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# Research on the development and performance evaluation of drift eliminator for seawater cooling tower

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## ABSTRACT

Seawater cooling towers (SCTs) have been used since 1970s in power generation and other industries to reduce the consumption of freshwater. The salts in seawater are known to create several considerable problems, including salt deposition, packing blockage, corrosion, and certain environmental impacts from salt drift and blowdown return. The drift phenomenon is of importance for the performance of SCT. Especially, conventional drift eliminator in large scale mechanical draft SCT usually fails to capture liquid droplets due to high flow velocity. To solve this problem, a novel drift eliminator for SCT has been developed. The drift eliminator is manufactured with a three-dimension trapezoidal wave structure, which is helpful to reduce the drift. An experiment was carried out to research the drifting ratio of the concentrated SCT. The results show that the average drifting ratio of SCT was only 0.000, 533% when the inlet flow rate was 2,822 $m^3$/h. It proves that the novel drift eliminator can satisfy the mandatory requirement for SCT. Overall, the novel drift eliminator for SCT has a perfect water drift performance.

*Keywords:* Seawater cooling tower; Drift eliminator; Drift; Thermal performance

## 1. Introduction

Along with the rapid development of coastal industry and the increase of environmental pressure, seawater circulation cooling technology has become an effective way to conserve fresh water resources and reduce the emission of heated discharge to the ocean. Compared with the same scale of once-though cooling system, saltwater can be used in cooling towers to avoid impacting environment. And both the intake water flow and the discharge capacity were reduced by more than 95%, which is of great economic value. Compared with the conventional cooling towers, the seawater cooling towers (SCTs) are exposed to more complex problems, such as salt deposition [1–3], corrosion [4–6], fill blockage [7–8], and emission drift [9–11].

SCTs are used to dissipate heat from power plant's generator unit. The large quantities of waste heat must be removed to maintain standard operating condition, which can be achieved through the heat and mass transfer process of the direct contact between ambient air and hot concentrated seawater [12–14]. SCTs distribute the concentrated seawater over a heat transfer surface where a stream of air is passing reversely. As a result, concentrated seawater droplets are incorporated in the air stream with high velocity and then will be carried out of the tower.

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Thus, the drift is formed, and it is independent of water lost caused by evaporation.

Cooling tower drift is objectionable due to several reasons [15]. And Bedekar et al. [16] examines the environmental regulations related to cooling tower emission. First, it causes an emission of chemicals or microorganisms to the atmosphere. In addition, corrosion of equipment, piping and structural steel are followed, and it can also lead to electrical systems' failure. Controlling the atmospheric emissions from cooling towers is becoming an increasingly important influencing factor in the design and operation of industrial and commercial cooling systems.

The drift eliminator is usually installed in cooling towers to minimize the water loss of cooling system. By changing the direction of the airflow when it passes through the eliminator, most of the entrained droplets are separated from the air stream and fall back into the tower. The presence of the drift eliminator mainly affects two aspects of cooling towers: the thermal performance and concentrated seawater drift loss.

Therefore, as the key equipment to control the water droplets of seawater cooling, the development of efficient drift eliminator is of great significance to reduce the environmental hazards of SCTs [17–24].

## 2. Novel seawater cooling tower eliminator

The performance of drift eliminators can be quantified by two factors: the droplet collection efficiency and the pressure drop across the eliminator. For the SCTs, drift eliminators should have the following excellent performance, such as: higher efficiency, lower ventilation resistance, corrosion resistance, anti-aging, and non-deformation. Common drift eliminators are usually composed of one or two wave plates. The widely used material of drift eliminators in China is PVC [25,26], as shown in Fig. 1. Waveform drift eliminators test results [27–29] show that the eliminator's water removal efficiency increases with the increasing of the air velocity; when the air velocity reaches 3 m/s, the water removal efficiency can be achieved to over 99%. In addition, the pressure drop increases with the increasing of the gas velocity, and the maximum pressure is less than 1 mm $H_2O/(kg/m^3)$. With the characteristics of low ventilation resistance and without affecting the cooling tower air distribution, the wave-shape PVC drift eliminator is widely used in fresh water cooling tower.

Fig. 1. PVC material wave eliminator.

