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Experimental study on the dynamic characteristics of heat and moisture exchange in wet film humidification

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Abstract
In view of the problem that circulating wet film humidifier is easy to breed bacteria, is not easy to clean, and the direct discharge type is not enough to save water, this paper adopts the method of intermittent sprinkling to find the best sprinkling interval on the premise of ensuring the humidification demand.According to the heat and mass exchange theory, the differential control equations of the wet film humidifier in the heat and mass exchange process are established, and then the characteristics of each variable are experimentally studied. The results show that intermittent water supply mode is feasible for wet film humidification, and the humidification volume can meet the design requirements.The humidification effect of wet film will be improved by properly reducing the air mass flow rate, increasing the inlet wet and dry bulb temperature and drenching density. However, when the air mass flow rate is greater than 1.8 kg/(m^2·s) and the drenching density is greater than 2.1 kg/(m^2·s), the humidification effect of wet film will no longer change significantly.During the whole intermittent water supply cycle, the humidity is difficult to be stabilized if the water sprinkling time is too short or the water shutoff time is too long, and the longer the water shutoff time is, the greater the influence on the humidity is.

Keywords: *Wet-film humidifier，intermittent water supply，dynamic characteristics*

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I. INTRODUCTION

With the rapid development of society and the continuous improvement of economy and living standards, people have higher and higher requirements for living and working environments. The winter in northern China is relatively cold, with low air humidity. At the same time, the indoor temperature will be increased by heating equipment, further reducing the relative humidity of indoor air, resulting in poor human comfort [1-3].

The wet film humidifier used in the traditional humidification method needs continuous water supply during the humidification process, which is generally circular, which makes the water pan easy to breed bacteria and not easy to clean, and will pollute the indoor air over time, affecting human health.Compared with the circulating humidifier, the direct discharge humidifier does not have a water pump in the pipeline, and the water on the wet film that does not evaporate in time flows out directly from the drainage outlet, reducing the air pollution but also increasing the water consumption dramatically. This paper will improve the direct discharge humidifier, change the previous mode of continuous water supply, and adopt intermittent and regular water supply. Through detailed research on the dynamic cycle of the whole wet film humidification under different working conditions, the best water sprinkling time interval will be found to provide theoretical and technical guidance for better application of wet film humidification.

II. Experimental System and Content

2.1 Experimental system

In order to study the humidification characteristics of wet film humidifier under different working conditions when intermittent water supply occurs, the air enthalpy difference method is used in the experiment [4]. The enthalpy difference laboratory is composed of indoor and outdoor parts, both of which are equipped with independent air handling units to ensure the uniformity requirements of different temperatures, humidity and wind speeds indoor and outdoor. The tested fresh air unit is directly connected with the air test body. The fresh air is introduced into the fresh air unit through a well sealed insulating duct, and then directly sent to the air volume test body after humidification treatment by the unit [5-9].

A fresh air unit equipped with a wet film humidifier is selected as the test equipment. The fresh air unit consists of an aluminum filter screen, a G4 filter, an H10 high efficiency filter, a jacket heat exchanger, a wet film humidifier and a forward centrifugal fan. The specifications and parameters are shown in Table 1. The fresh air unit is equipped with a controller to control the air volume by changing the fan voltage. The air volume selected for this experiment is 400m³/h,500m³/h,600m³/h. And control the minimum static pressure value that the unit air outlet needs to meet. The wet film humidifier part adopts the direct drainage water supply type, and the intermittent water supply is realized by controlling the water spraying switch through the time relay.

Table 1 Selection of Fresh Air Unit

Equipment name	Rated air volume (m^3/h)	Outlet static pressure （Pa）	Rated voltage （V）	Rated power （W）
Fresh air unit	500	140	220	134

2.2 Experimental content

In order to study the humidification effect of intermittent wet film humidifier under different outdoor working conditions and its change rule with time, this experiment was carried out in winter in Shanghai, and the fresh air simulation working conditions are shown in Table 2 [10-11]. In addition, the influence of fresh air volume, inlet dry bulb temperature and water spraying time ratio on the humidification effect can be obtained by adjusting the fan air volume, inlet water temperature and time relay of the sleeve heat exchanger. Agilent34970A instrument and power meter were used in the experiment to save and record the experimental data using LabVIEW software [12-13]. The outdoor measured air state was measured by the air temperature and humidity sampling system. The inlet dry bulb temperature was measured by the T-type thermocouple temperature sensor. The air state after wet film humidification was measured by the body air volume device in the enthalpy difference room.

