# The influence and analysis of natural crosswind on cooling characteristics of the high level water collecting natural draft wet cooling tower

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**Abstract.** Large capacity and super large capacity thermal power is becoming the main force of energy and power industry in our country. The performance of cooling tower is related to the water temperature of circulating water, which has an important influence on the efficiency of power plant. The natural draft counter flow wet cooling tower is the most widely used cooling tower type at present, and the high cooling tower is a new cooling tower based on the natural ventilation counter flow wet cooling tower. In this paper, for high cooling tower, the application background of high cooling tower is briefly explained, and then the structure principle of conventional cooling tower and high cooling tower are introduced, and the difference between them is simply compared. Then, the influence of crosswind on cooling performance of high cooling tower under different wind speeds is introduced in detail. Through analysis and research, wind speed, wind cooling had little impact on the performance of high cooling tower; wind velocity, wind will destroy the tower inside and outside air flow, reducing the cooling performance of high cooling tower; Wind speed, high cooling performance of cooling tower has increased, but still lower than the wind speed.

## 1. Introduction

With China's social progress, economic development, national energy policy and the adjustment of China's electric power industry is moving towards the direction of energy saving, environmental protection and efficient development, large-scale nuclear power and high parameter, large capacity thermal power units is becoming the driving force of China's energy industry the main force [1], large and super large cooling tower has been in favor of related industries. In various types of cooling towers, the natural draft wet cooling tower (NDWCT) with high thermal efficiency, less failure, low operation cost, parts easy to aging and has little influence on the surrounding environment and easy maintenance has become one of the most widely used cooling tower in China's power industry [2]. In the process of research and optimization of cooling tower with natural ventilation, and the high level water collecting natural draft wet cooling tower (HNDWCT) is based on usual natural draft wet cooling tower (UNDWCT). Compared with the UNDWCT, the HNDWCT can effectively reduce the static head of the circulating water pump and reduce the cooling water noise of the cooling tower, so as to achieve the effect of energy saving and noise reduction.

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HNDWCT first appeared in Europe and were installed on nuclear power plants [3]. Early 1990s, the HNDWCT technology [4] was first introduced into Shanxi Pooching power plant in China, but it was not further developed at that time. In recent years, the development of cooling tower is very rapid. Three units have been successfully equipped with HNDWCT, and successfully put into operation [5].

## 2. Structure principle of HNDWCT

### *2.1. Structure principle of UNDWCT*

The UNDWCT is composed of a tower cylinder, central shaft, water eliminator, water distribution system, and set a pool of filler, rain. The circulating water carrying waste heat from the condenser enters the water distribution system through the central shaft, and the water distribution system sprays the circulating water in the form of droplets through the nozzle. At this point, the circulating water and the surrounding air heat and mass transfer, cooling effect accounted for about 5 - 10% of the overall cooling tower cooling effect. The circulating water is sprayed onto the packing, and the heat and mass transfer between the air and the filler is again carried out. According to the packing material, the shape of the packing and the different arrangement of the packing in the cooling tower, film packing, drip packing and mixed packing [6] can be formed. The heat and mass transfer of the process is the most complicated, and the heat transfer time is the longest, which is the strongest stage of the air heat transfer and mass transfer effect in the circulating water and the high cooling tower. The cooling effect accounts for about 65-70% of the cooling effect of the cooling tower. Circulating water out of packing after free fall, eventually fell into the pool at the bottom of the tower in the bottom of the sump from the packing to this distance is called the rain. Circulating water after packing, the distribution change slightly, the heat and mass transfer in the air and rain, the cooling effect of cooling tower cooling effect is about 20 - 30% [7]. The circulating water in the collecting tank passes through the circulating water pump and enters the turbine condenser to condense the exhausted steam.

