defrosting. Electric heating defrosting uses electric heating wires to regularly melt the frost on the surface of the evaporator into water, which is then discharged outside the cabinet. However, the surface temperature of the electric heater is extremely high, far exceeding the ignition point of organic substances such as the refrigerator liner and foaming raw materials. Such a design brings significant fire safety hazards. Therefore, although electric heating defrosting technology is widely used, its potential safety issues cannot be ignored. In contrast, hot gas defrosting is a more advanced defrosting method, widely used in the field of cold air blowers, and is the same as the defrosting technology chosen in this article. Hot gas defrosting generates hot gas by heating air, which quickly melts the frost, thereby increasing the defrosting speed, reducing energy consumption, and achieving a better defrosting effect. This method can also reduce temperature fluctuations when refrigeration is resumed, ensuring stable temperatures in the cold storage. However, hot gas defrosting technology also has some problems. The frost layer on the surface of the evaporator will affect the refrigeration effect, hinder the conduction and emission of cold energy from the refrigeration evaporator (pipes), leading to a significant reduction in the refrigeration efficiency of the cold storage. When the thickness of the frost layer reaches a certain level, the refrigeration efficiency can even drop to below 30%, which wastes a lot of electricity and shortens the service life of the refrigeration system. Therefore, regular defrosting operations in cold storage are particularly important. Domestic researchers generally start from the problems encountered in the defrosting process and the application fields of defrosting technology, and put forward various improvement schemes. In recent years, with the rapid development of artificial intelligence technology, the technology of defrosting devices has gradually developed towards intelligence. From initially relying on component adjustment and external environmental factors to improve the defrosting process, to now integrating advanced intelligent control systems, the upgrading of defrosting technology has continuously promoted the progress of the refrigeration industry. For example, some studies have disclosed an automatic defrosting and deicing device specially designed for air conditioning equipment. The device has made innovations in structure and technology. Through the cooperation of the roller mechanism, baffle and spray pipe, combined with the role of the spray pump, it realizes the up and down reciprocating movement of the spray head, and at the same time sprays the deicing agent on the surface of the evaporator, and cooperates with the roller brush to remove the frost layer. This design can complete the defrosting operation without stopping the air conditioner, thus effectively improving the heating efficiency of the air conditioner. In order to further optimize the defrosting device, this device can significantly improve the heating efficiency and defrosting effect through the coordination of multiple key components. Specifically, the device includes the cooperation of components such as a mobile shell, an opening, a ventilation pipe, a water pipe, a heat-conducting water pipe, a water tank, a pump body, a water suction pipe, a water outlet pipe, a return pipe, and a heating rod to ensure effective heating of the air in the ventilation pipe. This design not only improves the heating efficiency but also makes the defrosting process more efficient. In particular, through the setting of the lifting mechanism, the lifting end of the mobile shell is fixedly connected to the lifting mechanism, thereby realizing the adjustment of the use height of the ventilation pipe and improving the flexibility and adaptability of the device. Through the design of this lifting mechanism, users can flexibly adjust the use height of the equipment according to actual needs, making the defrosting operation more convenient.

3. Design of the lifting device

In this design, the main function of the lifting mechanism is to realize automatic control and precise position adjustment during the defrosting process, to meet different operation requirements and improve work efficiency. In the intelligent defrosting device, the lifting mechanism is closely combined with the control system. Through precise position control and a synchronous lifting system, it ensures the stability and efficiency of the defrosting process. The precise control of the lifting mechanism is crucial to ensure the defrosting effect. It can ensure that the refrigerant or hot gas is evenly distributed in the defrosting area, thereby improving defrosting efficiency and effect. Through the setting of the lifting mechanism, the drive motor starts, drives the drive shaft to rotate and drives the first gear. The first gear meshes with the second gear on one of the threaded rods to realize the rotation of the threaded rod. Through the cooperation of the first transmission wheel, the first transmission chain, and the second transmission wheel, the other three threaded rods can also rotate, which in turn drives the moving sleeve to move up and down with the cooperation of the moving rod and the moving groove. In this way, the mobile shell can move up and down through the adjustment of the lifting mechanism, to adjust the use height of the ventilation pipe according to actual needs, making the operation more flexible and convenient.

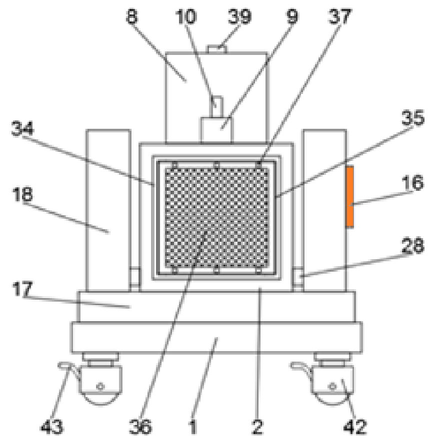

Figure 1. Schematic diagram of front view and the sectional structure of the intelligent detection device.

