# A COMPOSITE SYSTEM OF AIR CONDITIONING AND HEAT PIPES Promising Application to Outdoor Communication Cabinet

by

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*High energy consumption is an increasingly serious problem for air conditioners in mobile communication base stations, and a composite system of the air conditioning and the heat pipe is proposed to solve the problem. The experimental data obtained in Zhengzhou City elucidated the high efficiency in energy saving. The system offers a new opportunity for wide applications in outdoor communication cabinets.*

Key words: *air conditioning heat pipe composite technology, energy saving, base station*

## Introduction

With the extremely rapid development of communication technology, its coverage has become more and more widespread. China communications industry has also gradually shifted from the short message service and the call service to more diversified business, and mobile internet applications are becoming more and more widespread [1]. According to 2021 *China Internet Development Report* issued by *China Internet Association*, [2] by 2020, China had 5.75 million 4G base stations, with a total of 9.31 million communication base stations nationwide, and the market size of China Internet Data Center industry reached 195.8 billion yuan in 2020, and an even rapid development is predicted in the coming years. At present, the high power-consumption of communication equipment and cooling system has become the biggest obstacle, it accounts for more than 70% of the total energy consumption of communication. Due to the increasing number of equipment and its gradually increasing power, which leads to excessive air conditioning load and higher energy consumption, the energy consumption of base stations has become one of the hot spots in the field of communication [3], and promotes the nanofluid technology for enhancing heat conduction [4-8], fiber optical communication [9], and cloud computing [10-14].

In order to solve the problem of excessively high energy consumption in outdoor base stations, scientists have conducted extensive technical research. Ma *et al*. [15] developed a prototype for the air-air thermosyphon heat exchanger. He *et al*. [16] studied the impact of fin-column water-cooled heat sinks in data center server CPU chip cooling technology and found the optimal fin-column height and diameter. Wu *et al*. [17] studied the heat pipe vapor compression air conditioner. Wang [18] developed a high-efficiency axial flow base station

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air conditioner and designed a new indoor rack and air supply system to analyze the energy efficiency of the temperature field and airflow organization. Zhang *et al*. [19] analyzed the effect of liquid filling rate on the performance of micro-channel separated heat pipes for base stations and the optimal range of liquid filling rate for different air volumes and different outdoor temperatures. Wei *et al.* [20] studied the heat pipe plus storage cooling passive heat dissipation system of a communication base station through a mathematical modeling model and analyzed the influence factors of the heat dissipation system. Hao *et al*. [21] studied the performance of separated heat pipe heat exchanger, and revealed the characteristics of the heat pipe heat exchanger and the heat exchanger energy efficiency ratio. Wang *et al*. [22] proposed a heat pipe air conditioning system that can achieve secondary recovery of heat using heat pipes with a more obvious energy saving advantage.

The cited literature concluded that the use of cooling system can reduce the temperature of communication equipment and heat dissipation, which can make the base station communication equipment operated stably with a high energy consumption. The use of heat pipe technology with using natural outdoor cooling source can achieve the purpose of energy saving, however, the technology subjects to outdoor temperature control. In the research of heat pipe and cooling system, many studies on energy saving of the composite technology for cooling systems were conducted for outdoor mobile communication base stations, however, most of them only analyzed theoretical feasibility which leads to lack of practical analysis on actual operation. In this paper, a composite system of air conditioning and heat pipes is applied to the communication outdoor cabinet, and the problem of high energy consumption of heat dissipation of communication equipment inside the outdoor base station is analyzed by the actual measurement data.

## The composite system of air conditioning and heat pipes

The composite system of air conditioning and heat pipes is a new energy-saving cooling system which integrates the separation heat pipe technology and the air conditioning cooling technology to complement each other's merits. It has two modes: single heat pipe mode and heat pipe plus air conditioning composite mode. The technology is specific targeted and well suited for outdoor base stations which need to be cooled all year round.

As shown in fig. 1, the composite technology for air conditioning heat pipes includes refrigerant circulation unit, closed air system unit, heat pipe circulation unit and control system unit. In winter and seasonal changed period, when the outdoor temperature is low, and the temperature sensor of base station detects the temperature higher than 30 °C and lower than 45 °C, a single heat pipe work mode is applied. The heat pipe system and wind system start to operate for utilizing the natural outdoor air-cooling source to complete the natural heat exchange of the heat pipe, and to take the cabinet heat away. That reduces the power consumption of air conditioning and improves the operating reliability of the compressor, in the same time, the wind system uses a closed loop system to ensure a clean environment inside the cabinet, which greatly reduces the cost of filtration in the base station. In summer, when the outdoor temperature is high, and the temperature is higher than 45 °C, the heat pipe plus air conditioning composite work mode is applied. The cooling cycle, heat pipe cycle and wind system units work together. The heat pipe system takes the priority, and the cooling cycle system supplies the insufficient cooling capacity to reduce the usage of air conditioning and the power consumption of the base station in summer. That could guarantee the service life of the base station compressor.

