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Experimental Study on Effect of Three-way Valve Opening on Dehumidification Performance of Surface Cooler

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Abstract

In response to the mismatch between the supply flow of chilled water in variable flow refrigeration systems and the actual water flow required for cooling and dehumidification, this article relies on the standard enthalpy difference laboratory and takes the electric three-way valve and group air surface cooler as research objects to analyze the impact of the opening ratio of the electric three-way valve on the dehumidification rate of the surface cooler, and provides experimental parameters for reference in three-way valve control programming. The experimental results show that when the actual opening ratio of the electric three-way valve is 76.6%, the dehumidification rate of the group air surface cooler reaches the highest value of 0.268 °C /min. Designers can refer to the experimental curve when controlling logic programming of electric three-way valve, improve the matching degree of chilled water flow, and improve the energy waste caused by cold and heat offset.

Keywords

Combined air conditioning; Three-way valve opening; Dehumidification rate.

1. INTRODUCTION

The combined air conditioning system is divided into mixed flow section, filtration section, surface cooling section, heating section, humidification section, etc. according to the functions of each part. In the surface cooling section of the system, air and refrigerant exchange heat to achieve the purpose of cooling and dehumidification [1]. After being treated in the surface cooling section, the air is heated and humidified by electricity to reach the set value, and then sent out from the air supply outlet to the interior of the room, thereby changing the temperature and humidity of the air in the room. The surface cooling section of a combined air conditioner is generally composed of refrigerant pipes and fins, and the low-temperature refrigerant that enters the surface cooling section can be various refrigerants (such as R410a), as well as low-cost and easily accessible water. However, regardless of the type of refrigerant used in the system, how to control the refrigerant flow so that it can fully contact the air to achieve the purpose of cooling and dehumidification, while ensuring that there will be no significant cold and hot offset phenomenon is an important part of system debugging. This article aims to study the water flow control of a combined air conditioning chilled water supply system. It mainly analyzes the relationship between the opening of the electric three-way valve and the dehumidification rate of the refrigeration system, tests the dehumidification rate of the electric three-way valve with different opening degrees, and provides corresponding suggestions for designers to refer to.

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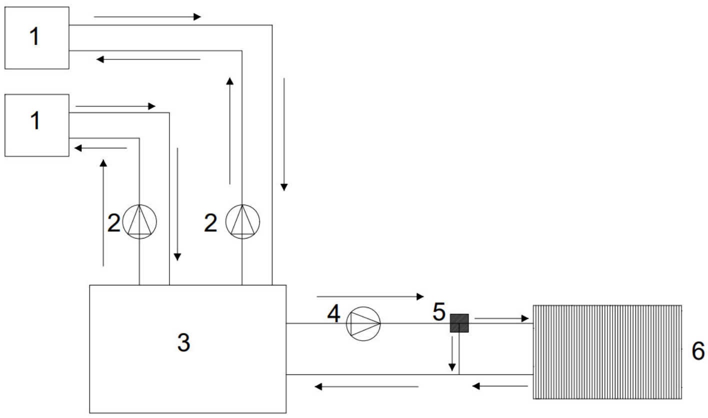
2. EXPERIMENTAL SYSTEM PRINCIPLES

This experimental system can be composed of a chilled water production circuit and a chilled water heat exchange circuit. The former is mainly used to produce low-temperature water and store it in a cold water tank, while the latter mainly controls the heat exchange between the chilled water and the room group's air water coil. The schematic diagram of the experimental system is shown below:



1 chiller unit; 2. cold water pump; 3. cold water tank; 4 sets of air water coil pumps; 5 electric three-way valve; 6 sets of air coils

Figure 1. Experimental system principle

The chilled water production circuit is composed of an air-cooled chiller, a water pump and a cold water tank (cold water tank is not required, and the cold water produced by the unit is directly channeled into the empty coil tube). The air-cooled chiller inhales and compresses the refrigerant through the compressor, and the gaseous refrigerant is discharged into the condenser to cool and condense into the liquid refrigerant. After passing through the throttle valve, the refrigerant flow is controlled. Finally, the low-temperature refrigerant enters the evaporator and convective heat transfer with water, so as to reduce the water temperature. The cold water tank is mainly used to store cold water, and the external insulation layer is laid to weaken the external heat transfer, and the coil of the refrigerant and water heat exchange is placed in the cold water tank. The main function of the cold water pump is to ensure that the water supply and return cycle of the tank is carried out continuously, and to prevent the coil from icing due to the uneven local heat transfer. After the cold water tank is filled with normal temperature water by the water refill pipe, the low temperature refrigerant made by the water chiller exchanges heat with normal temperature water, and then the cold water pump circulates cold water to ensure the continuous reduction of the water temperature in the cold water tank. If you want to make cold water with constant water temperature, you need to open the electric heating tank, balance the extra cold capacity generated by the unit, to achieve the purpose of constant water temperature.