### *2.2. Structure principle of HNDWCT*

HNDWCT belongs to the natural ventilation cooling tower, its operation principle and the conventional cooling tower is basically the same, by the tower, central shaft, water separator, water distribution system, filler, water collection device and set water. Compared with UNDWCT, the structure of HNDWCT is similar. The only difference is that HNDWCT is equipped with a water collecting device at the upper inlet, and the circulating water drops falling from the bottom of the packing are collected in advance, so the HNDWCT does not have a conventional cooling tower sump. As shown in Fig. 1, the structure of the HNDWCT is different from that of the UNDWCT.

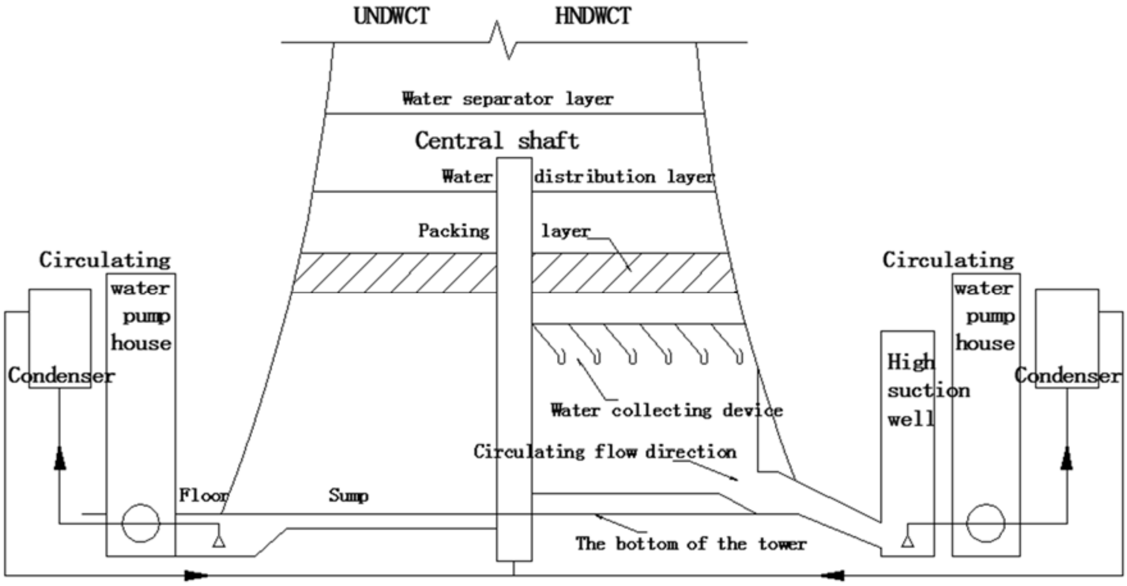


**Figure 1.** Comparison of structure between HNDWCT and UNDWCT

The tower, central shaft, water separator, water distribution system and filler of HNDWCT cooling tower is basically the same with UNDWCT, circulating water from the condenser out through the central shaft into the water distribution system, the water distribution system of the circulating water to form droplets sprayed to the filler; The circulating water falls freely after leaving the packing, but it does not fall directly to the bottom of the cooling tower, but is collected in the collecting tank [8] through the water collecting device. Finally, the circulating water in the collecting tank is sucked into the high water suction well, and then transported to the condenser through the circulating water pump to condense the steam cooling of the steam turbine. The water collecting device is a special part of the HNDWCT, which is mainly composed of inclined plate beam, water collecting oblique plate, splash proof cushion, water collecting tank and water retaining plate. The concrete structure is shown in figure 2. The general function of the water collecting device is to trap, transport and assemble the cooling water from the bottom of the filler to the water collecting tank at the upper part of the air inlet; At the same time, the air in the tower enters the inclined channel formed between the inclined plates, and smoothly enters the water drenching packing to participate in the heat exchange.

