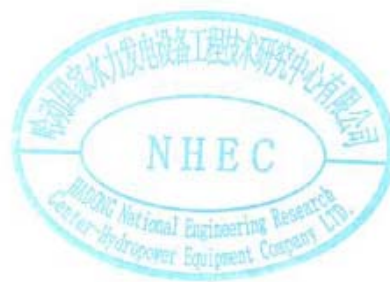


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Test Report of Heat Transfer Performance
and Wind Resistance Performance of Plate
Fin-and-Tube Air Cooler



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1 Introduction

According to the entrustment of GWA Industrial Heat Exchanger (Jiangsu) Co., Ltd.(GWA for short), the performance of plate fin-and-tube air cooler manufactured by GWA was tested on the "Closed Loop Medium Speed Wind Tunnel" of Harbin National Hydropower Equipment Engineering Technology Research Center Co., Ltd. The wind tunnel device includes air circulation system, electric heating system, water circulation system and measurement and control system, which can simulate the condition of the cooler operation. The technical parameters of plate fin-and-tube air cooler have been obtained through the test, and the test analysis report is presented.

2 Data of the air cooler model

The test was carried out using a model of an actual cooler. The cooler model is provided by GWA, which can not only match the test system, but also reflect the actual performance of the cooler.

The plate fin-and-tube air cooler is composed of cooling water pipes and through-fin cooling elements, while the through-fin cooling element is a piece of integral perforated sheet expanded by multiple tubes. Its structure is shown in Figure 1, and the basic data of the air cooler model are shown in Table 1.

Table 1 Basic data of the air cooler model

| Item | Data | Item | Data |
|---|---------------|-------------------------------|--------------|
| Cooler length (m) | 0.40 | Cooler width (m) | 0.40 |
| Water pipe diameter (m) | 0.0124/0.0140 | Water pipe row distance (m) | 0.0295 |
| Water pipe spacing (m) | 0.034 | Row number of water pipes | 3 |
| Number of tubes per row | 12,11,12 | Total number of water pipes | 35 |
| Plate spacing (m) | 0.0025 | Number of water routes | 2 |
| Number of plate fins | 160 | Water pipe/plate fin material | BFe10-1-1/T2 |
| Total heat dissipation area (m ²) | 10.09 | | |

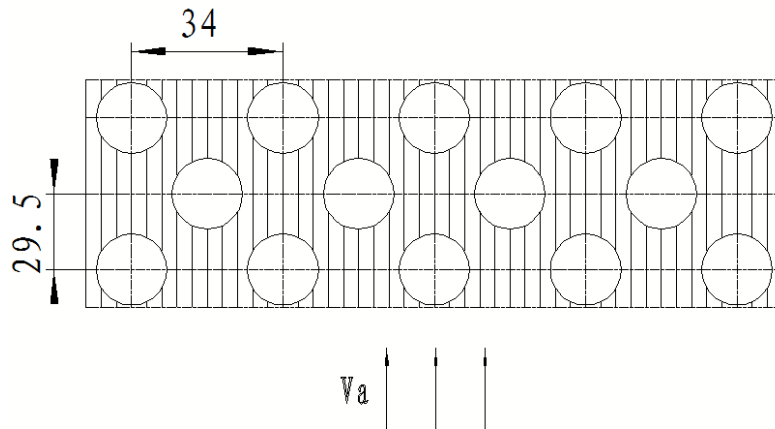


Figure 1 Arrangement of water pipes of plate fin-and-tube air cooler

3 Test contents

In the " Closed Loop Medium Speed Wind Tunnel ", the heat transfer performance and wind resistance performance test of the plate fin-and-tube air cooler with 3 rows of tube bundles were conducted.

Through experiments, the heat transfer performance and wind resistance performance of the plate fin-and-tube air cooler manufactured by GWA are determined to provide a basis for the design, manufacturing and operation of the plate fin-and-tube air cooler.

4 Test method

The model test method is used for the test.

In order to test the heat transfer performance and wind resistance performance of the cooler accurately, the cooler model is made to conform to the cross-sectional size of the wind tunnel, and the tube bundle arrangement are the same as the he cooler in actual operation. Install such a cooler model on the test section of a closed loop medium speed wind tunnel, and adjust different heating power, different wind speed, and different water speed to meet the test requirements.

The air volume through the cooler model is supplied by the blower, and the maximum air volume in the test section can reach $8640\text{m}^3/\text{h}$.

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The amount of water passing through the cooler model is supplied by a water tank through a water pump. The water tank is cylindrical, with a size of $\Phi 2.3\text{m} \times 2.5\text{m}$, and can hold 10m^3 of water.

The air through the cooler model is heated by the heating element to the required temperature value, and power of heating element can reach 60kW.