4. Design of temperature sensor

The frosting process is a complex temperature-changing process, which is affected by many factors, including cold surface temperature, air temperature, relative humidity, and humid air flow rate. The cold surface temperature is one of the key factors affecting the frosting rate and frost layer thickness. The lower the cold surface temperature, the faster the frost layer grows, and the thickness of the frost layer will also increase significantly [3]. When the cold surface temperature is relatively high (such as close to 0°C or higher than – 15 °C), liquid water droplets usually appear first before frosting, and then the water droplets freeze to form frost crystals. During this process, the wall temperature will rise briefly. When the cold surface temperature decreases (such as between - 3.5 °C and - 19.7 °C), the frosting rate accelerates, and the density and thermal conductivity of the frost layer will also gradually increase [4]. However, when the cold surface temperature is too low (such as lower than – 38 °C), the condensation stage may be skipped, and frost crystals will form directly. At extremely low temperatures (such as below – 7 °C), the amount of frosting decreases instead. Especially when the temperature is - 12°C and the relative humidity is 90%, there is almost no frosting phenomenon, which may be related to the freezing of moisture in the air or the too low dew point [5].

In addition, the lower the air temperature, the faster the frosting rate, and the more obvious the increase in the thickness of the frost layer [6]. For example, when the air temperature is 10.5 °C and the humidity is 80%, the cold surface temperature drops from - 3.5 °C to - 19.7 °C, and the characteristics of the frost layer will change significantly [7]. When the air temperature is between 0 °C and 4 °C (relative humidity > 80%), the frosting rate is the fastest, and the thickness and amount of frosting increase linearly with time. However, when the air temperature drops below – 20 °C, the amount of frosting is limited by the moisture content in the humid air [8,9]. The frosting process is very sensitive to temperature changes. Therefore, temperature sensors can be used to monitor the equipment temperature in real-time, judge whether frosting occurs, and issue early warnings, to realize timely defrosting. In practical applications, it is necessary to comprehensively consider parameters such as humidity and wind speed, and optimize the defrosting strategy by regulating temperature to improve the operating efficiency of the equipment. The design of the temperature sensor (15) is an important part of optimizing the defrosting device. It can monitor the temperature changes during the defrosting process in real-time, and judge whether the defrosting is completed by measuring the absolute temperature difference in the four regions of the liquid separator head assembly of the finned heat exchanger. If the temperature difference is within the normal range, the current defrosting cycle will be maintained; if it exceeds the set range, the defrosting cycle will be intelligently adjusted, thereby optimizing the defrosting control logic, reducing the occurrence of the "ice layer" phenomenon on the fins after defrosting, and improving the heating efficiency of the unit [9]. In addition, compared with the traditional timer control method, using temperature sensors for defrosting control can significantly reduce the energy consumption of the equipment. The temperature sensor starts defrosting in real-time according to the actual frosting situation, avoiding unnecessary energy waste [10].

5. Design of wind pressure sensor

The main function of an air cooler is to achieve cooling by reducing the air temperature. When air flows through the air cooler, if the temperature of the air cooler's surface is lower than the air's dew point temperature and 0 °C, water vapor in the air will condense into frost on the surface of the air cooler [11], forming a frost layer. The frosting process affects the air cooler mainly by reducing heat exchange efficiency and increasing energy consumption. As the frost layer accumulates, changes occur in the heat transfer area and heat transfer coefficient of the air cooler, as well as the pressure drop on the air side. These changes directly impact the operating efficiency and energy consumption of the air cooler [12]. The specific impacts of frosting on the air cooler are as follows: First, as the frost layer thickens, the heat exchange efficiency of the air cooler gradually decreases. This is because the frost layer increases the pressure drop on the air side and reduces the heat transfer area, leading to a decrease in the heat transfer coefficient [13].

Second, to maintain the required cooling effect, the air cooler needs to increase its operating power [14], which results in higher energy consumption. The frosting process of the air cooler significantly affects its operating efficiency and energy consumption. Therefore, optimizing the design parameters of the air cooler, adopting effective defrosting technologies, and controlling environmental factors can effectively mitigate the negative impact of frosting on the air cooler's performance. The wind pressure sensor [14] primarily functions to optimize the defrosting process by monitoring and controlling wind pressure, thereby ensuring improved defrosting efficiency and optimized energy performance. Specifically, the wind pressure sensor can not only precisely control the defrosting cycle but also play a key role in the intelligent defrosting control of air-source heat pump units. It can monitor the temperature difference of the liquid distribution header assembly in the finned heat exchanger and determine whether defrosting is complete based on changes in this temperature difference. When the temperature difference exceeds the set range, the system automatically adjusts the defrosting cycle to ensure more thorough defrosting, thereby enhancing defrosting effectiveness. In addition, the wind pressure sensor can improve defrosting efficiency and reduce energy consumption. In research on refrigerator defrosting control, the use of differential pressure sensors for precise control not only effectively improved defrosting efficiency but also significantly reduced the actual electricity consumption of refrigerators during user operation. Thus, the wind pressure sensor plays a crucial role in monitoring and controlling wind pressure, contributing to enhanced defrosting efficiency and reduced energy consumption [15]. The wind pressure sensor and temperature sensor are typically installed on the inner wall of the ventilation duct to monitor the temperature and wind pressure inside the duct in real-time. When the temperature is too high or the wind pressure is excessive, the system can adjust the heating temperature and air intake volume through the controller 16 (**Figure 1**). The controller is the core component of the system, which automatically adjusts the heating temperature and air intake volume by real-time monitoring of temperature and wind pressure changes inside the cold storage. Based on environmental conditions, the controller can precisely control various parameters to ensure defrosting effectiveness while avoiding excessive energy consumption, thereby achieving energy savings and cost reduction. This controller enhances the intelligence and automation level of the system, making energy efficiency management more accurate and efficient. As a result, it not only guarantees defrosting effectiveness but also effectively saves electricity and reduces operating costs. This intelligent control system improves the automation level of the cold storage and enables more precise energy efficiency management.