However, the widely used drift eliminators (Type BO-160/45 and BO-145/42) in the fresh water cooling tower are not suitable for the SCT. BO-160/45 wave-shape drift eliminators were used in the mechanical SCT located at Shenzhen Fuhuade power plant. After a period of operation, sodium chloride crystals appeared on the top of the tower platform and the motor shell. The phenomenon indicated that unsuitable drift eliminators would damage facilities of the tower and equipment. And then, adding another layer of drift eliminators on the above of the original eliminators could contain this phenomenon. This phenomenon shows that the SCTs have more stringent requirements than the freshwater tower because of the drift containing much salt content [30–34]. So, the general wave-shape drift eliminators are difficult to meet requirements of SCTs in controlling the water drift rate. To reduce the adverse effects of SCT drift on the environment, a new and efficient drift eliminator for the SCTs is important and necessary.

A novel specialized eliminator was developed for the SCTs. The structure feature of the eliminator is shown in Fig. 2. The novel SCT eliminator (SCTE) is made of two pieces of three-dimensional sheet of different structures. The sheet 1 is shown in Fig. 3. Sheet 1 is an oblique trapezoidal flap. The sheet 2 is deflected by 60° for the corresponding short side as shown in Fig. 4. The oblique side of the sheet 1 and the short side of the sheet 2 are bonded to each other to form an assembly structure of the novel SCT drift eliminator. Inside

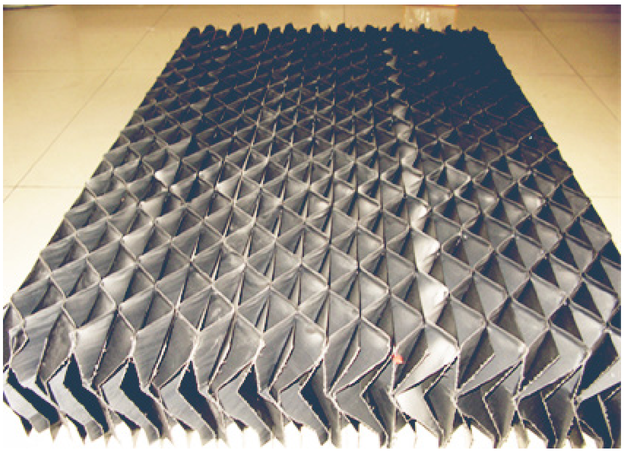

Fig. 2. Structure of the novel SCTE.

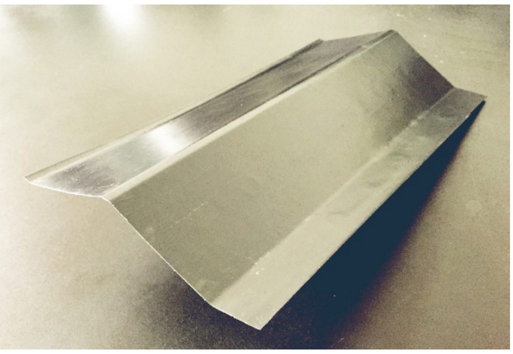

Fig. 3. Structure of the novel SCTE's sheet 1.

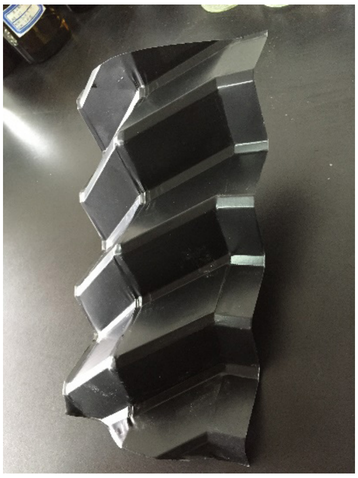

Fig. 4. Structure of the novel SCTE's sheet 2.

the novel SCT drift eliminator, the airflow space is tortuous continuous, which can effectively reduce the hot air back, and the strength and stiffness are greatly enhanced. Its span can increase to 2–3 m. The common cooling tower eliminators were made by polyvinyl chloride (PVC), polypropylene, glass fiber reinforced plastic, and other materials. The novel SCTEs were made with modified PVC material.

