Natural draft cooling tower

Most of the effluent from the steam turbine generator set of a thermal power plant is cooled by a hyperbolic natural ventilation cooling tower.
Natural draft cooling tower noise generated during normal operation includes water spray noise, pump noise, water pipeline and valve vibration noise. Water spray noise is the most significant noise source and the key to noise control.

Watering noise is mainly caused by two aspects:
The first is the sharp impulse noise radiated by water droplets directly impacting the water surface. The energy is proportional to the third-order power of the kinetic energy of the water droplets and the splash rate of the water droplets. The noise spectrum is broadband, and varies with the size of the water droplets and the impact velocity of the splash. The peak frequency is generally In a more gradual area nearby.
The second is the noise radiated by the bubble volume generated by the water droplets, and its spectrum is sharper than the peak of the impact sound between 500 and 10 000 Hz.

At 1.0 m outside the air inlet of the natural draft cooling tower, the noise level is generally 80~85 d B (A). The larger the unit capacity, the higher the air inlet height and the higher the water jet noise intensity. The tower body of the cooling tower is a cast-in-place reinforced concrete structure with high sound insulation. Therefore, the water spray noise is characterized by surface sound source, which can be regarded as only propagating outward through the air inlet of the cooling tower. In general noise reduction design, the water spray noise can be regarded as Surface sound source processing [2].

1 natural draft cooling tower noise status
The second phase of a power plant is two 350 MW cogeneration units. The measured noise is 81 d B (A) at a distance of 1.0 m from the cooling tower sump. The analysis of the cooling noise spectrum of the cooling tower (as shown in Figure 1) can be It can be seen that the cooling water leakage noise of the cooling tower is mainly medium and high frequency noise, mainly concentrated between 500 and 8 000 Hz.

The second phase of the project uses a hyperbolic natural ventilation cooling tower with a tower height of 114.7 m, a cooling area of 5,500 m2, an inlet height of 7.7 m, a cooling tower with a diameter of 90.0 m, and a water depth of 2.0 m. The plant is close to the south side. In the boundary, the cooling tower is about 100.0 m away from the south side of the plant boundary. The sensitive buildings outside the plant boundary are adjacent to the south side of the plant boundary, about 25.0 m away from the plant boundary. The cooling tower water noise has a significant impact on the noise-sensitive buildings outside the plant boundary.

The original cooling tower sound barrier height of the power plant is 8.2 m. The original sound barrier is arranged according to the cooling tower arc angle. The total length is 320.0 m. The sound insulation board is made of double-sided iron plate with rock wool structure. The measured sound insulation is 20 d B (A), the noise reduction effect is poor. The original sound barrier is in an upright form, the lower part is in the form of a brick wall, and the upper part is a sound insulating rock wool board structure, and the sound barrier façade structure is shown in Fig. 2.

With the economic and social development and government planning adjustment, the original site selection area of the power plant has gradually changed from an industrial park to a residential, commercial, and industrial mixed area. According to the requirements of GB/T 15190-2014 "Technical Specifications for the Division of Acoustic Environmental Functional Areas", the area meets Class 2 acoustic environment functional area division conditions. The environmental noise monitoring results of the site boundary show that the current nighttime ambient noise of the southern boundary is 58 d B (A), which cannot meet the GB12348-2008 “Industrial Enterprise Boundary Noise Standard” (hereinafter referred to as “Noise Standard”). The requirements of the standard, the night disturbing phenomenon is more prominent [3-4].

Therefore, based on the original natural draft cooling tower sound barrier, this paper proposes different noise control technical schemes, so that the environmental noise at the south side of the plant boundary meets the requirements of the Class 2 standard of Noise Standard, that is, no more than 60 d B between the daytimes (A), no more than 50 d at night B

2 Noise comprehensive management plan

In engineering practice, the main technical measures to control the cooling water leakage noise of the cooling tower are three kinds of sound barriers, muffler louvers and silencer pads [5]. In the design process of the cooling tower noise reduction treatment plan, the actual factors such as the old, the cost investment and the noise reduction effect are fully considered, and the noise reduction treatment is carried out on the basis of retaining the original cooling tower sound barrier structure.

