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# Study on Temperature Rise Characteristics of Radiator Based on Micro Heat Pipe Array in Plateau Area

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## Abstract

**In order to study and analyze the temperature rise characteristics of micro heat pipe array radiator. So compared with the existing copper aluminum composite radiator, it is found that: The micro heat pipe array radiator has good surface temperature uniformity. The maximum temperature drop in the horizontal direction is only 2.4℃, and the maximum temperature difference between the water supply temperature and the first surface temperature measurement point is only 3.5℃; In the vertical direction, the maximum temperature drop is only about 0.8℃, and the maximum temperature drop ratio is only 1.4%. When the water supply flow is 1600L/h and the water supply temperature is raised from 55℃ to 65℃: the thermal response time of copper aluminum composite radiator is 3.3-3.5 times of that of micro heat pipe array radiator. When the water supply temperature is 55℃, the water supply flow increases from 1050L/h to 2200L/h: the thermal response time of copper aluminum composite radiator is 2.2-3.9 times of that of micro heat pipe array radiator.**

## Keywords

**Micro heat pipe array; radiator; temperature rise characteristics; temperature difference.**

**Chinese classification number:TU832 Document code:A.**

## 1. Introduction

With the continuous development of heat pipe technology, Zhao Yaohua, Wang Hongyan and others[1] developed compact flat micro heat pipe arrays with micro structure, simultaneous interpreting the heat transfer performance of different heat transfer media. The results show that: The maximum heat flux of flat plate micro heat pipe array can reach 200W · cm - 2, and the best filling rate is 0.3. Kou Zhihai, Liu Chenxi, et al [2]. Conducted an experimental study on the heat transfer characteristics of a flat heat pipe radiator with micro channel as its wick. The experimental results show that the heat resistance inside the heat pipe accounts for a small proportion of the total heat resistance of the heat pipe radiator. Wang Wei, Fan Hongming and so on [3] applied the flat plate micro heat pipe array to the high-power LED heat dissipation technology, and designed a new high-power LED heat dissipation device, which improved the effective heat dissipation capacity of the LED heat source. Zhu Tingting and Diao Yanhua [4] designed a new solar air collector based on flat plate micro heat pipe array, and carried out detailed experimental research on its thermal performance and resistance characteristics. The results show that the collector's heat collection efficiency can reach 73% and flow resistance is less than 25 Pa under stable operation in summer. Therefore, the flat plate micro heat pipe array has the advantages of wide application range, strong heat transfer performance, better temperature uniformity, etc., but the application of flat plate micro heat pipe array in the end device of indoor heating system is relatively less. Only Dong Ruixue and Quan Zhenhua [5] designed and built a new type of floor radiant heating system based on the array of micro heat pipes. At the same time, the thermal performance of the core heat exchange unit of the system was experimentally studied. The results show that: under the same heating experimental conditions, the heat transfer power of the flat plate micro heat pipe array floor heating system is 29.33 w/m2 higher than that of the traditional floor radiation heating system.

In this paper, in view of the advantages of flat plate micro heat pipe array, such as strong heat transfer performance, rapid heat transfer, good temperature uniformity, and so on[2], and the experimental research on the application of flat plate micro heat pipe array to indoor radiator is still relatively blank at home and abroad. Therefore, a new type of flat plate micro heat pipe array radiator is proposed, and its temperature rise characteristics in the indoor heating system of plateau area are studied.