Table 2 Test conditions

	1	2	3	4	5	6
Dry bulb temperature（℃）	7	5	2	0	-3	-7
Wet bulb temperature（℃）	6	4	1	-1	-4	-8
Relative humidity（%）	86.9	85.9	84	80.6	78.3	72.6
Absolute humidity（g· m³）	6.7	5.8	4.7	3.9	3.1	2.1

III. Experimental RESULT AND DISCUSSION

During the experiment, first turn on the air handling unit on the outdoor side of the enthalpy difference laboratory. When the outdoor working condition is stable, turn on the fan of the measured fresh air unit, adjust it to the set air volume and the static pressure of the air outlet. Turn on the wet film humidification and wait for it to operate stably for a period of time before recording the experimental data. When recording the experimental data under each experimental working condition, an intermittent start stop watering cycle of the wet film humidifier is a group of data, and the data recording interval is one minute, Five groups of intermittent water supply cycle data are recorded for each working condition, and these five groups of data are analyzed and sorted out finally.

3.1 Influence of fresh air working condition

Set the air volume of fresh air unit to 500m³/h. The sprinkling density of wet film humidifier is 4.2kg /(m ². s) The water spraying temperature is 10 ℃, the inlet water temperature of fresh air preheater is set as 35 ℃, and it is set as a typical unit working condition. The water spraying time of wet film humidifier is set as 15min, and the water cut-off time of wet film is 5min. The outdoor working conditions are shown in Table 2. Figure 1 shows the change of absolute humidity with time under six groups of fresh air working conditions. It can be seen from the figure that the absolute humidity does not rise or fall rapidly due to the start and stop of water spraying, but there is a delay phenomenon. The minimum and maximum values appear at 1min and 18min respectively, and the air humidity tends to be stable from 5min to 18min. With the decrease of the dry and wet bulb temperature in the outdoor environment, the absolute humidity to reach a stable temperature also decreases, and the time is also shortened. It takes 7 minutes for the outdoor environment to stabilize at 7 /6 ℃, and the absolute humidity is 11g /m ³.While at - 7 /- 8 ℃, the absolute humidity is only 8.5 g /m³.

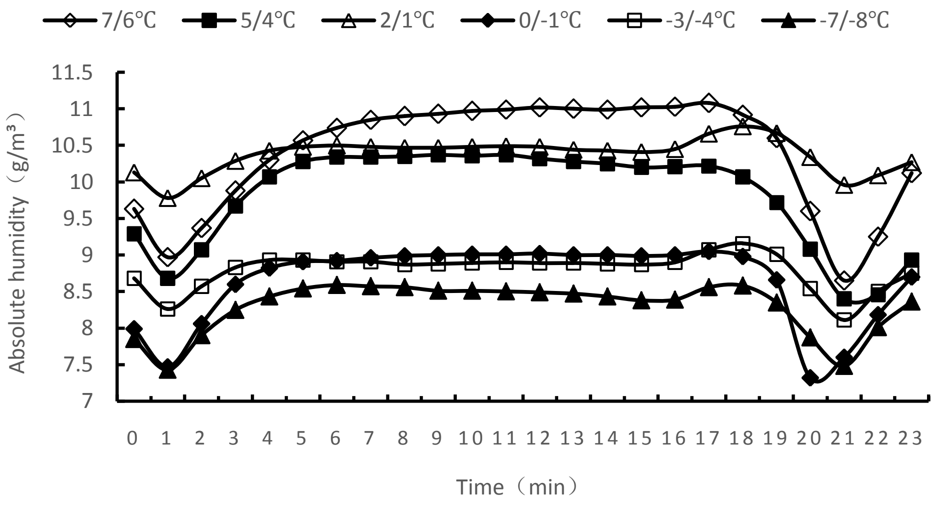

Figure1: 500m³/h Comparison chart of absolute humidity change with time under different outdoor working conditions under air volume

