Review on Water Distribution of Cooling Tower in Power Station

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Abstract. As the energy sources situation is becoming more and more severe, the importance of energy conservation and emissions reduction gets clearer. Since the optimization of water distribution system of cooling tower in power station can save a great amount of energy, the research of water distribution system gets more attention nowadays. This paper summarizes the development process of counter-flow type natural draft wet cooling tower and the water distribution system, and introduces the related domestic and international research situation. Combining the current situation, we come to the conclusion about the advantages and disadvantages of the several major water distribution modes, and analyze the problems of the existing water distribution ways in engineering application, furthermore, we put forward the direction of water distribution mode development on the basis knowledge of water distribution of cooling tower. Due to the water system can hardly be optimized again when it’s built, choosing an appropriate water distribution mode according to actual condition seems to be more significant.

1. Introduction

Cooling tower is of great significant thermal equipment in power station which is helping releasing the heat that circulating cooling water absorbed in via interchanging between water and steam, so that the circumstance in condenser can maintain the standard of vacuum[1]. As a exothermic terminal equipment of low temperature, cooling tower is not only an important link to guarantee the stability of exhaust pressure, but affects vacuum degree in condenser by the temperature of the discharge water, therefore, cooling tower can release the heat of circulating water into air timely or not influences the economical efficiency of cold-end system directly. In practical, the improving vacuum of condenser can lead to the dropping of turbine exhaust temperature, which reduces the fuel consumption that generate equal quantity of load. The falling of cooling tower discharge water temperature can improve
vacuum of condenser, which will influence cooling tower discharge water temperature and the coal consumption of power station.

At present, energy sources situation is becoming more and more severe, the state takes the issue of energy saving and emission reduction as the strategic key point of national economy development. The research on water distribution mode of natural draft cooling tower to optimize the water distribution system, on the one hand, can bring considerable economic benefit for the power station; on the other hand can save energy effectively.

2. Development of cooling tower

After entering electrified period, power plant produces great amount of waste heat in power generation process, the waste heat can hardly be further used according to the first law of thermodynamics and the second law of thermodynamics. Then the discussion about how to eliminate the waste heat pushes the cooling tower into rapid development. The principle of cooling water system is shown in figure 1 below:

![Figure 1. The principle of cooling water system](image-url)

In 1904, the first industrial cooling tower was built in France, and since then, the research on the cooling tower mainly focus on the optimization of cooling tower performance. In 1920, the Netherlandish engineer F K. Herson and G. Kuypers completed the design of hyperbolic cooling tower. This kind of air cooling tower makes use of the temperature difference between the air around the tower and the air inside of the tower air to cooling, as the hot air inside the tower rises, the cold air is inhaled through air entrance in the bottom of the tower[2]. Consequently, such cooling tower don't need a fan, there circulates scarcely any hot air in the tower that will affect the performance, which forms very good thermal properties. In addition, the curvature exists in vertical and horizontal directions of tower wall, the stress that the lower part of tower wall subjected is lesser, which can reduce the wall thickness to save building materials; also the minimum vibration frequency of hyperbolic cooling tower wall is higher, which provides good dynamic characteristics. The earliest
natural draft cooling tower (namely hyperbolic cooling tower) is built and put into use in British, and it’s widely used since the 1930s; hyperbolic cooling tower group was built in northeast of China in 1940s. Natural draft counter-flow cooling tower is shown in figure 2.

![Figure 2. Natural draft counter-flow cooling tower](image)

3. Analysis of water distribution mode

The role of the water distribution system is to ensure that hot water can be uniformly distributed on the packing surface within a certain limits, in order to make full use of the filler, which is an important aspect of improving the cooling effect of cooling tower. Besides, during the process of designing water distribution we should reduce Kinetic energy consumption as much as possible, pay attention to facilitating Maintenance Management and water flow adjustment, and minimize ventilation resistance. Water distribution mode of modern natural draft counter-flow wet cooling tower is classified main in two ways: piping distribution system and troughing distribution system. Piping water distribution system are divided into fixed and rotary two kinds.

3.1. Piping water distribution system

Piping water distribution system chooses steel pipes for water distribution, allocates the hot water to the various locations of the high elevation section of the cooling tower. The advantages of using this water distribution system is that flow velocity is high in the tube, and compared with the troughing water distribution system, this system takes up smaller area of the cooling tower ventilation, ventilating resistance is lower, and the water distribution is more uniform with the same water flow in the pipe. Due to high water pressure in the pipe, the flow of water through the splash device form small water droplets, which lead to good cooling effect, high quality of the installation, and difficult to
grow algae. The disadvantages are that the splash devices require higher water supply pressure and higher water quality, poor quality of water will clog pipes, and the blockage is hard to clean.

3.1.1. Fixed water distribution. In fixed water distribution mode, pipe decorates mostly as a ring. The water pressure is relatively uniform and water distributes relatively uniformly with ringing arrangement. Especially when the pipe system is locally clogged, ring arrangement plays more superiority. Pressure losses in the piping water distribution system is small, and uniformity of the cooling tower water distribution will not be affected by small changes of each nozzle outlet pressure.

3.1.2. Rotary water distribution. In rotary water distribution, many channels perforate the water distribution pipes, the water rises from the tower center to the water distribution pipes forced by pressure, then outflows from the water distribution pipes, spays on the filler. Water distribution pipes are promoted to rotate in the opposite direction due to the reaction force When water outflow from the channels. Accompanied by the rotation of water distribution pipes, the water is periodically sprinkling on the filler. It’s shown in figure 3:

![Figure 3. Rotary water distribution](image)

3.2. Troughing Distribution System

Troughing distribution system can be divided into main channel, bypass channel and distributing channel three grades for water distribution, the channel section is a rectangle, and is made of reinforced concrete. The working status, hot water flows through the shaft with rectangular or circular cross-section into the main channel, then flows into bypass channel and distributing channel, finally spays on the packing through the shower installed on the distributing channel.

