Large-Size Industrial Cooling Tower with a Water Conservation Function

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Abstract

EBARA constructed a large-size industrial cooling tower for Inner Mongolia Yitai Petrochemical Co., Ltd. This cooling tower, which contains an air-cooled heat exchanger, has achieved a water conservation function and a white-plume preventive function. The volume of circulating water in cooling towers widely used for large-size industrial water circulation equipment is huge, and so is the evaporation amount. This cooling tower is equipped with a water conservation function, which enables it to contribute greatly to water conservation in regions lack of water resources. It also incorporates a white-plume preventive function because white plumes from cooling towers are associated with pollution. This paper introduces the large-size industrial cooling tower and explains the water conservation function and the principles of operation of the white-plume preventive function.

Keywords: Industrial cooling tower, White-plume preventive, Water conservation type, Cooling tower, Evaporation amount

1. Introduction

The western area of the inland of China, where EBARA delivered a cooling tower, suffers a serious water shortage because of an increase in population and industrial expansion, and as a result, the price of industrial water is rising. Cooling towers are used for a wide range of large-size systems for industrial water circulation in the petrochemical and coal chemistry industries and at electric power facilities, etc. but there is a need to reduce the amount of evaporation due to the large amount of evaporation of the circulating water.

This particular cooling tower, containing an air-cooled heat exchanger, reduces the amount of evaporation by efficient cooling with sensible heat thereby reducing cooling with latent heat.

In addition, the air discharged from the cooling tower is passed through the heat-exchanger inside the tower and reaches a high temperature, and is also higher in humidity than the outside air. Thus, if the outlet air is exposed to cold outside air near the fan casings in a cold region or during operation in winter, the water content of the outlet air will be condensed, and a large amount of fine water droplets will be produced. If the outlet air containing water droplets rises from the cooling tower, it can take on the appearance of a white plume. This is called white plume phenomenon (Figure 1).

This white plume phenomenon can ruin urban scenery and reduce visibility, resulting in traffic impediment. In addition, a white plume discharged from equipment inside the facilities of industrial cooling towers gives nearby...
residents an image of pollution.
The white plume problem of cooling towers has long been recognized, and endeavors have been made to conduct research in predicting the impact of white plumes and develop technology to prevent them.
This particular cooling tower is designed to be able to prevent white plumes by incorporating an air-cooled heat exchanger with a water conservation function.

2. Delivered Product

Figure 2 shows the appearance of the large-size industrial cooling tower with water conservation function delivered to Inner Mongolia Yitai Petrochemical Co., Ltd. as its third cooling water circulation system. The entire building shown in Figure 2 is a cooling tower, and as indicated by the number of fan casings, it consists of six coupled units. Air is introduced through the opening in the front, and the outlet air is discharged from the fan casings in the top. The air blowers at the top are as large as 10 meters in diameter, and to help you understand how big the cooling tower is, the size of a person is shown in the lower right area of Figure 2.

The specifications of the cooling tower concerned are shown in Table 1. The amount of circulating water in the cooling tower can reach as much as 30000 m³/h in the six units and the amount of evaporation of the circulating water is also large volume. In Ordos City, where the cooling tower is constructed, water resources are poor, and industrial water is expensive. As a result, we were requested to reduce the amount of evaporation by 15 % or more from the level of general industrial cooling towers.
Assuming that 1 % of 30000 m³/h of circulating water is evaporated, 2400 m³ of water will be evaporated in eight-hours of operation, which is equal to the water in an Olympic-size swimming pool measuring 50 meters in length, 25 meters in width, and 2 meters in depth.

Further, the water conservation feature of the cooling tower is also designed to prevent the white plume phenomenon.

Installation of the cooling tower began in May 2016 and was completed in May 2017. Through test runs, we were