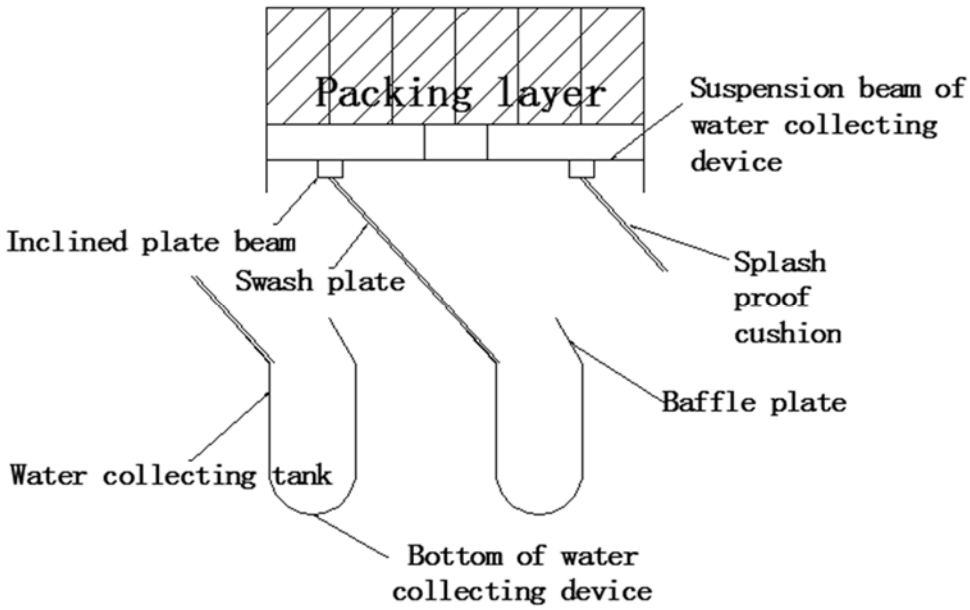


**Figure 2.** Basic structure drawing of water collecting device

Similar to the UNDWCT, the heat and mass transfer of the circulating water and the tower air in the HNDWCT can be divided into three parts, that is, the distance between the water distribution system and the top of the filler, referred to as the water distribution area; The packing zone and the bottom of packing and circulation water point of water and the distance between the inclined plate, referred to as high rainfall. The heat transfer of water collecting sink is negligible, the circulating water cooling tower cooling load for high proportion of the total cooling load in order to: high rainfall is 3.2 - 3.5%, water distribution area is 10.3 - 11.5%, the packing area is 85 - 86.5%[9]. Compared with the UNDWCT, cooling water and the proportion of filling area have increased significantly, while the proportion of high cooling rain fell sharply. Compared with the UNDWCT, cooling water distribution area and packing area performance is obviously increased and the cooling performance of the high rainfall is greatly decreased. This is not only because of the high rainfall rain without regular long distance, but also because of the HNDWCT without circulating water droplets prevents ambient air into the HNDWCT, which makes the air cooling tower into the high speed faster and therefore the ventilation of cooling tower is larger, so that increasing the heat transfer area and the area with filler the two part, the cooling efficiency was improved. In addition, the inlet of the HNDWCT is generally higher than the inlet of the UNDWCT [5] makes the higher inlet air volume of the high cooling tower is also one of the reasons causing the change of the cooling ratio in each region.

## 3. Influence of crosswind on cooling performance of HNDWCT

In order to describe and analyze the different regions of the tower, the bottom inlet area of the HNDWCT is divided into four different regions: A, B, C and D. The A area is the windward side, and the B and C areas are the crosswind side area, and the D area is the leeward side. The detailed division of the inlet area of the UNDWCT is shown in figure 3.