## 3. Test method and results

Experiments were carried out on a test facility assembled on the roof of a laboratory in the city of Shenzhen in the southeast of China, as shown in Fig. 5. The main device of this test plant is a forced draft cooling tower with a cross-sectional area of 18 × 18 m$^2$, a total height of 9.14 m and a packing section of 2 m high. The packing material consists of fiberglass vertical corrugated plates. Water pressure nozzles are used to distribute water uniformly above the packing and the air is circulated counter-flow by an axial fan. The thermal load is provided by an electrical heater located in a water tank. The fan's motor is equipped with a variable speed control, which allows the change of the air mass flow rate. The sprayed water mass flow rate can be changed manually by means of a balancing valve.

The novel SCT drift eliminator was used as the test object, and the test was carried out with the circulation water flow of 2,940 m$^3$/h under the cold condition, and the fan ventilation rate ranged from 250 × 10$^4$ to 280 × 10$^4$ m$^3$/h [35–38].

The experimental procedure is as follows: start the circulation pump, switch on the electrical heater, and switch on the fan as the temperature of the feed water increases a few degrees. Nine sets of experiments were performed. Thermal load was fixed by means of the electrical heater, which can ensure that all test conditions are consistent. The tower performance of the drift eliminator was obtained under stationary test environment and operating conditions. Test standard industrial cooling tower test procedure [39] was selected as the reference. To get valid test results, the circulating water flow rate and heat load cannot fluctuate more than 5%. Wet-bulb and dry-bulb temperature linear least square trends shall not exceed 1°C and 3°C per hour, respectively. The maximum deviation of the wet-bulb temperature may not exceed its average value during the test period (±1.5°C). The same is valid for the dry-bulb temperature with a deviation of ±4.5°C. The wind velocity shall not exceed 7 m/s for 1 min and its average value during the test period shall not exceed 4.5 m/s. The duration of the test run shall be not less than 1 h. The experiment operation conditions are shown in Table 1.

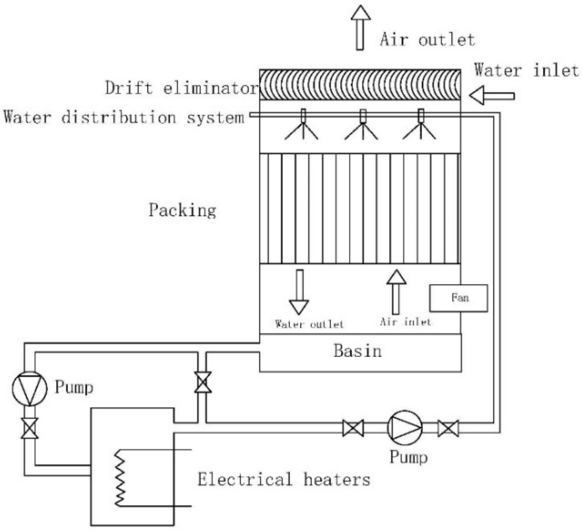

Fig. 5. Schematic diagram of forced draft SCT.

The water loss in the test is calculated as follows:

$$\Delta Q_w = \frac{\Delta q \cdot F}{f \cdot t} \times 60 \times 10^{-6} \tag{1}$$

where $f$ is the filter paper suction area (m$^2$), $F$ is the test section area (m$^2$), $\Delta q$ is the filter paper to absorb the number of droplets (g/min), which can be defined as:

$$\Delta q = \frac{1}{n}\sum_{i=1}^{n}(M_{2i} - M_{1i}) \tag{2}$$

where $M_{1i}$, $M_{2i}$ are the weight of blotting paper before and after each test (g).

The drift rate can be written as:

$$W_{\text{pd}} = \frac{\Delta Q_w}{Q_t} \times 100\% \tag{3}$$

where $Q_t$ is the quantity of water entering to cooling tower.

The resistance performance of the water collector can be calculated as follows:

$$\frac{\Delta P}{\rho_1} = \xi v_c^2 \tag{4}$$

where $\Delta P$ is the total pressure drop through the eliminator (Pa), $v_c$ is the average wind speed at the drift eliminator (m/s), and $\xi$ is the resistance coefficient of the drift eliminator.