The function of heat transfer coefficient $K=f(V_a)$ is to adjust the speed of the blower while maintaining a certain constant water speed V_w , so that the wind speed can reach different values, and the relationship between the K value and the wind speed V_a is obtained.

The wind resistance characteristics are obtained by testing the pressure difference before and after the cooler model under different wind speed states.

The wind speed is measured by the " Pitot tube" to obtain dynamic pressure and static pressure, and then sent to the "differential pressure transmitter", and finally displayed by the anemometer on console. The calculation formula of wind speed is:

$$V_a = \sqrt{\Delta H \times 2g / \gamma} \quad \text{m/s}$$

ΔH — dynamic pressure difference Pa

g —acceleration of gravity 9.81 m/s^2

γ —Specific gravity of air kg/m^3

The gas temperature is obtained by measuring the resistance value of the copper wire resistance net.

The inlet and outlet water temperatures of the cooler model are measured using two platinum thin film thermal resistors respectively installed on the inlet and outlet pipes of the cooler.

To ensure the accuracy of water temperature measurement, thermocouples are installed at the inlet and outlet valves to directly measure the water temperature difference for comparison and verification.

The water speed is measured with a turbine flowmeter-frequency meter.

During the test, the gas flow rate, temperature and cooling water flow rate remained stable.

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5 Test data and results

5.1 Heat transfer performance test data and calculation results

The passing area of the finned cooler used in the test is 0.16m^2 ; the heat dissipation area per meter of the single tube is 0.721m^2 ; the effective length of the single tube is 0.4m .

The test was carried out at three different water speeds. Table 2 shows the test results of the water volume at $7.6\text{m}^3/\text{h}$ and the water speed at 1.0m/s . Table 3 shows the test results of water volume at $11.4\text{m}^3/\text{h}$ and the water speed at 1.5m/s . Table 4 shows the test results of the water volume at $15.2\text{m}^3/\text{h}$ and the water speed at 2.0m/s .

Table 2 Test results of water volume at $7.6\text{m}^3/\text{h}$ and water speed at 1.0m/s

| Sampling point | | 1 | 2 | 3 | 4 | 5 |
|------------------------------|--|--------|--------|--------|--------|--------|
| Hot air temperature | ($^{\circ}\text{C}$) | 60.163 | 64.646 | 66.897 | 69.732 | 68.388 |
| Cold air temperature | ($^{\circ}\text{C}$) | 34.814 | 41.819 | 46.894 | 51.576 | 53.216 |
| Wind temperature difference | (K) | 25.348 | 22.828 | 20.003 | 18.156 | 15.172 |
| Hot air density | (kg/m^3) | 1.1043 | 1.0859 | 1.0745 | 1.0629 | 1.0624 |
| Cold wind density | (kg/m^3) | 1.1485 | 1.1247 | 1.1073 | 1.0921 | 1.0865 |
| Specific heat of air | ($\text{kJ}/(\text{kg}\cdot^{\circ}\text{C})$) | 1.009 | 1.009 | 1.009 | 1.009 | 1.009 |
| Wind speed | (m/s) | 2.194 | 4.308 | 6.389 | 8.508 | 10.554 |
| Air side capacity | (kW) | 9.917 | 17.242 | 22.169 | 26.505 | 27.464 |
| Hot water temperature | ($^{\circ}\text{C}$) | 29.3 | 29.2 | 30 | 31 | 31.4 |
| Cold water temperature | ($^{\circ}\text{C}$) | 28.204 | 27.276 | 27.551 | 28.04 | 28.364 |
| Water temperature difference | (K) | 1.096 | 1.924 | 2.449 | 2.96 | 3.036 |
| Specific heat of water | ($\text{kJ}/(\text{kg}\cdot^{\circ}\text{C})$) | 4.175 | 4.176 | 4.175 | 4.174 | 4.174 |

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|--|----------------------|--------|--------|--------|--------|--------|
| Density of water | (kg/m ³) | 996 | 996.1 | 996 | 995.8 | 995.7 |
| Water side capacity | (kW) | 9.619 | 16.897 | 21.504 | 25.975 | 26.64 |
| Water temperature difference calculated by air side | (K) | 1.097 | 1.925 | 2.452 | 2.961 | 3.039 |
| Logarithmic temperature difference | (K) | 15.739 | 23.463 | 27.182 | 30.505 | 30.519 |
| Heat transfer coefficient | | 0.0606 | 0.0714 | 0.0784 | 0.0844 | 0.0866 |