3.2 Influence of the time ratio of the drenching to water cutoff

In order to better analyze the impact of the wet film humidification process on the operating performance of the system, the typical working conditions in winter are selected to conduct the experiment of changing the ratio of the wet film humidification time. The outdoor fresh air working conditions are dry bulb temperature- 7 ℃, wet bulb temperature- 8 ℃, fresh air volume, fresh air preheating temperature, and water spraying density remain unchanged. By changing the ratio of the wet film humidifier's water spraying time, the water spraying intermittent ratio is 3:1, 2:1, 1:1, namely T1-15-T2-5, T1-10-T2-5 Comparison diagram of changes in wet film humidification effect under T1-10-T1-10. As shown in Figure 2, the absolute humidity changes with time under the three water showering time ratios are basically the same, but the humidity is difficult to stabilize if the water showering time is too short or the water shutoff time is too long, and the longer the water shutoff time is, the greater the impact on the humidity. This is because too long water cut off time will destroy the wet film on the filler surface. When entering the water spraying stage, the boundary layer needs to be reestablished on the filler surface, which requires more time to achieve stability. By comparing the analysis results under different water showering time ratios, it can be seen that the water showering time ratio of 3:1, namely T1-15-T2-5, is the relatively appropriate water showering time under the experimental conditions.

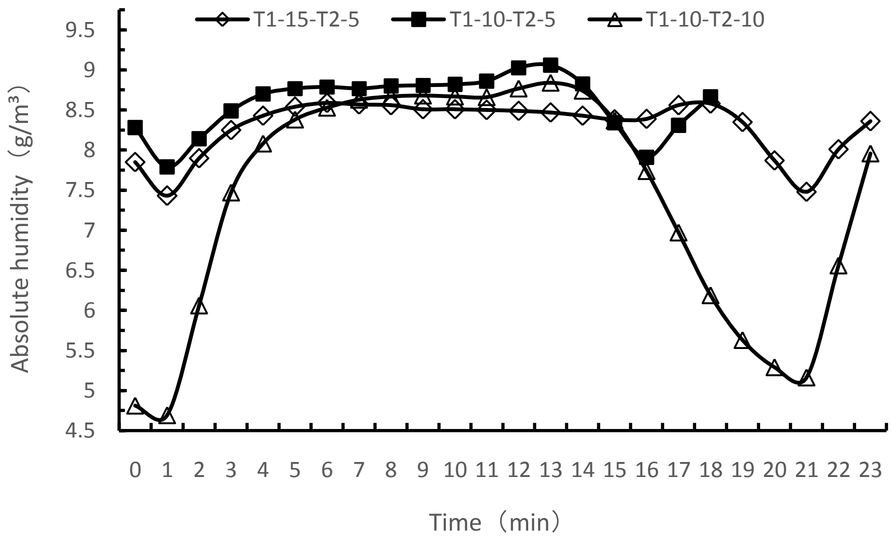

Figure2:Comparison chart of absolute humidity change with time under different watering time ratios at - 7 /- 8 ℃

3.3 Influence of fresh air volume

The typical outdoor working condition in winter is selected to compare and analyze the wet film humidification performance of fresh air volume. The outdoor dry bulb temperature is2℃, the wet bulb temperature is 1 ℃, the sprinkling interval time and density remain unchanged, and the preheating temperature is 35 ℃. Figure 3 shows that under this working condition, 400, 500, 600 m^3/h (The wet film frontal wind speed is 2.08m/s, 2.6m/s, 3.12m/s) The change of absolute humidity of three groups of air volume with time. The absolute humidity value corresponding to the air volume of 600m^3/hhas the shortest time to reach stability. About 6 minutes after the water spraying switch is turned on, 500m^3/h is slightly longer. About 7 minutes, 400m^3/h is the longest, which is 8 minutes. This is because the larger the air volume, the faster the air water heat value exchange rate on the wet film surface, and the faster the wet film surface can reach the heat and moisture balance in the stable section. The difference between the three absolute humidity values is not obvious in general, which is 10.2g /m^3 about. When the air mass flow is greater than a certain value (theoretical calculation value is 267 m^3/h), the absolute humidity has little change with the increase of air mass flow.