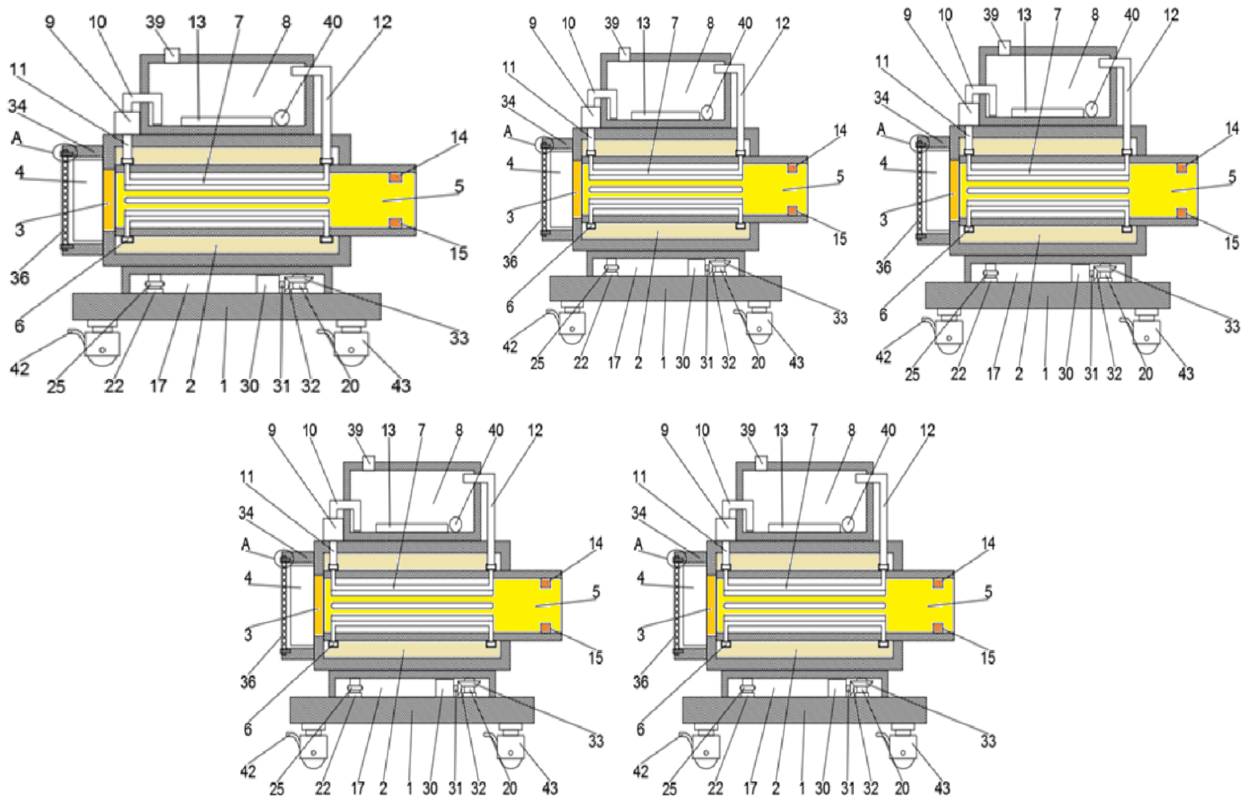

Figure 2. Schematic diagram of the left view structure of the device.

6. Conclusion

The adoption of an intelligent detection device enables real-time monitoring of frost formation, thereby reducing the negative impact of frost on the normal operation of equipment. The introduction of a lifting device makes the machine operation more flexible. The temperature sensor can accurately identify the presence of frost and start defrosting on time; the wind pressure sensor helps effectively control the formation of frost and further optimizes equipment operation. The combination of these technologies improves the efficiency and stability of the equipment, which helps extend its service life and reduce energy consumption.

Disclosure statement

The authors declare no conflict of interest.

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