## 2. Experimental System

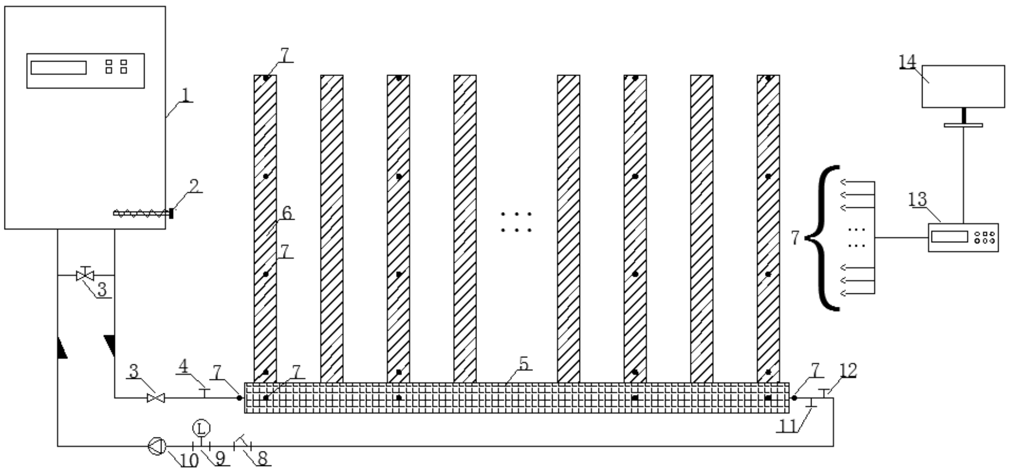
### 2.1. Experimental Device

In this paper, the experimental system principle of micro heat pipe array radiator in indoor heating system is shown in Figure 1. The data were collected by calibrated Φ0.1mm copper / constantan thermocouple. This experiment consists of the following three parts:

Heating source: Electric heater is used to heat constant temperature water tank to simulate heating source.

Heating object: The wall width of the experimental room is 370mm and it is brick concrete structure, its indoor size is 3m×2.5m×2.2m (length×width×height). The local altitude is 3650m, the outdoor ambient temperature is -2℃, the initial indoor air temperature is ±2.5℃, and the relative humidity is 11%.

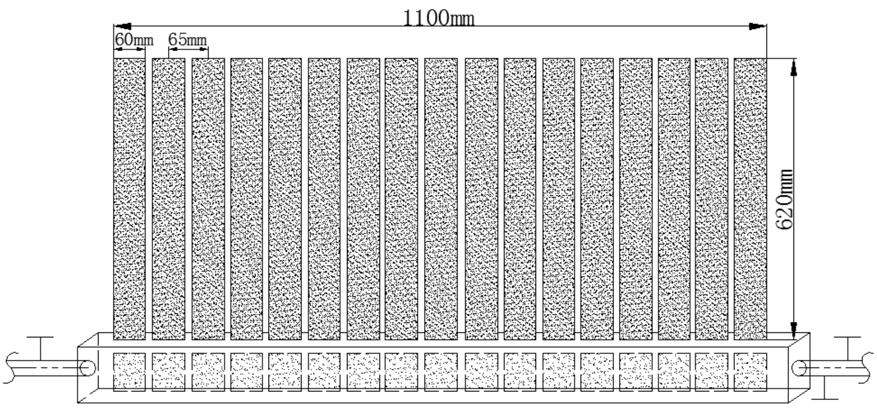
Heating terminal: In this experiment, the special micro heat pipe array radiator is used as the end device of the heating system, and the indoor heating system is composed of constant temperature water tank, circulating water pump, pipeline system and accessories. Through the convection and radiation of the special radiator, the indoor heating is realized. In this experiment, the micro heat pipe array radiator is mainly composed of two parts: micro heat pipe array and special shaped pipe, which is in contrast with the existing copper aluminum composite radiator (1150mm×635mm×80mm for upper supply and lower return on the same side), as shown in Figure 2 (a). The overall size of its heat dissipation surface is 1100mm×620mm×3mm. There are 17 micro heat pipe arrays in total, and the center distance of each is 65mm. The micro heat pipe array radiator is shown in Figure 2 (b). The size of single micro heat pipe array is 700mm×60mm×3mm (length×width×thickness), in which the length ratio of evaporation section to condensation section is 1:7.75, the length of evaporation section is 80mm, and the length of condensation section is 620mm. The micro heat pipe array is filled with R141b and acetone respectively, and the filling rate is 0.3 [2]. The micro heat pipe array is shown in Fig. 3 (a). The external dimension of the special shaped pipe is 1150mm×90mm×20mm (length × width × thickness), the internal dimension is 1100mm×80mm×10mm (length × width × thickness), and the internal diameter of the hot water inlet and outlet is Φ25mm, as shown in Figure 3 (b). In order to make the connection between the micro heat pipe array and the special shaped pipe reliable and the hot water does not leak, the special rubber gasket is used for tight connection in this experiment. The socket and rubber gasket of the micro heat pipe array are shown in Fig. 3 (c) and Fig. 3 (d), respectively. The parameters of the instrument and equipment selected in this experiment are shown in Table 1.