Table 1
Experiment operation conditions

| Parameter | Range | Accuracy |
|---|---|---|
| Atmospheric pressure (hPa) | 1,026 | 1 |
| Inlet air dry-bulb temperature (°C) | 16.4 | 0.1 |
| Inlet air wet-bulb temperature (°C) | 13.4 | 0.1 |
| Influent water temperature (°C) | 28.3 | 0.1 |
| Outlet water temperature (°C) | 22.7 | 0.1 |
| Water flow rate (t/h) | 2,822 | 1 |

The filter paper absorption method (DL/T1027-2006 "Industrial cooling tower test procedure") was used to measure the water loss rate. In the test, two different diameter rings were divided into two vertical diameters at the outlet of the cooling tower. Ten measuring points were set, and 20 measuring points were set in the whole tower. Measuring paper and stopwatch were used. Respectively, test the different test section of the wind speed filter paper absorption drop, the filter paper absorbs the droplets in the electronic balance after weighing, electronic balance resolution of 0.1 mg. And the average rate of floating water is calculated by Eqs. (1)–(3), results are shown in Table 2.

The experimental results show that the average drift rate of the novel SCT drift eliminator can achieve 0.000, 533% when the water flow is 2,822 m$^3$/h. The drift rate increases with the increasing of the water flow in the tower, but the fluctuation is small. When the wind speed is 2.08 m/s, the average water loss is 0.199 kg/(m$^2$ h).

When a small amount of the circulating water in a cooling tower is entrained and carried aloft by the air stream, the droplets, which vary from a few to several thousand microns in diameter, are referred to as drift. In a modern cooling tower system, with efficient eliminators, the drift ratio of circulating water can be as low as 0.002%. The test drift rate of novel seawater cooling tower drift eliminator satisfies the standard value in Design Code for Seawater Circulating Cooling Water [40]. The test result should be smaller than the system hour circulating water 0.002% of the requirements, and the water efficiency is higher than the commonly used waveform eliminators. This result can be explained as follows. The eliminator is made of two pieces of folded three-dimensional structure. The air flow path is formed between the crests of the two wave swash plates and the crests along the edge of the horizontal waveform. When the saturated hot and humid air through the channel to enter the SCT drift eliminator, vertical upward air flow channel can be formed. In this process, the airflow space is continuous and the air flows vertical upwards into the atmosphere. Small hot air reflux improves the water efficiency, so that it has a good drift controlling performance.

The drift eliminator surface is wetted by the entering water droplets and an additional packing volume is formed which contributes to the heat and mass transfer exchange. The structure of the drift eliminator plays a main role in the process. As the novel drift eliminator's three-dimensional structure is more complex, the resistance performance is obviously higher than the commonly used wave-shape drift eliminator. The special structure of the novel drift eliminator improves the strength, rigidity, and span, and can effectively reduce the deformation and fracture. It is more durable and suitable for the strict requirements for design and operation of the SCTs.

Table 2
Test drift rate of the novel SCT drift eliminator result

| Number of measuring points | $\Delta q$ (g/min) | $v_c$ (m/s) | $\Delta Q_w$ (kg/(m$^2$ h)) | $W_{\text{pd}}$ ($1 \times 10^{-3}$)% |
|---|---|---|---|---|
| 1 | 0.075 | 2.08 | 0.183 | 0.490 |
| 2 | 0.085 | | 0.207 | 0.553 |
| 3 | 0.085 | | 0.208 | 0.555 |
| 4 | 0.083 | | 0.202 | 0.540 |
| 5 | 0.062 | | 0.151 | 0.403 |
| 6 | 0.092 | | 0.224 | 0.599 |
| 7 | 0.087 | | 0.211 | 0.565 |
| 8 | 0.080 | | 0.197 | 0.526 |
| 9 | 0.086 | | 0.211 | 0.565 |
| Average | 0.082 | | 0.199 | 0.533 |

## 4. Conclusions

Due to high wind speed, the drift effect of large mechanical SCT equipped with ordinary drift eliminator often cannot meet the standard requirements. To solve this problem, a novel efficient drift eliminator is developed. The novel drift eliminator has a composite trapezoidal wave three-dimensional structure and is especially suitable for the concentrated seawater in the cooling tower.

The experimental results show that the average drift rate of the novel drift eliminator can achieve 0.000, 533% when the water flow is 2,822 m$^3$/h. When the wind speed is 2.08 m/s, the average water loss is 0.199 kg/(m$^2$ h). The efficiency will be influenced by the eliminator's configuration. In China, the limit value for the drift ratio is 0.02%.

The design and application of the inside element of the SCT are still in the initial stage. The novel drift eliminator proposed in this paper is greatly beneficial to the popularization and application of the seawater circulating cooling technology.

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