

Study on a New Kind of Direct Evaporative Cooling Air Conditioner

Jiheng Qin, Zhongbao Liu, Lina Fang

Refrigeration center, College of Environmental and Energy Engineering,
Beijing University of Technology, Beijing, China

Abstract: Because of its advantage of energy saving, economy, environment protection and the quality of indoor-air improving, the evaporative cooling technology is used more and more in the project. The electricity consumed by this direct evaporative cooling air conditioner is 20% of that of the traditional air-conditioning system. The structure and principle of this new kind of direct evaporative cooling air conditioner are discussed. The performance of the fibrous composite filler used in this air conditioner is fully discussed. With the psychrometric chart, the air handling process is analyzed. The experiment data corresponding to different weather conditions are given at the same time. Many applied projects and its application prospect are introduced. The problem existed is also discussed.

Keywords: Direct Evaporative Cooling, Air Conditioner, Psychrometric Chart, Composite Fiber Filler.

NOMENCLATURE

t_{w1} — dry-bulb temperature of inlet air, °C
 σ — moisture conductance, $\text{kg}/(\text{m}^2 \cdot \text{s})$
 r — latent heat of evaporation, kJ/kg
 t_{w2} — dry-bulb temperature of outlet air, °C

t_3 — wet-bulb temperature of the air, °C
 d_1 — humidity content of air inlet, kg/kg
 d_2 — humidity content of air outlet, kg/kg
 α — surface film conductance, $\text{W}/(\text{m}^2 \cdot \text{s})$

1. INTRODUCTION

Direct evaporative cooling air conditioner is applicable in open or half-open air place. The outdoor-air is filtrated and cooled through direct evaporative cooling air conditioner and then sent into the room. At the same time, the indoor-air is sent out through the fan. Cooling, air exchanging are realized. So it is especially fit for the high temperature, peculiar smell, serious polluted and populous place. In these no demanding constant temperature and humidity place, direct evaporative cooling air conditioner can be used to substitute the conventional air condition system not only to achieve the goal of improving the air quality of the place but also to save the preliminary investment and working expense. So its application foreground is favorable. [1-4]

2. THE ORY ANALYSIS OF PERFORMANCE OF DIRECT EVAPORATIVE COOLING AIR CONDITIONER

2.1 The analysis of factor affecting the performance of the filler

The filler is a key component of direct evaporative cooling air conditioner. Its hygroscopicity, water evaporative ability on its surface, specific surface area, resistance, intensity after moisture absorption,

anticorrosive performance, nonflammable directly influence its capacity of cooling and humidifying, formal size, natural life of service and safety of using.

When the filler and its thickness are decided, the main factors affecting the performance of the direct evaporative cooling air conditioner are: relative humidity(ϕ), face velocity of the filler(V), spray density of water (ρ). Based on the heat and mass transfer theory of air and water, it is known that with ϕ getting smaller, the impetus of heat and humidity exchange increases, so the effect of cooling and humidifying becomes better. With V getting bigger, the coefficient of heat and mass exchange increases, the effect of cooling and humidifying becomes better at the same time. Once V is too large, the effect of cooling and humidifying reduces because the water and air don't have enough time to contact. It also results in the rapid increasing of the resistance of the air, and then the energy consuming, so the value of V should be appropriate; when ρ gets bigger, the filler's wet condition gets improved, so the cooling and humidifying effect of direct evaporative cooling air conditioner enhances correspondingly. Once ρ is too big, it not only reduces the conditioner's effect but also leads to the increasing of resistance and the air content of water, and increases the energy consuming and restricts its using at last. ρ should be an

optimal value too.^[1]

2.2 Air handling process analysis with psychrometric chart. ^[2-4]

When air and water contact directly, the air handling process is different with the various temperature of the water which contacts with the air. The air handling process is an adiabatic humidifying course. Circulating water which is sprinkled on the treated air has the same temperature with the wet bulb temperature of the inlet air. At the spraying point, because the equi-wet-bulb temperature line is close to adiabatic line, it is considered that the air is humidified along the adiabatic line. The air handling process is shown in figure 1 (the i-d diagram).

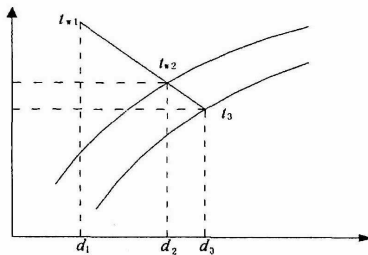


Fig1. psychrometric chart

- 1-Parameter of air inlet
- 2-Parameter of air outlet
- 3-Parameter of the saturated air.