2.1 Adding an anechoic pad (Scheme 1)

Under the premise of keeping the original sound barrier structure unchanged, Scheme 1 intends to add a layer of silencer pad in the cooling tower collection basin. The sound-absorbing pad is a cushioning water-reducing and noise-reducing nylon material. It is mainly composed of a floating support frame and a sound-absorbing pad. The principle of noise reduction is to avoid the direct impact of falling water on the pool and reduce the impact of water spray noise. The sound-absorbing and noise-reducing process of the anechoic pad belongs to the tower internal treatment process. The thickness of the design sound-absorbing pad is 50 mm, nylon material, the single-tower laying area is 7850 m2, and the noise reduction can reach 5~8 d B.

2.2 Improving the sound barrier (Scheme 2)

A sound barrier is installed around the cooling tower of the power plant. The sound barrier is made of a rock wool with a double-sided iron plate. The structure has a certain sound insulation effect, but no sound absorption treatment is performed, so that the sound waves reflected in the barrier form a reverberation. The effects, mutual interference, may even enhance the noise at the cooling tower sound source, while the noise generated by the cooling tower watering has a high frequency characteristic. In order to reduce the reverberation effect and its adverse effects, and further improve the sound insulation effect, the design adds a layer of sound absorption structure inside the original sound barrier. The sound absorbing structure is made of 0.8 mm aluminum perforated plate + 100mm 32 K ultra-fine glass wool (tarpaulin) + keel form.

The acoustic attenuation of the sound barrier diffraction can be calculated by:
Where: ?Ld is the attenuation of the sound barrier diffraction sound, d B; N is the Fresnel number; ? is the wavelength of the acoustic wave, m; dA is the distance from the sound source to the top of the sound barrier, m; dB is the receiving point to the sound barrier The distance from the top, m;d is the distance from the source to the receiving point, m. From the acoustic effect of the sound barrier, the noise barrier diffraction loss is completely dependent on the Fresnel number N, that is, depending on the sound path difference between the sound source and the sound receiving point (dAtd), the sound path difference The larger the diffraction loss of the sound barrier, the better the noise reduction effect.

Therefore, the original linear sound barrier is improved to an inverted L shape, the original sound barrier of the cooling tower is raised by 1.0 m, and a 1.0 m long inner fold design is made at the top, and the horizontal portion and the vertical portion are at an angle greater than 135°. The heightening method is to connect the steel column at the top of the existing sound barrier concrete column, and the sound insulation board adopts a structure consistent with the original plate piece, and the specific structure of the sound barrier improvement design is shown in FIG.

When the sound barrier is raised, the distance from the sound source to the top of the barrier increases, and the diffraction distance of the low-band noise increases. The sound barrier is improved in design, and the diffraction distance of the acoustic wave is increased to enlarge the sound-image area. It has a certain effect on the boundary of the sound source near the cooling tower. It can be calculated to increase the insertion loss of the sound barrier by about 4 d B. Therefore, scheme 2 mainly improves the original sound barrier and performs sound absorption and noise reduction processing inside the sound barrier, and the overall noise reduction amount of 8 d B can be obtained.

2.3 New Silencing Channel (Scheme 3)
Acoustic louvers are also effective measures to control the noise of natural ventilation cooling towers. Generally, 10~15 d B (A) noise reduction can be obtained [6]. Compared with the sound barrier, it has good ventilation and therefore can be placed closer to the cooling tower for better noise reduction. Under the premise of keeping the original sound barrier structure unchanged, scheme 3 adopts the noise reduction measures of the new muffling channel. The noise reduction effect of the anechoic louver can be evaluated by the noise reduction of the photo-resistive muffler. The anechoic louver is arranged around the air inlet of the cooling tower. In order to balance the ventilation and noise reduction effect, the distance between the anechoic louver and the tower body is 4.0 m, and the investment is also saved. The amount of noise reduction can be calculated by the following formula:

Where: ?L is the amount of noise reduction, d B; ? (?0) is the noise cancellation coefficient; C is the perimeter of the cross section of the muffler channel, m; S is the cross-sectional area of the muffler channel, m2; l is the effective length of the muffler, m.

After calculation, the width of the muffler is 150.0 m and the height is 8.0 m. The effective length of the muffler along the airflow direction is 2.0 m. In order to balance the ventilation performance and prevent high frequency failure, the noise reduction piece spacing is designed to be 300 mm, and the muffling channel has a noise reduction of about 10.4 dB.

The muffling channel combines a wide-band, high-performance sound absorbing material into the wind deflector structure, and two adjacent air deflectors form a muffling channel, which can effectively absorb the broadband noise energy in the tower and reduce the noise radiation. . The muffling channel is mainly composed of a basic frame, a muffler assembly and a sound insulation top plate, as shown in FIG.

