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Process Analysis and Application of Spray Cooling for Indirect Air Cooling Condenser

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ABSTRACT: In order to adapt to high temperatures in the summer, indirect air cooling unit with high load power, can adopt the spray cooling method as the peak summer measures. This article describes the working principles of indirect air cooling unit in the process of spray cooling, analyses the droplets in the exchange of heat and moisture and the main factors influencing the spray cooling effect at the entrance of air. A single in domestic 330 MW indirect air-cooling unit as an example, to design a set of spray cooling system, the cooling effect is remarkable by using.

1 GENERAL INSTRUCTIONS

Air cooling system, which obtained the rapid development in the word electric power construction in recent years, especially in the rich coal and water shortage region in north China, has become the inevitable choice of power station of the cold end system. Air cooling system of power station can be divided into direct air cooling and indirect air cooling. Whether it is direct air cooling or indirect air cooling system, both of them will be affected by the severe environment because they both transfer heart through the air. Indirect air cooling system lags behind direct air cooling system when it comes to the turbine back pressure [1].

In recent years, many domestic scholars conducted thorough study on the summer safety problems of direct cooling system and put forward many solutions [2] - [7]. Effectively improving the ability of indirect air cooling system going through the summer, is very important to the safe, stable and economic operation of the indirect air cooling units. But it is seldom reported.

2 INDIRECT AIR COOLING SPRAY COOLING PRINCIPLE AND THE ANALYSIS OF WET AND HEAT EXCHANGE

2.1 *The spray humidification and cooling system principles [4]*

Water forms a certain particle size of droplets through the nozzle, then the droplets are fully mixed with air in the process of movement and quickly evaporate. Heat exchange between the droplets and air is shown figure 1. Due to large latent heat of vaporization of water, the water will absorb a large number of heat from the air when it evaporates, and then reduce the dry bulb's temperature of the air. Spray humidification and cooling process is a complex and irreversible thermodynamic process, which includes flow, heat transfer and multiple transfer process influenced with each other at the same time. The process belongs to the direct evaporation cooling method and its treatment methods on h - d figure belong to air enthalpy humidification process. Process line is shown in figure 2. The air condition before spray is in point 1. The air condition after spray is in point 2. In order to improve the heat transfer of air cooling island, carrying cooling wet air to air cooling heat sink. Under the condition of certain intensity of atomization and spray Angle, spray will form a water film on the face of the air cooler, then water film further takes away heat when it evaporates, which can greatly improve the heat transfer ability of air cooler and improve the output of the unit.

2.2 *Damp and heat exchange analysis [8]*

Assume that injection cooling air droplets completely returned to air through evaporation, when the air contact with the water on the surface of a tiny dF,

Sensible heat quantity is:

$$dQ_x = \alpha(t_1 - t_2)dF \quad (2\text{-}1)$$

Wet and heat exchange capacity is:

$$dW = \sigma(d_1 - d_2)dF \quad (2\text{-}2)$$

Latent heat exchange capacity in the same time with wet exchange is:

$$dQ_q = r \cdot dW = r \cdot \sigma(d_1 - d_2)dF \qquad (2\text{-}3)$$

So, the total heat transfer quantity is:

$$dQ = dQ_x + dQ_q$$

$$= \left[\alpha(t_1 - t_2) + r \cdot \sigma(d_1 - d_2)dF\right] \qquad (2\text{-}4)$$

Lewis relation can be exported according to the adiabatic heat and humidity

$$\frac{\alpha}{\sigma} = c_p \qquad (2\text{-}5)$$

Application of the relation can transform (2-5) into:

$$dQ = \alpha\left[c_p(t_1 - t_2) + r(d_1 - d_2)\right]dF \qquad (2\text{-}6)$$

To consider liquid heat transfer of water, we use water steam enthalpy instead of the latent heat of vaporization, at the same time we replace the specific heat of moist air with 1.005 + 1.005 d. In this way, the type (2-6) turns into:

$$dQ = \sigma\left\{\left[1.005t_1 + (2501 + 1.86t_1)d_1\right] - \left[1.005t_2 + (2501 + 1.86t_2)d_2\right]\right\}dF$$

$$dQ = \sigma(h_1 - h_2)dF \qquad (2\text{-}7)$$

It can be found that the power pushing total heat transfer will be enthalpy difference rather than temperature difference from the formula. Air cooling condenser cool the air through spray. The effect has a direct relationship with temperature and relative humidity.

