Experiment Research on Direct-expansion Evaporative Condensation Air-conditioning System

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Abstract: This paper introduces the working principle and characteristics of the direct-expansion evaporative condensation air-conditioning system, and an relative experimental research has been conducted. The result shows the direct-expansion evaporative condensation air-conditioning system has the advantages of energy saving, water saving, land saving, compact structure and low pollution. Therefore, the direct-expansion evaporative condensation air-conditioning system has great potential for use and it also has the capacity in automation controls.

1. Introduction

At present, the main condensing methods for large central air conditioning system are water cooling tower or air-cooled. Some construction sites such as high-end office buildings, convention centers, exhibition halls, and subway stations have higher requirements for building appearance, noise, and water pollution control. However, air-conditioning and refrigeration equipment, especially outdoor cooling towers, occupy a large equipment area or space, which has a great impact on appearance and pollution, resulting in conflicts with high-quality building requirements.

Evaporative condensation air-conditioning system has the advantages of energy saving, water saving, land saving, compact structure and low pollution. It is used in special requirements such as high-quality buildings and subway stations, and has achieved good results[1][2][3]. In practical applications, there are still many questions to be answered about equipment performance, operation management, and test evaluation. This paper provides a reference for the design, control and evaluation of this system through the actual measurement and analysis of the evaporative condensation air-conditioning system.

2. Working principle and characteristics

The direct-expansion evaporative condensation air-conditioning system is based on the evaporative condensation technique to change the cooling mode and structure of the air-cooled condenser. The evaporative condenser is mainly based on latent heat exchange and sensible heat exchange, and uses the suction of water to remove the heat of condensation of the air conditioning system. The operating principle is as follows: the water is used to pump the cooling water from the nozzle above the condensation side refrigerant tube group, and the nozzle sprays the cooling water evenly on the refrigerant tube to form a water film. The refrigerant gas in the refrigerant pipe on the condensing side absorbs heat into a liquid state, and some water evaporates after the cooling water absorbs heat, and the rest flows into the water collecting tray for recycling[4]. The structure is shown in Figure 1.
The evaporative condenser is a high-efficiency condensing device that combines a condenser and a cooling tower. The evaporative condenser can combine the cooling process of the cooling water and condensation process of the condensing agent, omitting the transfer phase of the cooling water from the condenser to the cooling tower. It also has the advantages of energy saving, water saving and compact structure\cite{5}.

3. Test content and test equipment
The test locates at a subway station which has an evaporative condensation air-conditioning system. It uses the TESTO-480 multi-function tester to measure indoor and outdoor temperature and humidity in real time. Each test area is evenly distributed by four points. The temperature and humidity of each zone are taken as the average of 4 measuring points.

The TESTO-480 multi-function tester is used to test the air cooler and the evaporative condenser air volume and the inlet and outlet air enthalpy difference, and finally calculates the cooling capacity and heat extraction of the system.

This test uses the FLUKE True RMS AC Clamp Meter to test power. The test is divided into: fan power test; pump power test and compressor power test.

For the system intake and exhaust temperature, due to the arrangement of fins on the system evaporator, the evaporation condenser has a water film effect leading to the evaporation temperature, and the condensation temperature cannot be directly measured. Therefore, the intake temperature and the exhaust temperature are measured as system performance parameters.

The system suction temperature passes through the test system evaporator refrigerant outlet temperature. The instrument uses the Tianjian Huayi temperature self-meter to arrange the temperature measurement point on the evaporator outlet pipe wall.

The system exhaust temperature is passed through the test system to evaporate the condenser inlet refrigerant temperature as the compressor discharge temperature.
4. Test results and discussion

![Graph showing cooling capacity and wet bulb temperature]

Figure 2. Cooling capacity in 2016-2018.

The rated cooling capacity of the refrigeration system of a subway station tested is 3200 kW. The maximum value of the cooling capacity is seen in Figure 2. It can be seen that this system runs for a long time under partial load conditions, so it is necessary to adopt a reasonable equipment self-control strategy. The cooling capacity of the system basically follows the working conditions of the outdoor wet bulb temperature change. In Figure 2, 7-11; 14-16; 24-26 indicate the working time of the weekend rest day. The flow rate of the subway station is larger based on the measured data. Relevance, less affected by human traffic. In Figure 2, the black vertical line is used to divide the map into three areas: the July 2016 working condition, the August 2017 working condition, and the September 2018 working condition. It can be seen from the figure that as the air-conditioning season gradually ends, the cooling capacity of the system decreases, the overall cooling capacity of the system decreases, but the overall cooling capacity changes little, indicating that there is a stable large heat source in the room (such as equipment heat generation).

The energy consumption of each working point and the measured air volume of the main blower and the induced draft fan are shown in Figure 3 and Figure 4. It can be seen that the energy consumption of the compressor in the energy consumption of the refrigeration system in the subway station is the largest, followed by the energy consumption of the exhaust fan. The energy consumption of the induced draft fan and the spray pump is relatively small. In combination with the change in the cooling capacity of the system as described above, the energy consumption of the compressor changes greatly and the energy consumption of the main exhaust fan remains basically unchanged. Combined with the wind volume measurement map, it can be seen that the air volume of the main blower is basically unchanged during the three-year period, and the main blower is operated at a fixed frequency. The main blower is responsible for supplying air to the subway station. The cooling capacity is determined by the air supply volume and the difference between the two ends of the direct expansion type cooler. Therefore, the change of the system cooling capacity mainly depends on the compressor frequency conversion.
Figure 3. Analysis of energy consumption of each system.

Analysis of the condensation side power can be found that the evaporative condenser water pump has the lowest power consumption and fixed operating frequency, and the energy consumption of the induced draft fan and the air volume have a certain frequency conversion effect with the change of the working condition. The decrease in the wet bulb temperature gradually leads the decrease of the air volume of the draft fan. So there is a large energy-saving optimization range for the joint operation strategy of the compressor, fan unit and water pump.

Figure 4. Main blower air volume and induced draft fan air volume.

From the test data, with similar outdoor wet bulbs temperature, the data with similar loads are averaged by the test data at the same wind speed as the cooling system COP at the wind speed. The result is shown in Figure 5. It can be seen that when the wind speed gradually decreases and the water-gas ratio gradually increases, the system COP first increases and then decreases. It can be seen that there is an optimum value of water vapor ratio in actual operation so that the system COP reaches the highest.

Figure 5. Influence of water-gas ratio and system COP.

5. Summary
After the actual measurement and analysis of the direct-expansion evaporative condensation air-conditioning system of the subway station, the following conclusions are obtained:

1. Compared with conventional refrigeration systems, direct-expansion evaporative condensation air-conditioning system reduces the energy consumption of cooling system transmission because it omits the energy consumption of cooling water from the condenser to the cooling tower.
(2) This direct-expansion evaporative condensation air-conditioning system has a large energy-saving optimization range in the joint operation strategy of compressor, fan unit and water pump.

(3) The COP of the direct-expansion evaporative condensation air-conditioning system rises first and then decreases with the water-gas ratio. In actual use, there is an optimum value to maximize the system COP.

Reference
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