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Value</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling tower model</td>
<td>–</td>
<td>SCC-5000H</td>
<td>6-unit-coupled type</td>
</tr>
<tr>
<td>Cooling capability</td>
<td>kW</td>
<td>58055</td>
<td>6 units</td>
</tr>
<tr>
<td>Amount of circulating water</td>
<td>m³/h</td>
<td>5000</td>
<td>6 units</td>
</tr>
<tr>
<td>Water temperature at inlet in cooling water</td>
<td>℃</td>
<td>40</td>
<td>–</td>
</tr>
<tr>
<td>Water temperature at outlet in cooling water</td>
<td>℃</td>
<td>30</td>
<td>–</td>
</tr>
<tr>
<td>Dry-bulb temperature in summer</td>
<td>℃</td>
<td>28</td>
<td>–</td>
</tr>
<tr>
<td>Wet-bulb temperature in summer</td>
<td>℃</td>
<td>21</td>
<td>–</td>
</tr>
<tr>
<td>Water conservation rate</td>
<td>%</td>
<td>15</td>
<td>–</td>
</tr>
<tr>
<td>Air blower diameter</td>
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<td>10350</td>
<td>–</td>
</tr>
<tr>
<td>Motor output</td>
<td>kW</td>
<td>250</td>
<td>6 units</td>
</tr>
<tr>
<td>L dimension</td>
<td>m</td>
<td>20</td>
<td>–</td>
</tr>
<tr>
<td>W dimension</td>
<td>m</td>
<td>120</td>
<td>Total value of 6 units</td>
</tr>
<tr>
<td>H dimension</td>
<td>m</td>
<td>23</td>
<td>–</td>
</tr>
</tbody>
</table>
able to verify water conservation through the reduction in makeup water and visually confirmed the prevention of white plumes.

3. Water Conservation Function

The amount of evaporation (E) of the circulating water in the cooling tower can be calculated using the following equation:

\[ E = \frac{\Delta t \times L}{600} \]

\( \Delta t \): Water temperature difference between inlet and outlet [°C]
\( L \): Amount of circulating water [kg/h]
600: (evaporative latent heat of water/specific heat of water) \( \approx 600 \)

An example of the estimated water conservation in the cooling tower is shown in Table 2.

When the water conservation function is activated, the temperature of the incoming circulating water from the heat source can be reduced by 2.3 °C by running the circulating water through the air-cooled heat exchanger with fins attached to the tube, as shown in Figure 3. The temperature of the circulating water can be further reduced by 7.7 °C by cooling it with evaporative latent heat by spraying it over a filler from a spraying pipe, and by 10 °C by cooling the air-cooled heat exchanger and the filler.

In a general cooling tower without a water conservation function, the entire difference of 10 °C in the circulating water between the inlet and the outlet in the cooling tower is the result of cooling with evaporative latent heat.

Comparing a general cooling tower with a cooling tower with a water conservation function, the temperature difference \( \Delta t \) in connection with evaporative latent heat is reduced from 10 °C to 7.7 °C, and this enables the cooling tower with a water conservation function to reduce the evaporative amount by 23 % compared to that of a general cooling tower.

4. Operating Principle of the White Plume Preventive Function

When the white plume preventive function (water conservation function) is activated, the circulating water first passes through the air-cooled heat exchanger with fins attached to the tube and is then sprayed over a filler from the spraying pipe, as shown in Figure 3. In this step, the hot high-humidity air (2) after heat exchange with the filler is overheated, decreases in relative humidity, and becomes unsaturated (3) as it passes through the air-cooled heat exchanger above the spraying pipe. The white plume phenomenon can be thereby reduced or prevented even if the outlet air of the cooling tower is cooled during operation when the temperature of the outside air is low.

We explain how this white plume occurs and the principle of preventing it based on an air diagram showing the change in the state of air (Figure 4).
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Figure 4 shows a diagram showing the state of air, with the horizontal axis representing dry-bulb temperature and the vertical axis representing absolute humidity. The solid line indicates 100 % relative humidity and is called a saturated vapor curve.

The saturated, wet air discharged from the filler is in a saturated state, or the state of (2) on the saturated vapor curve. When this air is discharged into the outside air, its state changes from (2) to (1), but in this stage, the state changes to the oversaturated region, which is on the left side of the saturated vapor curve, and a white plume occurs. When the white plume preventive function activated, the air is heated to the state of (3) in the air-cooled heat exchanger and then discharged into the outside air and changes to the state of (1). No white plume occurs in the process of the change in state from (3) to (1) because the change exists on the right side of the saturated vapor curve. The states of (1) to (3) indicate air in positions (1) to (3) of the cooling tower shown in Figure 3.

5. Summary

This cooling tower was the first large-size industrial cooling tower offering water conservation and white plume preventive functions delivered by EBARA Refrigeration Equipment & Systems (China) Co., Ltd. In the Chinese market, in addition to enhanced performance, demand for water conservation and white plume preventive functions in cooling towers is rising. We hope that the cooling tower we delivered will be used for a wide variety of applications and contribute to industrial growth in good harmony with the local environment.