Table 3 Test results of water volume at 11.4m³/h and water speed at 1.5 m/s

| Sampling point | | 1 | 2 | 3 | 4 | 5 |
|------------------------------|----------------------|--------|--------|--------|--------|--------|
| Hot air temperature | (°C) | 64.105 | 65.432 | 65.847 | 65.199 | 66.11 |
| Cold air temperature | (°C) | 34.41 | 41.401 | 45.072 | 47.573 | 50.011 |
| Wind temperature difference | (K) | 29.695 | 24.031 | 20.775 | 17.626 | 16.099 |
| Hot air density | (kg/m ³) | 1.0985 | 1.0852 | 1.079 | 1.0761 | 1.071 |
| Cold wind density | (kg/m ³) | 1.1501 | 1.1259 | 1.1133 | 1.1052 | 1.097 |
| Specific heat of air | (kJ/(kg·°C)) | 1.009 | 1.009 | 1.009 | 1.009 | 1.009 |
| Wind speed | (m/s) | 2.209 | 4.316 | 6.428 | 8.535 | 10.642 |
| Air side capacity | (kW) | 11.634 | 18.172 | 23.263 | 26.135 | 29.624 |
| Hot water temperature | (°C) | 28.5 | 29.6 | 29.4 | 29.4 | 29.5 |
| Cold water temperature | (°C) | 27.643 | 28.248 | 27.686 | 27.455 | 27.318 |
| Water temperature difference | (K) | 0.857 | 1.352 | 1.714 | 1.945 | 2.182 |
| Specific heat of water | (kJ/(kg·°C)) | 4.176 | 4.175 | 4.175 | 4.175 | 4.175 |

| | | | | | | |
|--|----------------------|--------|--------|--------|--------|--------|
| Density of water | (kg/m ³) | 996.2 | 996 | 996 | 996.1 | 996.1 |
| Water side capacity | (kW) | 11.285 | 17.808 | 22.565 | 25.612 | 28.735 |
| Water temperature difference calculated by air side | (K) | 0.857 | 1.353 | 1.715 | 1.945 | 2.184 |
| Logarithmic temperature difference | (K) | 17.367 | 22.63 | 25.751 | 27.21 | 29.099 |
| Heat transfer coefficient | | 0.0644 | 0.078 | 0.0869 | 0.0933 | 0.0979 |

Table 4 Test results of water volume at 15.2m³/h and water speed at 2.0 m/s

| Sampling point | | 1 | 2 | 3 | 4 | 5 |
|------------------------------|----------------------|--------|--------|--------|--------|--------|
| Hot air temperature | (°C) | 61.908 | 64.443 | 65.01 | 63.992 | 65.448 |
| Cold air temperature | (°C) | 34.634 | 39.718 | 43.885 | 46.142 | 48.607 |
| Wind temperature difference | (K) | 27.274 | 24.725 | 21.125 | 17.85 | 16.84 |
| Hot air density | (kg/m ³) | 1.1016 | 1.0896 | 1.0823 | 1.0803 | 1.0744 |
| Cold wind density | (kg/m ³) | 1.149 | 1.132 | 1.1174 | 1.11 | 1.1018 |
| Specific heat of air | (kJ/(kg·°C)) | 1.009 | 1.009 | 1.009 | 1.009 | 1.009 |
| Wind speed | (m/s) | 2.222 | 4.311 | 6.453 | 8.6 | 10.717 |
| Air side capacity | (kW) | 10.777 | 18.751 | 23.818 | 26.774 | 31.302 |
| Hot water temperature | (°C) | 29.5 | 28 | 28.5 | 28.7 | 28.4 |
| Cold water temperature | (°C) | 28.905 | 26.954 | 27.185 | 27.206 | 26.672 |
| Water temperature difference | (K) | 0.595 | 1.046 | 1.315 | 1.494 | 1.728 |
| Specific heat of water | (kJ/(kg·°C)) | 4.175 | 4.176 | 4.176 | 4.176 | 4.176 |

| | | | | | | |
|--|----------------------|--------|--------|--------|--------|--------|
| Density of water | (kg/m ³) | 996.1 | 996.3 | 996.2 | 996.2 | 996.3 |
| Water side capacity | (kW) | 10.453 | 18.376 | 23.104 | 26.239 | 30.363 |
| Water temperature difference calculated by air side | (K) | 0.596 | 1.047 | 1.317 | 1.494 | 1.73 |
| Logarithmic temperature difference | (K) | 15.396 | 22.571 | 25.327 | 26.271 | 28.834 |
| Heat transfer coefficient | | 0.0673 | 0.0807 | 0.0905 | 0.099 | 0.1044 |

According to the test results, the relationship curve between the heat transfer coefficient and wind speed and water speed of the cooler can be obtained, as shown in Figure 2.