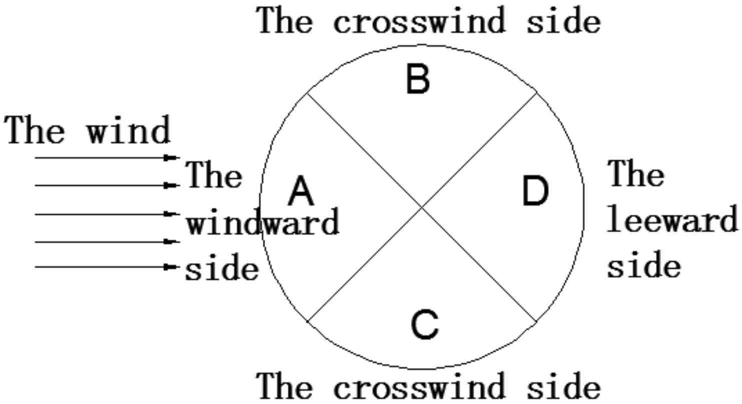


**Figure 3.** Schematic diagram of air inlet division of HNDWCT

### *3.1. Influence of small cross wind on HNDWCT*

When wind speed is 0m/s, high cooling tower and air velocity on the tower axis symmetry, cooling tower and the surrounding air evenly into the cooling tower, cooling at high maximum ventilation quantity. The air flow around the tower in the process of the cooling tower of the air inlet, the air velocity gradually increases, the air inlet of the channel due to the air suddenly narrowed, velocity is greatly increased. Enter the cooling tower, because there is no resistance to conventional rain air, the air flow enters the cooling tower and the cooling tower is higher than conventional. Since the tower inside and outside air velocity is circular symmetric distribution, the outside of the tower will be at the bottom of the tower center collision caused the tower air velocity decreases gradually along the radial direction of the air into the cooling tower, and the air velocity center tower bottom minimum. Due to the uneven velocity field in the HNDWCT and the diversion effect of the water collecting device, the air gap between the water collecting inclined plates at the upper part of the air inlet will form a whirlpool because of the backflow, and the vortex is not very big at that time [9]. On the other hand, the collision between the flow upward flow, heat exchange and circulating water droplets from the water distribution system and spray and the resulting air temperature rises rapidly, and the density decreases, the tower outer pressure difference increases gradually. The velocity of the tower will be higher and higher before the air flows out of the water distribution system. Because the hyperbolic structure of the high cooling tower can play a scaling role, the air velocity in the tower will still increase and then decrease, and the maximum velocity will appear in the throat of the cooling tower, which will enhance the suction capacity of the tower. The temperature field in the tower is also symmetrical and uniform, and the heat transfer uniformity is good. Without crosswind, the cooling efficiency of the HNDWCT is the highest.

When the wind speed is less than 2m/s, meet high environmental wind cooling tower is formed after the split, toward the cooling tower side area flow, collide with the cooling tower side region of the external air, the cooling tower side region of the external flow of radial wind pressure decreases, resulting in the wind speed B, C area decreased, the air flow into the corresponding reduced. At the same time, the wind pressure on the windward side of the tower increases with the increase of the ambient wind speed, which makes the wind speed in the A area increase, and the inlet air volume in the A zone increases, which causes compression resistance to the air inlet in the D zone. In the A and D zones, the two air streams with different strength will roll up the reverse vortex near the central region after the encounter, and increase the inlet air resistance in the central region. High speed high temperature airflow at the outlet of the HNDWCT appears slightly skewed to the downwind direction due to the transverse wind action. At this time, compared with the existing deviation symmetry of the air flow in the high cooling tower with no wind, but because the wind speed is smaller, the deviation is not obvious, but the wind into the tower around the still approximately equal to the upper part of the air inlet of the recirculation vortex change is not obvious. Therefore, when the ambient wind is small, the air velocity field and temperature field inside and outside the tower can still be regarded as the central axis symmetry of the tower, and its cooling efficiency has no great influence compared with that without crosswind.