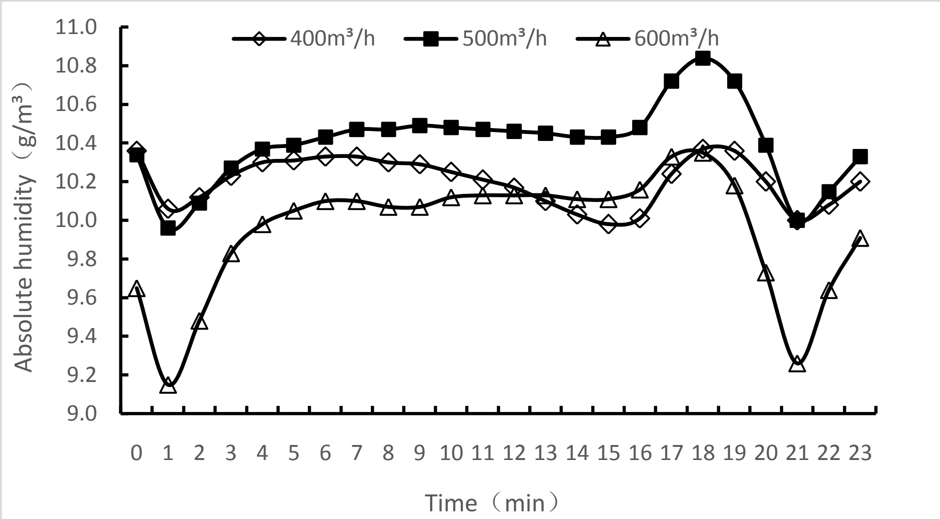

Figure3:Comparison chart of absolute humidity changes of three air volumes with time at 2 /1℃

3.4 Influence of fresh air preheating temperature

Simulate that the outdoor dry bulb temperature is 2℃ and the wet bulb temperature is 1℃,and the sprinkling intermittent time and density remain unchanged. Figure 4 shows the change of absolute humidity with time under different fresh air preheating temperatures. It can be seen from the figure that as the temperature of fresh air preheated hot water decreases, the time for the absolute humidity to reach stability is shorter, and the value after reaching the absolute humidity stability is smaller. It takes 3 minutes to stabilize at 9.8g/m at 31 ℃, It takes 6 minutes to stabilize at 10.5g /m at 35 ℃.This is because the lower the inlet air dry bulb temperature is, the higher the inlet relative humidity is. The saturated partial pressure of water vapor on the wet film surface is smaller, and the wet film surface is easier to reach the heat and humidity balance. However, the poorer the air's ability to absorb water is. On the other hand, the temperature of the wet film surface will also increase with the increase of the air dry bulb temperature, which will increase the saturated partial pressure of water vapor on the surface, thus increasing the humidification amount.

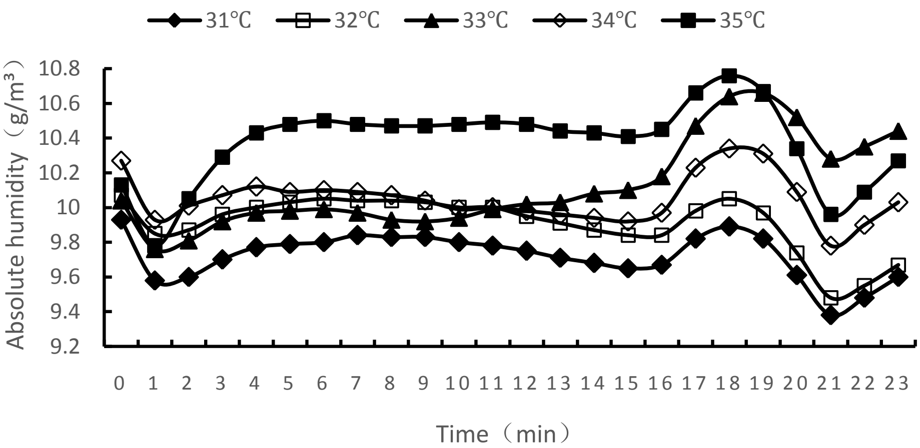

Figure3:Comparison chart of 5 fresh air preheating temperatures and absolute humidity changes with time at 2 /1 ℃