The chilled water heat exchange circuit includes a cold water tank, a cold water supply solenoid valve, a water pump, a three-way valve and a group of empty coils. The cold water tank is used to store the cold water taken by the cold water mechanism, the solenoid valve is used to control the on-off of the cold water, the water pump is used to overcome the resistance of the water loop, the electric three-way valve is used to control the proportion of the cold water into the empty coil, the empty coil is used for cold water and indoor air heat transfer. The cooling water of the water chiller is stored in the water tank. Open the water supply solenoid valve of the water tank and the corresponding water pump. The water pump sends the chilled water to the three-way valve. The other part of the cold water directly into the return water line back to the cold tank. After returning to the cold water tank, the water passes through the heat exchange and cooling with the coil of the cooler, and then through the circuit into the empty coil and indoor air heat exchange, so the indoor air can reach the target condition.

3. EXPERIMENTAL METHOD

3.1. Experimental parameter analysis

In order to verify the relationship between the opening of electromotive force three-way valve and the dehumidification capacity of combined air conditioning units, it is necessary to identify the factors affecting both. The electric three-way valve is controlled by the piston lifting its opening proportion, can be artificially set its opening, and ensure that it is as stable as possible. The dehumidification ability of the combined air conditioner can be measured by the degree of wet-bulb temperature drop per unit time. In order to verify the dehumidification capability of combined air conditioning units, corresponding evaluation standards should be adopted. In this experiment, the drop value of indoor wet bulb temperature in standard enthalpy difference laboratory was used to measure the dehumidification ability of the group. It is considered that some factors will affect the evaluation index, such as indoor dry bulb temperature, air volume per unit time through the combined air conditioning unit, air supply temperature, chilled water flow, etc. It is necessary to adopt the control variable method to ensure that the decrease of wet bulb temperature is only related to the dehumidification of the empty surface cooler. Therefore, it is necessary to analyze the influence of various parameters on the wet bulb temperature.

For indoor dry bulb temperature, it indicates the overall temperature of indoor air. If the overall air temperature drops significantly, then the dry bulb temperature will drop, and the wet bulb temperature will drop along with the dry bulb temperature. At this time, the wet-bulb temperature falling per unit time will be larger than the normal dehumidification drop value. In order to reduce the experimental error, it is necessary to turn on the corresponding electric heating when the combined air conditioning unit treats the air, to supplement the heat taken away by the cold water dehumidification in the indoor environment, and to ensure the stability of the dry bulb temperature.

For air volume, constant frequency fan is used in this experiment to provide air circulation power. With the aid of the regulator, the air fan outputs the fixed air volume to ensure the stability of the parameter.

Cold water temperature has a significant impact on the relative dehumidification ability of surface cooler [2]. The air supply temperature is controlled by the cold water production circuit. The water leading to the air tank is directly extracted from the cold water tank, and the water supply pipe from the cold water tank to the empty coil pipe is equipped with insulation layer to reduce the cooling loss. The temperature rise of the actual measured water supply pipe does not exceed 0.1℃, so it can be approximately considered that the water temperature of the cold water tank is equal to the water supply temperature of the air tank. The water temperature of the cold water tank can be controlled by the chiller and the electric heating of the water tank, so as to ensure the constant water supply temperature.

As for the chilled water flow, it can be seen from the cold water heat exchange circuit that the cold water flow to the empty coil is jointly controlled by the water pump and the electric three-way valve. The cold water pump used in the laboratory is a variable frequency water pump, which can run stably through the input of a fixed working frequency. The flow fluctuates little during stable operation. The actual flow can be measured by the electromagnetic flowmeter,

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and the average value is taken according to the actual fluctuation range, and it is regarded as the fixed value of the cold water flow. The electric three-way valve can manually set the fixed opening, and the actual water flow for the empty coil can be calculated by the following formula:

$$Q = NQ_0 \tag{1}$$

In the formula:

Q is the water flow rate of empty coil, m^3/h;

N is the opening ratio of electric three-way valve;

Q_0 is the empty coil water flow, m^3/h.