If the quantity of water which contacts with the air is indefinitely large and the period of contact lasts for an indefinitely long time, the air can be treated to the state of point 3. However the air can only be treated to the state of point 2 in practical process.

In this process, the sensible heat capacity of air reduces, meanwhile, the latent heat capacity increases and the two are approximately equal to each other. The general quantity of heat exchange is close to zero. In fact, the quantity of heat of evaporation comes from the air.

In this process ^[2].

Quantity of sensible heat exchange is shown as

$$Q_s = \alpha(t_{w1} - t_{w2})F \quad (1)$$

Quantity of humidity exchange can be described as

$$W = \sigma(d_2 - d_1)F \quad (2)$$

Quantity of latent heat exchange is shown as

$$Q_q = rW = r\sigma(d_2 - d_1)F \quad (3)$$

Generally, cooling efficiency and humidifying efficiency are used to evaluate the direct expansion cooler.

Temperature difference between air inlet and air outlet is shown as

$$\Delta t = t_{w1} - t_{w2} \quad (4)$$

Quantity of humidification is shown as

$$\Delta d = d_2 - d_1 \quad (5)$$

Cooling efficiency is illustrated as

$$\eta = \frac{t_{w1} - t_{w2}}{t_{w2} - t_3} \quad (6)$$

Humidifying efficiency is illustrated as

$$\eta_R = \frac{d_1 - d_2}{d_1 - d_3} \quad (7)$$

3. EXPERIMENTAL RESEARCH OF THE DIRECT EVAPORATIVE COOLING AIR CONDITIONER'S PERFORMANCE

This experiment is based on a certain kind of direct evaporative cooling air conditioner. Its filler is composite fiber filler. The main reason we choose this filler is: good hydrophilic and ventilation performance, huge evaporative area, effective evaporative area is 100 times of its exterior area. The parameters are: air quantity $15000m^3/h$, power $0.6kw$, water consumption $18l/h$. The state parameters of the air are directly changed by heating and humidifying in the air inlet. The data which are measured by the experiment includes: dry bulb temperature, relative humidity (both inlet air and outlet air of the direct evaporative cooling air conditioner), quantity of circulating water etc. The change of inlet dry bulb temperature and relative humidity and the relations among the drop of temperature, quantity of humidifying, cooling efficiency and humidifying efficiency can be reduced by dealing with the data.

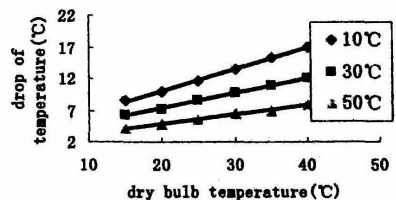


Fig2. the relationship of dry bulb temperature and drop of temperature

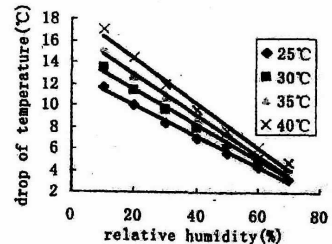


Fig3. the relationship of relative humidity and drop of temperature

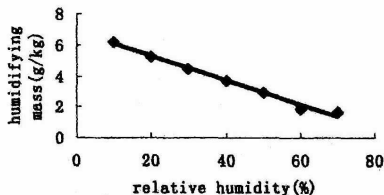


Fig4.the relationship of relative humidity and humidifying mass when the temperature is 35°C

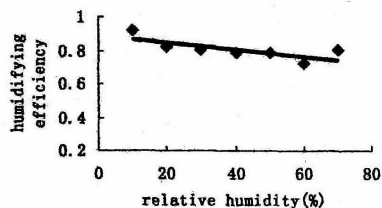


Fig5.the relationship of relative humidity and humidifying efficiency when the temperature is 35°C

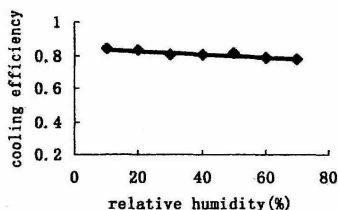


Fig6.the relationship of relative humidity and cooling efficiency when the temperature is 35°C