The new civil construction foundation in the natural draft cooling tower area is mainly used to support the entire muffler, so the new basic form requirements are relatively low. Because the uppermost layer of the actual stratum on the site is mixed with soil, the structure is loose and the mechanical properties are poor. If this layer is used as the bearing layer, all the excavation needs to be replaced after the excavation, and the construction amount is large. Therefore, this time it is considered to remove all of them. The distance between the inlets of the cooling tower and the circumferential direction of the cooling tower is in the form of a beam-plate type strip foundation. The foundation bearing layer is (1) clay, the bearing capacity characteristic value fak=120 kPa, and the foundation depth is 2.0 m.

The frame is made of steel and is mainly used to support the entire muffler set and the sound insulation cover. The main force-receiving members are columns and beams, and the beams and columns are hot-rolled HM200×150 steel. The column is fixed to the foundation by anchor bolts embedded in the foundation. One end of the beam is bolted to the top of the column, and the other end is fixed to the cooling tower by a high-strength chemical anchor.

The muffler group is the core part of the whole muffling channel. The muffler group consists of muffler sheets with a spacing of 300 mm. The effective height of the muffler is 8.0 m, the thickness is 150 mm, and the two faces are 0.8 mm thick. The middle is filled with 32 K glass wool. In order to prevent the noise accumulation on the surface of the muffler from affecting the noise reduction effect of the muffler, the muffler is installed vertically, and the high-quality aluminum plate with smooth surface is used as the protective layer. The sound insulation top plate provided by the beam can prevent the water spray noise from being diffracted through the top end of the muffler group, thereby assisting the noise reduction effect and preventing the noise reduction group from raining. The sound insulation top plate is made of 0.8 mm thick color steel plate + 80mm centrifugal glass wool (tarpaulin wrap) + 0.8 mm thick aluminum plate.

Due to the outdoor arrangement of the muffler channel, the service life is seriously affected by the climatic conditions and the cooling tower water vapor. To ensure the overall performance and long service life of the cooling tower muffler, the steel structure and the muffler are strictly treated. The sound absorbing material in the sound absorbing sheet is wrapped with an alkali-free water-repellent glass cloth, and a drainage hole is designed at the bottom of the sound-absorbing sheet.

3 Comparative analysis of noise reduction technology solutions

In Scheme 1, the noise reduction measures in the tower with the new silencer pad are adopted, and the total static investment of the project is about 1.95 million yuan. However, the noise reduction pad has a limited amount of noise reduction, generally less than 8 d B, and there is a hidden danger to the circulating water. Due to the large drop of water in the large cooling tower, the impact of the water droplets is strong, and the sound-absorbing mat is easily damaged, which not only has high maintenance and replacement costs, but also has trouble in processing the material. Especially in the cold regions of the north, the general anechoic pad has poor weather resistance. In winter, the icing in the tower is seriously damaged by the anechoic pad, which will affect the safe and stable operation of the cooling tower. Therefore, the cooling tower noise treatment plan takes priority outside the tower. Governance. Scheme 2 adopts the noise reduction measures of the improved sound barrier, and the original linear sound barrier is designed to be inverted L-shaped, and the inner side is subjected to sound absorption treatment. The total static investment of the project is about 2.35 million yuan, and the overall noise reduction effect can satisfy the south. The ambient noise of the side plant boundary meets the requirements of Category 2 standards.

Option 3 uses noise reduction measures for new noise reduction channels around the natural draft cooling tower. The total static investment of the project is about 10.8 million yuan. The cooling tower noise reduction louver has better noise reduction effect, but in practical engineering applications, the number of anechoic louvers is relatively large and the material is expensive. Therefore, the noise louver cost is much higher than the sound barrier. Due to the open-air use of the anechoic louver, considering the stiffness of the anechoic sheet, the scattering of the sound absorbing material, the weather resistance, the service life, the anti-corrosion and the like, the outer surface of the anechoic sheet is made of aluminum plate. Although the scheme 3 can obtain a good noise reduction effect, the one-time cost is high.

In addition, the heat and mass transfer between the gas-water phase in the natural draft cooling tower is highly susceptible to ambient wind, air temperature and humidity. The noise reduction measures combined with the new muffling channel and the original sound barrier in Option 3 may affect the aerodynamic field inside and outside the tower. The change of the flow field directly affects the gas-water ratio distribution in the tower and reduces the gas-water phase. The heat and mass transfer intensity, especially the mass transfer heat transfer intensity in the packed zone, will adversely affect the efficient and energy-saving operation of the thermal system of the power station.