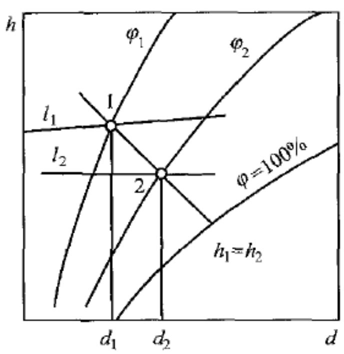

Figure. 1 air h - d figure before and after spray.

3 THE MAIN FACTORS INFLUENCING THE SPRAY COOLING EFFECT [8]

There are many factors influencing the heat exchange between air and the droplets in the air cooling unit, such as environment temperature and humidity, the initial state of water, the quality of the air flow rate, nozzle type, nozzle aperture and horsepower, the nozzle arrangement, air and water contact time, the movement direction of the air and water and so on.

3.1 *The influence of air velocity*

Spray cooling system in the heat exchange of air and droplets, firstly depends on the situation of the air contacting with the droplets. In the process of flow, air velocity will be changed along with the temperature, which is usually said the quality of the air flow. $V_\rho\left(kg/m^2 \cdot s\right)$ The calculation formula is:

$$V_\rho = \frac{G_a}{3600A_f} \qquad (3\text{-}1)$$

In the formula: G_a air quantity going through air cooling fin, kg/h. A_f Sectional area of cooling triangle, m^2 Experiments show that increase can increase the relative disturbance between water and air, so that the process of the heat exchange efficiency coefficient and contact coefficient grow bigger and heat exchange effect become more obvious. But too much will increase the system's energy consumption, decrease the time of air and water staying in the air cooling unit for a shorter time, and reduce its heat exchange time, which is bad for heat exchange.

3.2 *The effects of water-gas ratio*

The water quantity has a enormous influence on the effect of spray humidification and affects whether the spry system operates economically at the same time. In the spray humidification system, we usually represent the size of spray water quantity with water-gas ratio, which stand the sprayed quantity of water for every 1 kg gas. Its expression is:

$$\alpha = \frac{G_w}{G_a} \qquad (3\text{-}2)$$

In the formula: G_w stand for the amount of water in the air cooling type A, kg/h. The bigger the water-gas ratio, α, the greater the air contacts with water, which could increase the heat transfer efficiency coefficient and contact coefficient between droplets and air and. And the effect of spray cooling will be better. But too much will make the system energy consumption and water consumption increase, which may cause the waste of water.

3.3 *The influence of nozzle forms*

Automization is a key step in the progress of air cooled condenser cooling air and spraying. The more small the spray droplet diameter is, the more easy the droplet quickly evaporates in the air, so as to speed up the heat exchange process. Even if smaller droplets can not vaporize rapidly, they can also follow the air into the radiator. Due to air flow change direction in radiator, droplets adhere to the wing, absorb heat because of vaporization, and enhance heat transfer effect.

Nozzle form contains the nozzle aperture, pressure of spray, and spray Angle. The commonly used industrial spray nozzle causes the liquid atomization mainly through pressure. There are many factors that can influence the effect of nozzle, including: type of nozzle, resistance of water supply, pump head, flow matching between nozzle and pump, etc. Measuring the atomization quality includes two aspects, the particle size and particle size distribution of droplets. Droplets size determines the size of contact area between droplets and air, which is an important factor of strength for heat and mass transfer of water and air. The experimental results show that, the more small the spray nozzle hole is, the more high the pressure of spray water is, the more small the diameter of the droplets is, the more narrow the size distribution range is. But if the nozzle aperture is too small, there will be a nozzle clogging problem. And the spray pressure will be excessive, which may induce the phenomenon of water leakage.