1-Constant temperature water tank; 2-Electric heater; 3-Control valve; 4-Cleaning inlet; 5-Special pipe; 6-Micro heat pipe array; 7-Copper/Constantan thermocouple; 8-Y filter; 9-Flow meter; 10-Circulating water pump; 11-Cleaning outlet; 12-Exhaust valve; 13-Data acquisition instrument; 14-Computer

**Fig 1.** The schematic diagram of the experimental system

(a) Existing copper aluminum composite radiator




(b) Micro heat pipe array radiator

**Fig 2.** Micro heat pipe array radiator and existing copper aluminum composite radiator

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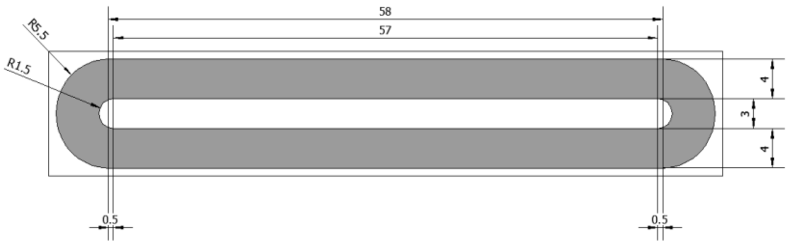
(a) Micro heat pipe array

(b) Special shaped pipe

(c) Socket of micro heat pipe array




(d) Special rubber pad

**Fig 3.** Components of the array radiator with micro heat pipe

**Tab 1.** Instrument and equipment parameters used in the experiment

| Name | Model | Range | Accuracy |
|---|---|---|---|
| Constant temperature water tank | DC-0506 | -5~100℃ | ±0.1℃ |
| Thermocouple | Copper / constantan thermocouple | -35~95°C | ±0.1℃ |
| Flowmeter | 316L | 0.1~10m/s | Level 0.3 |
| Circulating pump | FS32X25-11 | 0~4m3/h | Level1 |
| Data acquisition instrument | Agilent 34972A | 100mV`300V | 0. 004% |

## 2.2. Experimental Content

For the room with radiator, the main factors that affect the heating effect are: radiator cooling area, water supply temperature and water supply flow. In this experiment, in order to measure the surface temperature uniformity of the micro heat pipe array radiator and the existing copper aluminum composite radiator (upper supply and lower return on the same side), only the overall length and width of the two radiators are similar, and the effective heat dissipation area is not considered. Therefore, the factors that determine the surface temperature uniformity of the radiator under this condition are: water supply temperature and water supply flow. At the same time, in this experiment, the average test temperature of the room is only used to reflect the heat dissipation and temperature rise characteristics of the micro heat pipe array radiator filled with R141b and acetone respectively. According to code for design of heating ventilation and air conditioning of civil buildings (GB50736-2016), the temperature of heat medium of radiator with common radiator is 55-85℃, and the average economic velocity of heat medium is ≤1.2m/s. So the experimental conditions are designed as follows: the water supply temperature is 55℃, 65℃, 75℃, 85℃, and the water supply flow is 1050L/h, 1600L/h, 2200L/h (at this time, the water supply flow rate is about 0.6m/s, 0.9m/s, and 1.2m/s respectively). In order to study and analyze the temperature uniformity of the micro heat pipe array radiator in the plateau area, the experimental data of the micro heat pipe array radiator filled with R141b and acetone and the existing copper aluminum composite radiator were tested by two experimental methods of constant temperature and variable flow and constant flow and temperature.

## 2.3. Performance Evaluation Index

According to the required experimental data, different experimental conditions are set. After the operation state of different experimental conditions is stable, the operation lasts for 1h, during which the required experimental data are tested uninterruptedly. Each performance evaluation index is defined as follows:

1.3.1 The temperature uniformity of the micro heat pipe array radiator in the horizontal direction

$$\Delta T_{xx} = T_{x1} - T_{x2} \tag{1}$$

Where: $\Delta T_{xx}$ is the temperature difference between two horizontal points of the micro heat pipe array radiator, ℃; $T_{x1}$ is the temperature value of a certain upstream temperature measuring point of the micro heat pipe array radiator along the water flow direction, ℃; $T_{x2}$ is the temperature value of a downstream temperature measuring point at the same level as $T_{x1}$ temperature measuring point, ℃.