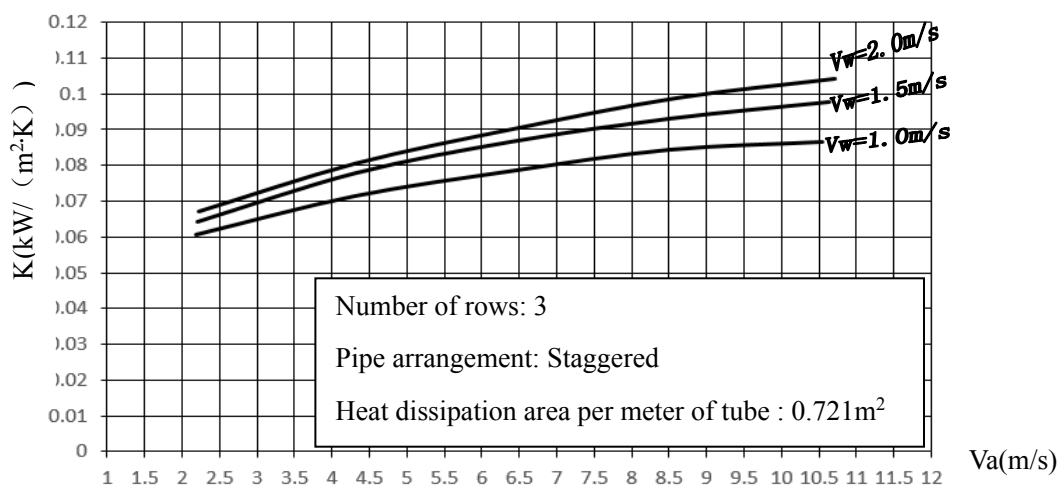


Figure 2 The relationship between the heat transfer coefficient of the plate fin-and-tube cooler and the air inlet speed

5.2 Wind resistance performance test and results

The wind resistance performance test and its results are shown in Table 5.

Table 5 Wind resistance performance test results

| Sampling points | 1 | 2 | 3 | 4 | 5 |
|-------------------------|------|-------|-------|------|-------|
| Wind speed (m/s) | 2.13 | 4.15 | 6.25 | 8.37 | 10.45 |
| Wind pressure drop (Pa) | 39.2 | 127.4 | 225.4 | 343 | 470.4 |

According to the test results, the relationship between the wind resistance pressure drop and

the wind speed of the plate fin-and-tube cooler can be obtained, as shown in Figure 3.

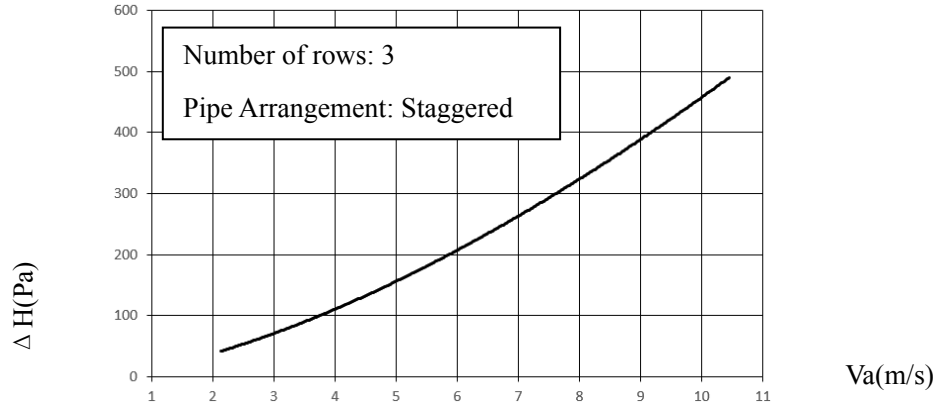


Figure 3 The relationship between the wind resistance pressure drop of the plate fin-and-tube cooler and the air inlet speed

6 The relationship equations of heat transfer coefficient $K=f_1(V_a)$ and wind resistance characteristic $\Delta H_a=f_2(V_a)$

6.1 Using one-variable nonlinear regression analysis to obtain the relationship between heat transfer coefficient and air inlet speed

(1) When water speed $V_w=1.0$ (m/s)

$$K=0.0507 \times V_a^{0.2331} \quad R=0.9959$$

(2) When water speed $V_w=1.5$ (m/s)

$$K=0.0524 \times V_a^{0.2684} \quad R=0.9981$$

(3) When water speed $V_w=2.0$ (m/s)

$$K=0.0536 \times V_a^{0.2818} \quad R=0.9994$$

Note: R: correlation coefficient of regression analysis

6.2 Using one-variable non-linear regression analysis, the relationship between the wind resistance pressure drop and the air inlet speed in the case of pipes in 3 rows is obtained. The actual wind resistance pressure drop can be converted according to the linear change of the number of water pipe rows.

$$\Delta H_a=12.812 \times V_a^{1.5529} \quad R=0.9966$$

Note: R: correlation coefficient of regression analysis