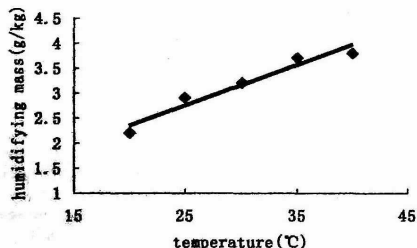


Fig7.the relationship of temperature and humidifying mass when the relative humidity is 40%

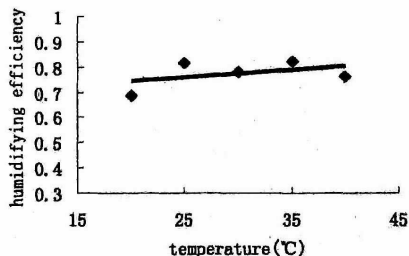


Fig8.the relationship of temperature and humidifying efficiency when the relative humidity is 40%

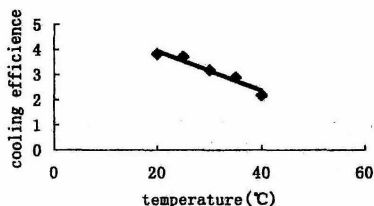


Fig9.the relationship of temperature and cooling efficiency when the relative humidity is 40%

From the figure 2 to figure 9, we can see that under the instance of changeless relative humidity, the higher the dry bulb temperature is, the bigger the drop of temperature and the quantity of humidifying are. But the efficiency of cooling and humidifying just has unobvious change. Under the instance of changeless dry bulb temperature, the relative humidity increases, the drop of temperature and the quantity of humidifying decrease, the efficiency of cooling and humidifying decrease but not obviously [1]. When the outdoor temperature is 35°C, relative humidity ϕ is 10% or 20%, the drop of temperature can reach 13.4°C or 11.4°C. Even when the relative humidity ϕ is 60%, the drop of temperature also can reach 5.4°C; when the outdoor temperature is 40°C, relative humidity ϕ is 10% or 20%, the drop of temperature can reach 17°C or 14.4°C. Even when the relative humidity ϕ is 60%, the drop of temperature also can reach 6.1°C. It is obvious that the direct evaporative cooling air conditioner can apply not only in the northwest area of our country but also in the northeast and north of China which relative humidity are not large.

4. CONCLUSION

4.1 The composite fiber filler which we use has big specific surface area and resistance. The effect of cooling and humidifying is better. When the outdoor

temperature is above 25°C, relative humidity ϕ is less than 50%, the drop of temperature can reach more than 6°C. The cooling efficiency is around 80% and the humidifying efficiency is more than 78%.

4.2 The direct evaporative cooling air conditioner not only has good effect in hot and dry area but also can improve the air quality by replacing the traditional air conditioning. It can also save the preliminary investment and working expense. The cost saving of preliminary investment is 40% and the working expense is 70%. And it uses water as the refrigerant to replace the Freon, so this air conditioner can be called green air conditioner because it won't pollute the environment. This can be widely applied in the factories, restaurants, show business, gymnasium and other business situations.

4.3 From the data measured, when the relative humidity exceeds 80%, the drop of temperature is less than 3°C, so it is not applicable in the south of China with large humidity in summer.

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REFERENCE

- [1] Wu Junmei. The Performanc Study on a Direct Evaporative Cooling Air Conditioner. Refrigeration and Air condionging. Feb, 2001. China
- [2] Zhang Qingmin. Chen Peilin. 1995. Heat and Mass Transfer Performance of a Domestic Product of Sprayed Corrugated Cellulose Media. Journal of Tongji University. Vol.23 No.6. China
- [3] Du Juan. Wu Junmei. Huang Xiang. 2005. Numerical Simulation of Heat and Mass Transfer Process in Directive Evaporative Cooling System. Refrigeration and Conditioning. Vol.5.No.2. China
- [4] Dowdy I A, Karabash N S. Experimental determination of Heat and Mass Transfer Coefficient in Rigid Impregnated Cellulose Evaporative Media. ASHRAE Transactions, 1988,93(part 2);382-395.US
- [5] NELL ESKRA. Indirect/Direct Evaporative Cooling System. ASHRAE JOURNAL. May,1980.US
- [6] P L Chen et al. The Energy-Saving Potential of Precooling Incoming Outdoor Air by Indirect Evaporative Cooling. ASHRAE Transactions. 99(1),1993.US