1.3.2 The temperature uniformity of the micro heat pipe array radiator in the vertical direction

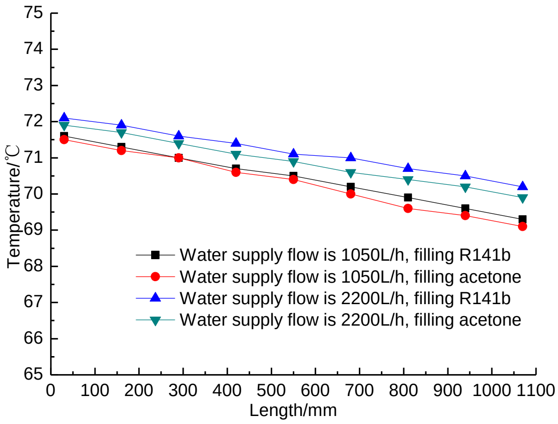
$$\Delta T_{yy} = T_{y} - T_{yy} \tag{2}$$

Where: $\Delta T_{yy}$ is the temperature difference between the evaporation section and a condensation section of the micro heat pipe array radiator in the vertical direction, ℃; $T_y$ is the temperature value of a certain evaporation section on the array radiator of micro heat pipe, ℃; $T_{yy}$ is the temperature value of a condensation section corresponding to $T_y$ evaporation section, ℃.

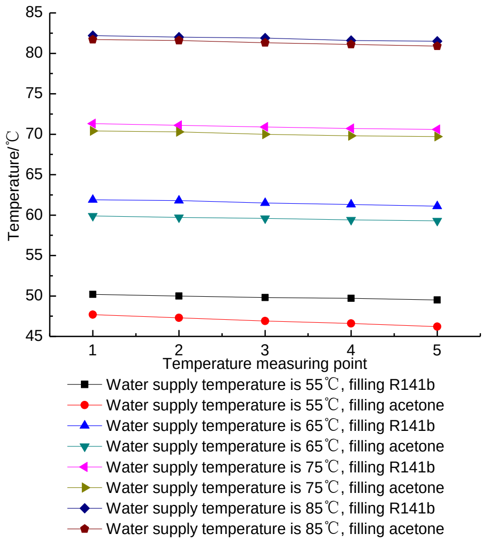
# 3. Experimental Results and Analysis

## 3.1. The Surface Temperature Uniformity of Micro Heat Pipe Array Radiator

In this paper, the temperature of water supply is 75℃, and the flow rate of water supply is 1050L/h and 2200L/h (the flow rate of water supply is 0.6m/s and 1.2m/s respectively). After the micro heat pipe array radiators filled with R141b and acetone respectively run stably, the temperature data of the two kinds of micro heat pipe array radiators in the horizontal direction are tested, and the surface temperature uniformity in the horizontal direction is analyzed. As shown in Fig. 4 (a), whether it is the micro heat pipe array radiator filled with R141b or the micro heat pipe array radiator filled with acetone, their surface temperature uniformity in the horizontal direction is good. The maximum temperature difference between the water supply temperature and the first surface temperature measurement point is only 3.5℃, and the maximum temperature drop in the horizontal direction is only 2.4℃. As shown in Figure 4 (b), the surface temperature uniformity of the micro heat pipe array radiator filled with R141b and acetone respectively in the vertical direction is also good. Except for the water supply temperature of 55℃, the maximum temperature drop in the vertical direction is only about 0.8℃, and the maximum temperature drop ratio is only 1.4%. Therefore, the micro heat pipe array radiator has good surface temperature uniformity.