3.2. Experimental procedure

The dehumidification speed of the empty table cooler in the enthalpy difference laboratory is related to the above parameters. While ensuring the stability of other parameters, the relationship between the dehumidification speed of the table cooler and the opening degree of the electric three-way valve is verified. Considering the external air environment and the electric humidification power equipped in the laboratory during the experiment, the experimental conditions can be ensured to be relatively stable under the action of electric humidification [3]. The experimental dehumidification conditions adopted in this experiment were dry bulb temperature of 24℃ and wet bulb temperature of 22.3℃, the relative humidity of this condition was 86.7%, and the corresponding dew point temperature was 21.6℃. In the experiment, the dry and wet bulb temperature measured under the experimental condition within ±0.2℃ can be regarded as stable working condition. The water supply temperature of empty coil has little difference with that of cold water tank. When the water pump runs stably, the actual measurement error is within ±0.1 ℃. In this experiment, the water supply temperature of cold water is set at 10℃, which is far lower than the dew point temperature under experimental conditions, which can effectively ensure the dehumidification of water after the air and water coil heat exchange. During the experiment, the corresponding chiller and the electric heating of the water tank should be turned on to ensure the constant water supply temperature. The cold water needs to be heated by the empty coil water pump and the air in the room. The heat load changes greatly before and after the water pump is opened, so the temperature of the water tank can be regarded as stable within ±1℃. The wet and dry bulb temperature of the room is measured by platinum resistance and the error caused by measurement is very small. In addition, after each pump water, the temperature of several spheres is not stable near the experimental condition, which can be stabilized by opening the electric heating, so as to reduce the experimental error caused by the decrease of wet bulb temperature due to the decrease of dry bulb temperature.

In the experiment, the number of electric heating and electric humidification is determined according to the difference between the measured dry and wet bulb temperature and the target high humidity condition, and the air in the room is pretreated with heating and humidification to achieve the target high humidity condition. Since the heat and humidity input in the room has a large lag when it is fed back to the measurement module, it is necessary to turn off the electric humidification in advance before the measured value approaches the target value. At the same time, in order to ensure the constant temperature of the water tank, it is necessary to turn on the chiller and the electric heating of the water tank to stabilize the cold water at about 10℃. When the cold water temperature and indoor dry and wet bulb temperature are close to the target value, manually set the opening of the electric three-way valve from 10%, increase by 10% in each experiment until the opening reaches 100%, after the opening proportion of the

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three-way valve is stable and the cold water temperature and the actual working condition of the room reach the target value, open the empty coil water pump. Shut down the empty coil water pump after the system runs stably for 20 minutes. Depending on the actual dry bulb temperature, it is necessary to turn on the electric heating to make the dry bulb temperature rise back to the value before water flow. Record the wet bulb temperature at this moment after the dry bulb temperature becomes stable. As shown in the figure, the experimental curve of wet bulb temperature at a certain fixed opening can be roughly divided into three stages: humidification, stabilization and dehumidification.

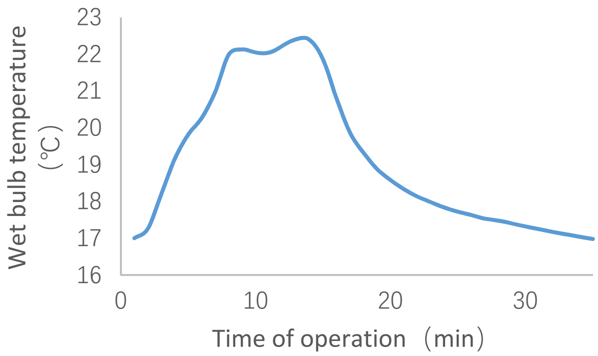

Figure 2. Wet bulb temperature experimental curve

The dehumidification speed of the three-way valve at the opening degree can be calculated by the following formula, that is, the ratio of the difference between the wet bulb temperature before and after water passage and the water passage time is the dehumidification speed of the three-way valve at the opening degree. After calculation, it is necessary to repeat the cycle of humidification - stabilization - dehumidification, respectively measure the remaining openings of the electric three-way valve and calculate the dehumidification speed of the table cooler under different openings.

$$\mathrm{V} = \frac{t_0 - t_1}{\mathrm{T}} \tag{2}$$

In the formula:

V is dehumidification rate of empty coil under target opening, ℃/min;

t_0 is the initial wet bulb temperature of the environment, ℃;

t_1 is the wet bulb temperature after environmental dehumidification, ℃;

T is the opening time of empty coil water pump, m^3/h.