The advantage of troughing distribution system is that water pressure of supply system is low, which saves more water pump power consumption and can be easier cleaned compared with piping water distribution system. Defect is that algae and mud would be likely deposit on the water channel, and change the height of the flow, which aggravates corresponding areas packing load, and nonuniform packing load increased damage to packing; the mud can also lead to serious shower nozzle blocking, and reduce water distribution capability greatly; when the splash dish matched with nozzle plots a scale, water film becomes umbrella-shaped and effect of nozzle splash becomes poor. What’s more, the splashing water exists "hollow" phenomenon due to splash dish mud, namely water is splashing
around, but nozzle below forms an area without water. Meanwhile, structure of troughing distribution system is relative complex, the air resistance is high, and area without water often emerges in distributing channel under the situation of small flow of water, then the packing cannot be fully used.

3.3. Central shaft water distribution

In thermal power plant, in order to enable the cooling water temperature reaches the design value, and saving energy consumption (mainly the circulating water pump operation power consumption), and prevent cooling tower freezing in winter, natural ventilation cooling tower operation against type, use commonly the condition with inside and outside area water distributing, all summer with tower (inside and outside area are water distribution) operation, only the outside area with water distributing in winter operation. the central shaft water distribution combined with trough pipes mode appears in recent years, so that can realize water distribution in different partitions[3]. It’s construction is shown in figure 4:

![Figure 4. Central shaft water distribution combined with trough pipes](image)

The advantages of this water distribution is energy saving, though flow velocity in pipes maybe so high that is far beyond the economic velocity range design code requires. The reason why flow velocity inside pipes is so high is that no matter how to decorate pipes the longest pipes increases and not less than $1/\sqrt{2}$ times of water tower shell radius with the increasing of cooling tower area. The longest water distributing pipe is so long that leads to high flow velocity.

3.4. Multiple shafts water distribution

Multiple shafts water distribution may have 3 or 4 or 5 shafts, each shaft lead branch from circulating water main pipe external the tower separately for water supply[4]. Because the layout, length and diameter of each branch pipe in the tower is different, the routing loss and local friction drag differs, can hardly allocated the total amount of water in different season of the year satisfyingly. Water distribution is not appropriate, the design of the cooling water distribution is difficult to achieve the expected requirements. The shaft with large water supply has high water level, and shaft with small water supply has low water level, the difference can reach about 0.5m according to the measure. The
shaft with high water level pouring water density is large in water supply area, and the shaft with low water level pouring water density is small in water supply area, which leads to nonuniform of cooling tower water distribution, also affects cooling efficiency of cooling tower directly.

3.5. *Suction Type Shaft Water Distribution*

Suction type shaft water distribution is realized by siphon device in the shaft central, it’s a kind of improvement of troughing water distribution system. The siphon device is composed of siphon mask and siphon weir. Suction type shaft water distribution is shown in figure 5:

![Figure 5. Suction type shaft water distribution](image)

A suction type shaft is set in cooling tower central, a intake pipe without valve stepped into the tower feed water for shaft. The pressure main channels of inside and outside of cooling tower should be set respectively in order to realize the water distribution of tower area or only the outside area. Pressure main channel is divided into upper and lower layers, the upper for inside area, and the lower for outside area. The outside area is running water throughout the year, and the lower main channel connected with the shaft directly, the inside area can stop the water distribution in winter. As the upper main channel has water supply or not conditions, the siphon device is installed in the import. Since there is only one shaft water level, hydraulic head is the same for each main channel, and the hydraulic head for nozzle working is the same of the tower corresponding positions, so that water-spraying density is necessarily the same, which is helpful for improving the cooling efficiency of cooling tower. Suction type shaft water distribution has applied in cooling tower of many domestic projects[5]. The units capacity include unit level of 300 MW and 600 MW, such as two 8500m² cooling tower in the Liaocheng power plant, two 9000m² cooling tower in Dezhou power plant.

The advantages of suction type shaft water distribution are list as follows: it can automatic adjust the water distribution for all the area or only the outside area according to water quantity without valves in or out tower, and the nozzle working hydraulic heads of tower corresponding regions are the same lead to water distribution uniformity, and there do not exist water distribution uniformity in pipes, which can improve cooling tower efficiency. The disadvantage is that the siphon sometimes can’t be created[6].
4. Conclusion

In the future, the optimization of water distribution system may carry out numerical simulations for cooling tower to calculate the temperature field, velocity field, stress field of the tower completely, at the same time, take the influence of the surrounding environment such as wind speed, the direction of the wind, temperature, humidity and so on into consideration, for the sake of getting closer to the actual engineering practice[7]. In addition, as the scope of optimization and adjustment is very small once the water distribution system is built, the power plant should pay more attention to choose the suitable water distribution system according to the cooling tower structure form. We need to pay attention to these main points: (1) Try as far as possible to uniformize the water distribution when decorating the shower nozzle. (2) The design should not only save pipe fitting but be beneficial to the pipeline hydraulic condition. (3) The cooling tower should be installed and maintained easily, and cleared conveniently.

The power plant operators should take the design documents as the basis, and combine with the operation regulations formulated with engineering practice of cooling tower, and be familiar with the operation maintenance requirements of cooling tower, grope operation rule and accumulate operation experience in practical operation.

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