(a)Temperature uniformity in horizontal direction

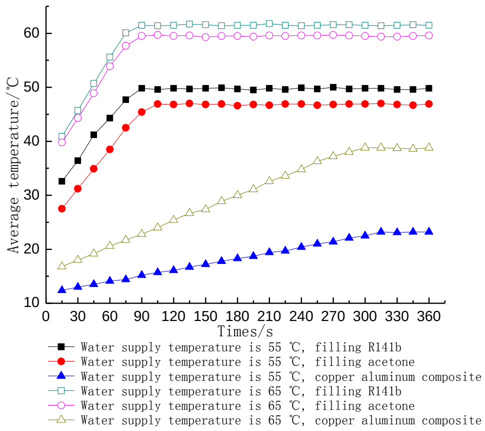



(b) Temperature uniformity in the vertical direction

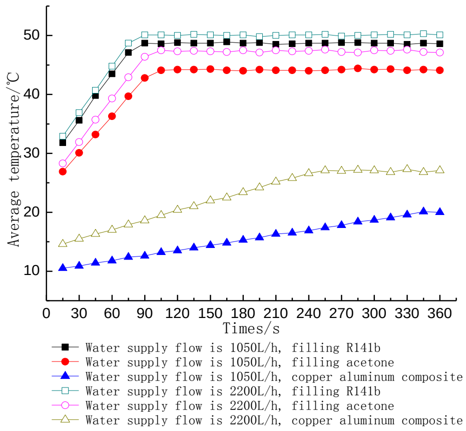
**Fig 4.** Surface temperature uniformity

## 3.2. Temperature Rise Performance Comparison

Considering that "scald" may occur due to the high surface temperature, the water supply temperature is set as 55℃ and 65℃, and the water supply flow is set as 1050L/h, 1600L/h and 2200L/h respectively. The average temperature of the three kinds of radiators was tested by changing the flow rate and temperature, and the relevant data from the start of operation to the stable surface temperature of the three kinds of radiators were collected, so as to compare the thermal response time required for the three kinds of radiators to reach the stable state, and analyze their temperature rise performance. As shown in Figure 5 (a), when the water supply flow is 1600L/h and the water supply temperature is increased from 55℃ to 65℃: The thermal response time of micro heat pipe array radiator is reduced from 90-100s to 80-85s, and the thermal response time of the existing copper aluminum composite radiator is reduced from about 315s to about 290s. So the thermal response time of the existing copper aluminum composite radiator is about 3.3-3.5 times of that of the micro heat pipe array radiator under the experimental conditions, and increasing the water supply temperature is conducive to reducing its thermal response time. As shown in Figure 9 (b), when the water supply temperature is 55℃, the water supply flow increases from 1050L/h to 2200L/h: The thermal response time of the micro heat pipe array radiator is between 90s and 120s, and that of the existing copper aluminum composite radiator is reduced from about 350s to about 260s. Therefore, under the experimental conditions, the thermal response time of the existing copper aluminum composite radiator is 2.2-3.9 times of that of the micro heat pipe array radiator, and compared with the water supply temperature, the water flow has a greater impact on its thermal response time. To sum up, whether changing the water supply temperature or water flow, the temperature rise performance of the micro heat pipe array radiator is better than the existing copper aluminum composite radiator (upper supply and lower return on the same side).




(a) The same flow and the different temperature




(b) The same temperature and the different flow

**Fig 5.** Temperature rise performance under different working conditions

## 4. Conclusion

(1) The micro heat pipe array radiator has good surface temperature uniformity. Under the experimental conditions in this paper, the maximum temperature drop of the micro heat pipe array radiator in the horizontal direction is only 2.4℃, and the maximum temperature difference between the water supply temperature and the first surface temperature

measurement point is only 3.5℃; The maximum temperature drop in the vertical direction is only about 0.8℃, and the maximum temperature drop ratio is only 1.4%.

(2) Under the condition of different water supply temperature and flow rate, the thermal response time of the micro heat pipe array radiator is far lower than that of the existing copper aluminum composite radiator. When the flow rate of water supply is 1600L/h and the temperature of water supply is raised from 55℃ to 65℃, the thermal response time of copper aluminum composite radiator is 3.3-3.5 times of that of micro heat pipe array radiator. When the temperature of water supply is 55℃ and the flow rate of water supply is increased from 1050L/h to 2200L/h, the thermal response time of copper aluminum composite radiator is 2.2-3.9 times of that of micro heat pipe array radiator.

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