### *3.2. Influence of cross wind with medium speed on HNDWCT*

When the ambient wind speed is between 2 and 4m/s, the axial symmetry of the air flow field inside the HNDWCT is further destroyed. The wind environment around the cooling tower to improve the high velocity flow, collision and cooling tower side region of the external flow is more intense, leading to lateral region of the external flow of radial wind pressure decreases again, inlet velocity B, C area is further reduced and the air volume is greatly reduced. Two wind will bypass shunt in the external of cooling tower D air inlet collided to form vortex, vortex will increase with wind speed, the air inlet resistance of D area increasing, and thus will reduce air flow into the region caused by D. At the same time, because of the wind speed of An area increased to D region into the wind pressure resistance is further enhanced, An area and D area two flows to the wind side collision position offset, air flow into the D region to further reduce air flow into the A area of the corresponding increase. The receiving device in the water refluxing swirl is greatly increased, the effective ventilation area was significantly reduced, and the HNDWCT outlet temperature by high speed airflow cross wind appear skewed to the wind direction is more and more obviously, the tower air is discharged into the atmospheric environment inhibited the wind environment. Compared with no cross wind, the axial symmetry of the air flow field in the high cooling tower has been greatly damaged [11], the air flow velocity in the tower decreases, the cooling tower water temperature rises, and the cooling efficiency becomes 88 ~ 96% without crosswind.

When the wind speed is 4 ~ 8m/s, with the increase of wind speed, wind on the air flow field of HNDWCT side outside the area the more serious damage, in the wind B, C area is further reduced, the air volume continues to decrease; high crosswind bypass cooling tower, forming larger eddies in the D area of the external air inlet at the D region hinder the outside air into the cooling tower; And when the wind speed reaches 4m/s, began to appear Chuan tang feng phenomenon, there is a part of the wind from the A area after entering into the tower to heat directly from the D area to flow away, wind speed greater Chuan tang feng phenomenon more serious. On the other hand, the pressure distribution of water collecting device in the Liao dynasty refluxing swirl uneven water collecting device occupies most of the regional area, backflow vortex increases with wind speed, resulting in a large number of tower air flow decreases, high temperature air gathered in the D area of the tower; cross wind and high cooling Tata outside the head-on wind, high speed and high temperature cooling tower outlet flow deflection angle increases, stronger inhibitory effect on the air entering the air column in high speed flow tower above the suction capacity of the tower, with the increase of wind environment and greatly reduced. At this time, the ventilation quantity is only 73 ~ 91% of the wind, the cooling efficiency is 76 ~ 88% [12].

### *3.3. Influence of super crosswind on HNDWCT*

When the wind speed is greater than 8m/s, because the wind speed is too large, the influence on the air flow field around HNDWCT, the phenomenon of HNDWCT and the crosswind suppression of the cooling tower outlet air have tended to be balanced; On the other hand, with the increase of crosswind wind speed, the wind in the tower will gradually destroy the backflow vortex in the water collecting device, and increase the effective ventilation area of the UNDWCT. When the wind speed is greater than 10m/s, high ventilation of cooling tower will again increase, but due to the cooling tower through the wind and wind phenomenon of cooling tower air export inhibition still exists, the cooling efficiency of the cooling tower has increased, but the increase rate is lower than that with low cross wind [9].

## 4. Conclusion

In the large and super large cooling tower has gradually become the mainstream of national electric power industry situation of the cooling tower, HNDWCT due to its excellent high energy saving and noise reduction to enter people's vision, and favored by more and more people. In recent years, China's

HNDWCT's technology started late and developed rapidly, and how to improve the cooling efficiency of the high cooling tower has been paid more and more attention.

When the cross wind is less than 2m/s, the air flow field inside and outside the HNDWCT has little change, and the cooling performance of the cooling tower has little change; When the cross wind is 2m/s~8m/s, the air flow field inside and outside the cooling tower becomes uneven gradually, and the upstream water inlet of the windward side of the air inlet forms a backflow vortex, and the cooling efficiency of the cooling tower becomes 76 ~ 88% without crosswind; When the ambient wind speed is greater than 8m/s, the cooling tower ventilation decreases first and then increases somewhat, but the growth rate is not large. The cross wind has great influence on cooling performance of cooling tower, so we need further structural optimization research.

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