IV. CONCLUSION

1) The main factors affecting the humidification effect of wet film are air mass flow, wet and dry bulb temperature at the inlet of wet film, and water spraying density. The greater the difference between the dry and wet bulb temperature of the air at the inlet of the wet film, the stronger the water absorption capacity of the air and the better the humidification effect. The humidification effect of wet film will be improved by properly increasing the water spraying density, but when the water spraying density is greater than 2.1kg /(m^2·s), the humidification effect of wet film will no longer be significantly enhanced. With the increase of air flow, the relative and absolute humidity of air decreases obviously at first, and then slows down. When the air mass flow is greater than 1.8kg /(m^2·s) (the corresponding air volume is 267m³/ h), the air mass flow rate has little effect on the relative and absolute humidity at the outlet.

2) The absolute humidity will not rise or fall rapidly due to the start and stop of water spraying under three different water spraying time ratios, but there is a delay phenomenon. The minimum value and maximum value appear at 1 min and 3 min after the water is stopped, respectively. The change of absolute humidity with time is basically the same for different water showering times. However, if the water showering time is too short or the water shutoff time is too long, the humidity is difficult to stabilize, and the water shutoff time has a greater impact on the humidity.

REFERENCES

[1]. Zhang Yongquan, Ju Yongping, Guo Fengxia Research on the performance of permeable membrane humidifier [J]. HVAC, 1997 (04): 44-46.
[2]. Huang Qiuju, Liu Nailing, Chen Wei, Shao Dongyue Numerical simulation analysis of humidification performance of wet film humidifier [J]. Refrigeration, 2006 (03): 4450.
[3]. Zhang Qingmin, Chen Peilin Heat and moisture exchange process when air passes through water drenched paper packing [J] Journal of Tongji University (Thermal Engineering Edition), 1995 (06): 648-653.
[4]. Li Manman. Design of automatic control system for enthalpy difference laboratory [D]. Jinan University, 2019.
[5]. Liu Zhentong. Design and implementation of measurement and control system for enthalpy difference laboratory [D]. Jinan: Shandong University of Architecture and Architecture, 2016.
[6]. Zhang Zhongbin, Deng Qingqing, Cai Dandan, Zhang Daoming, Zeng Jianguo. Discussion on the application of enthalpy difference performance laboratory of refrigeration and air conditioning equipment in teaching [J]. China Equipment Engineering, 2019 (23): 149-150.
[7]. Yuan Mingchun, Luo Jian. Analysis of the Causes Affecting the Testing Accuracy of Enthalpy Difference Laboratory [J]. Metrology and Testing Technology, 2013,40 (09): 2223.
[8]. Tang Lihua Analysis of relevant requirements for enthalpy difference test room for air conditioner testing [J]. Guangdong Science and Technology, 2014, 23 (20): 159+135.
[9]. Luo Jian, Yuan Mingchun Energy saving technology research of enthalpy difference laboratory [J]. Measurement and Testing Technology, 2013,40 (06): 23+25.
[10]. GB /T 25,128-2010, Direct evaporative fresh air air handling unit [S].
[11]. Air to air energy recovery device China Academy of Building Sciences GB\/T21087-2007.2008.
[12]. Xu Chao Research on the application of LabVIEW in real-time measurement and control system [D] Chongqing: Chongqing University, 2005.
[13]. Wang Shudong, He Ming Research on the Application of LabVIEW in Data Acquisition System [J] Foreign Electronic Measurement Technology, 2014 (06): 103-106.