3.4 *Influence of structure characteristics in spray system*

The effect of heat exchange system of spray strengthen related to the strength and uniformity of spray. In addition to reasonable nozzle type, nozzle system structure characteristics is the key to the system design. The structural characteristics of spray system mainly refer to the number, arrangement form and the direction of the spray nozzle, etc. The structure of the spray system directly affects the scope and degree of air and droplets and directly affects the spray humidification effect. When nozzle quantity is large, the process can form a dense mist curtain, which could greatly reduce the by-pass air, so as to improve the efficiency of heat exchange. When the nozzle density is big, the process may cause water mist overlay each other, collide with each other to form bigger drops of water, and cause the "wet bottom" phenomenon when air-cooled steam condenser spray. Spray direction has a great influence on the effect of heat exchange. The effect of inverse injection is better than suitable injection because of the enhanced heat transfer between droplets and air.

4 APPLICATION INSTANCE

Based on the above principle and analysis, a set of spry cooling system was designed for certain domestic 330 MW indirect air cooling system. The spray system includes four part: multistage pumps, pipe section, spray device and control system.

Multistage pump: The water come directly from the water tank. Water conditions: source of water SS ≤1mg/l. Water temperature: 5~30℃. Hardness: ≈ 0mmol/L (1/2Ca+1/2Mg). Electrical conductivity: ≤0.2 μS/cm(25℃). Silica: ≤20 mu g/L . PH = 7 ~ 8.

A manual valve is assembled on the inlet pipeline. Manual gate valves, electric control valves, check valves and drain valves are equipped on the outlet pipeline. At the same time there are pressure gauge and pressure transmitter on the pipeline.

Pipeline: Pipe diameter is selected according to the in-line circulation water. Spray head road in circumferential direction is arranged in the bottom of triangle condensing. Spray branch line is arranged in the center position of shutters and cooling triangle perpendicular to the ground, to ensure the security and stability of pipeline. Each front end of brand pipe, which can choose the spray scope according to the actual working condition.

Design of spray system is mainly related to nozzle spray device selection, arrangement of the position, direction of jet and jet Angle. According to the calculation, nozzle distance is 1.5 meters or so. Jet Angle is about 110 degrees. The injection direction is perpendicular to the surface of the radiator. Atomization granularity is no more than 80μm. Nozzle arrangement and covering effect are shown in figure 2, 3. The spray particle size and droplet velocity distribution are shown in figure 4,5.

Control system: whether the device open is determined by the dry bulb's temperature of ambient air and the relative humidity. The system arrange 2-3 sampling temperature and humidity sensors in 25 meters high platform, sending signals to center control room through the DCS. Based on the current condition, The control room control water pump and electric valve through DCS. Pressure transmitter and digital meter are installed in the system, sending the real-time traffic signals to center control room through controlling valve opening and adjusting water supply. Spray area are equipped with video monitoring network, which monitor the fault of spray devices. The comparison of data is shown in table 1 before and after spray system installed.

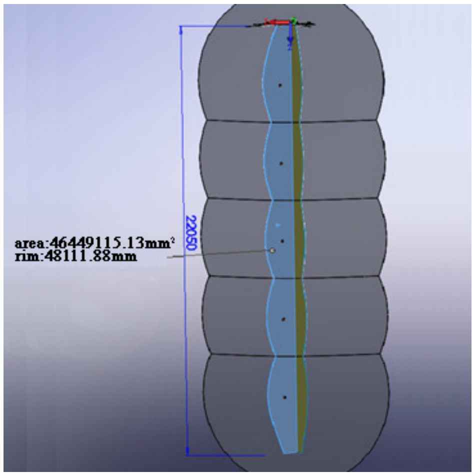

Figure 2. The simulation of spray area for one cooling triangle.