3.3. Analysis of experimental results

After the three-way valve under different opening speed test, can be obtained table dehumidification speed and three-way valve opening between the experimental data. After fitting these experimental data, the trend line obtained is shown in the figure below.

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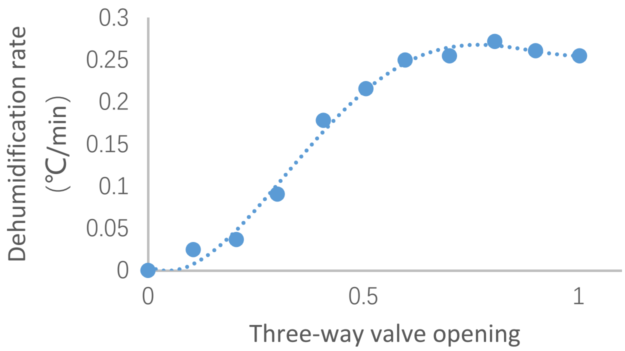

Figure 3. Effect of three-way valve opening on dehumidification speed

The fitting degree of the curve is R 2 = 0.992, and the equation of the fitting curve is as follows :

$$V = 1.800N^4 - 4.348N^3 + 3.045N^2 - 0.247N + 0.005 \tag{3}$$

In the formula:

V is the dehumidification speed of the group empty coil at the target opening, °C / min ;

N is the opening ratio of the electric three-way valve.

The derivation of the curve fitting equation can be solved: when the opening of the three-way valve is 0.766, the predicted maximum dehumidification speed of the empty water coil is 0.268 °C / min.

It can be concluded from the above curves that the dehumidification speed of the surface cooler rises slowly when the opening ratio of the electric three-way valve is between 0 and 0.2, which is caused by the rapid heat exchange between the small flow cold water and the air after it is introduced into the group empty coil, and the water temperature rises rapidly to above the indoor air dew point temperature. When the opening ratio is between 0.2 and 0.7, with the increase of water flow through the empty coil, the actual dehumidification area of the surface cooler increases, and the dehumidification speed increases obviously. When the opening ratio is between 0.7 and 1, due to the excessive water flow, the water flow rate of the empty coil is high, and the cold water flows into the backwater pipe before it can heat exchange with the air, resulting in a slight decrease in the dehumidification speed [4].

In addition, at a constant water supply temperature, in order to ensure that the dry bulb temperature remains stable during the dehumidification period, additional heat needs to be input into the room to balance the heat loss caused by water-gas heat transfer. The relationship between the opening ratio of different three-way valves and the additional heat needed to be put into the room is shown in the following table. Generally, the larger the opening of the three-way valve, the more heat needed to be put into the room, and the more serious the cold and heat offset.

Table 1. The relationship between the opening of the three-way valve and the amount of electric heating input

Three-way valve opening	Electric heating input quantity (kW)
0~0.2	0~32
0.2~0.4	16~48
0.4~0.8	32~64
0.8~1.0	48~80

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4. CONCLUSION AND PROSPECT

The dehumidification speed of the surface cooler is affected by many conditions, including the change of indoor dry bulb temperature, the air volume of the air fan, the water supply temperature of the air coil, and the chilled water flow. The electric three-way valve affects the dehumidification rate by adjusting the flow rate of chilled water through the opening degree. Based on the experimental data, the following conclusions can be drawn.

1. The dehumidification rate of the surface cooler first increases slowly, then increases sharply and finally decreases slowly with the increase of the opening ratio of the electric three-way valve. When the actual opening ratio of the electric three-way valve is 76.6 %, the dehumidification speed of the air cooler reaches the highest value of 0.268 °C / min.

2. The experimental data can be used as a reference for programmers to realize the programming control of the electric three-way valve to improve the matching degree between the dehumidification speed and the opening of the three-way valve.

3. There are some optimizations in the experiment. For example, because of the heat exchange between cold water and indoor air, the heat load of the cold water preparation circuit fluctuates greatly during the start and stop of the pump, so the temperature of the air supply fluctuates greatly; the indoor space of the experiment is large, and the wet bulb temperature has a large lag in the actual measurement.

4. The dehumidification speed and energy saving should be fully considered during debugging, so as to ensure a faster dehumidification speed and avoid energy waste caused by the cold and heat offset caused by dehumidification as much as possible.

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