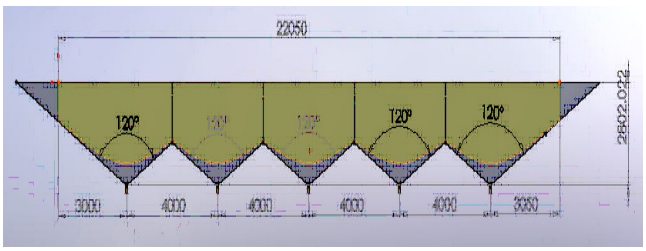

Figure 3. Nozzle arrangement in vertical.

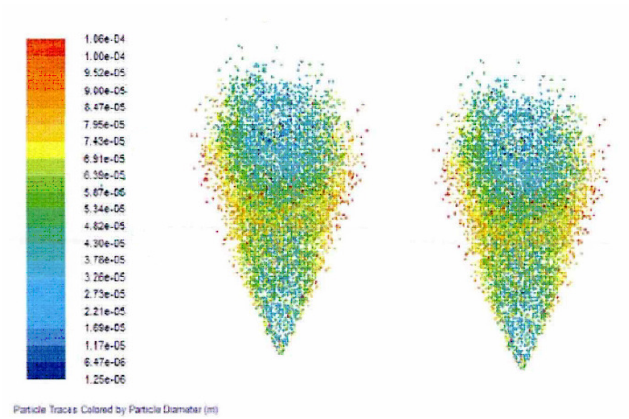

Figure 4. The spray particle size distribution.

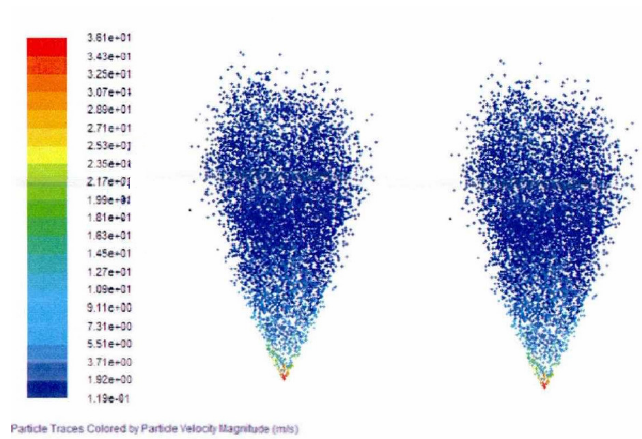

Figure 5. The droplet velocity distribution.

Table 1. Data comparison of spray system before and after operation.

Relative humidity before spray φ=40%, (average air pressure 894.87hPa)						
Relative humidity after spray	The amount of water	Temperature before spray □				
		26	30	34	38	42
%	kg/s	Temperature after spray □				
60	57.6	21.85	25.42	28.98	32.55	36.18
70	80.0	20.33	23.67	27.09	30.51	34
80	100.0	18.87	22.15	25.42	28.76	32.11
90	117.7	17.64	20.76	23.96	27.16	30.44
100	134.8	16.55	19.6	22.73	25.83	28.95

5 CONCLUSION

Adding the spray cooling system for air cooling unit, can significantly reduce the air temperature in air cooler inlet, effectively relieve the contradiction of the unit work in summer, and improve the economic benefit and safety of the unit. But the measure have not been widely used in indirect air cooling power plant. Through analyzing the indirect air cooling system in the process of spray cooling, this article summarizes the main factors affecting spray cooling effect, develops spray cooling system for indirect air cooling system for a certain domestic power plant, and get obvious cooling effect after using. With the rapid development of the future high-capacity indirect air cooling system, developing spray cooling for indirect air cooling system has a higher engineering promotion value.

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