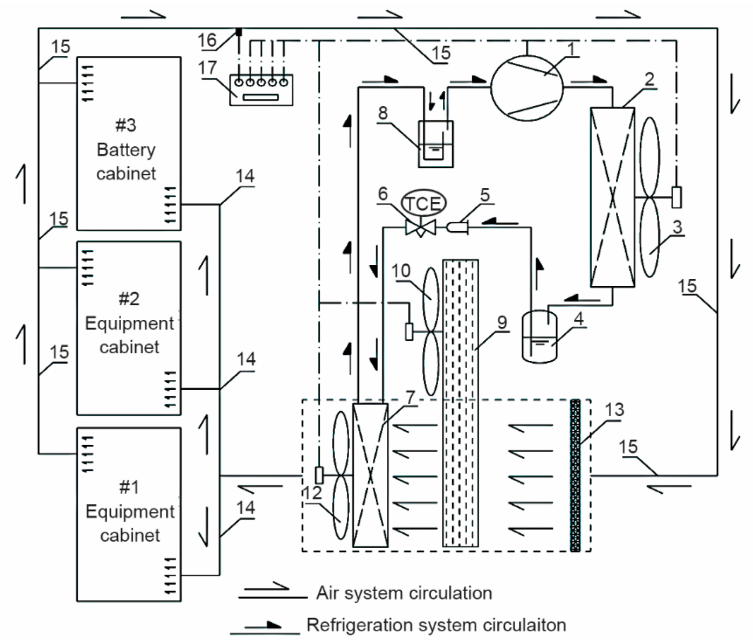


**Figure 1. The composite system of air conditioning and heat pipes;** *1 – refrigeration compressor, 2 – condenser, 3 – condensing fan, 4 – reservoir, 5. – filter drier, 6 – expansion valve, 7 – evaporator, 8 – gas-liquid separator, 9 – heat pipe, 10 – heat pipe cold end fan, 11 – equipment integrated box, 12 – duct fan, 13 – filter dust screen, 14 – feed air duct, 15 – return air duct, 16 – temperature sensor, and 17 – regulator*

## Efficiency analysis of practical applications

Figure 2 shows a centrally placed equipment for a triplex cabinet system. The test was conducted in Zhengzhou City, China, the ambient temperature of base station cabinet was set 40 °C and the base station equipment was guaranteed to operate normally. This paper uses data from September 2021 to August 2022, which includes three periods: summer June to August, September to November and March to May are seasonal changed period, and winter December to February. Conducting a comparison test with the unmodified communication base station, the selected area of the communication base station envelope and outdoor environment should be as similar as possible to reduce the impact of external factors.

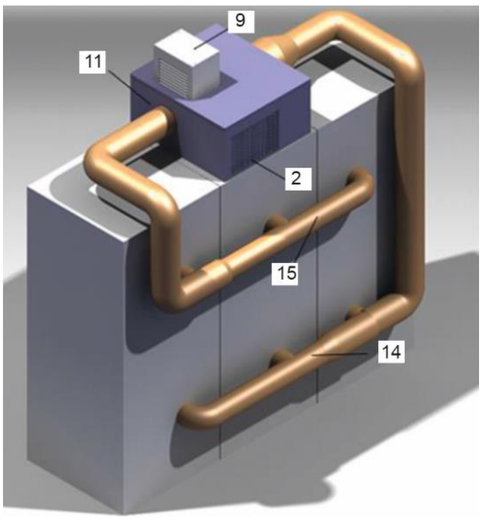

**Figure 2. System structure appearance**

Figure 3 presents the effect of the energy saving rate of the air conditioning heat pipe composite system with the change of outdoor temperature in summer. As can be seen from fig. 3, the energy saving rate of the base station gradually decreases with the increase of outdoor temperature in summer from 23 °C to 35 °C, especially when the outdoor temperature is greater than 25 °C, the energy saving rate decreases rapidly, and the energy saving rate decreases from 67.6% to 22.6% with the temperature difference of just 12 °C outdoor and the average energy saving rate in summer is calculated as

40.6%. Its reason is that the temperature is higher in summer, the system uses the air conditioning + heat pipe linkage operation mode. First of all, the base station achieves the initial cooling of the return air through the heat pipe heat exchanger, and then achieves the second cooling of the return air through the closed-cycle unit evaporator. The heat transfer coefficient of heat pipe heat exchanger is related to the outdoor temperature. With the outdoor temperature increasing, the heat pipe heat transfer rate decreases, which could not reach the working temperature in the base station. Then, the air conditioning and refrigeration system start to work, the power consumption increases and its base station energy saving rate gradually decreases.

Figure 4 shows the effect of the energy saving rate of the air conditioning heat pipe composite system with the change of outdoor temperature in spring. In fig. 4, it can be seen that the energy saving rate decreases in different degrees as the outdoor temperature increases in spring from 7 ℃ to 20 ℃, between 7 ℃ and 18 ℃, the energy saving rate of the base station decreases gently, however, all of them are above 70%. Between 18 ℃ and 20 ℃, the energy saving rate of the base station decreases rapidly, and the energy saving rate reaches 66.8% when the outdoor temperature is 20 ℃. The average energy saving rate in spring is 68.6% according to the comprehensive analysis. The reason of it is that the outdoor temperature is lower in spring and the temperature inside the cabinet is higher. The system uses heat pipe + air conditioner in parallel operation mode, and when the return air cooling is completed through the heat pipe heat exchanger, the temperature difference between the outdoor temperature and the temperature inside the cabinet is larger, thus, the heat pipe heat exchange rate is larger.

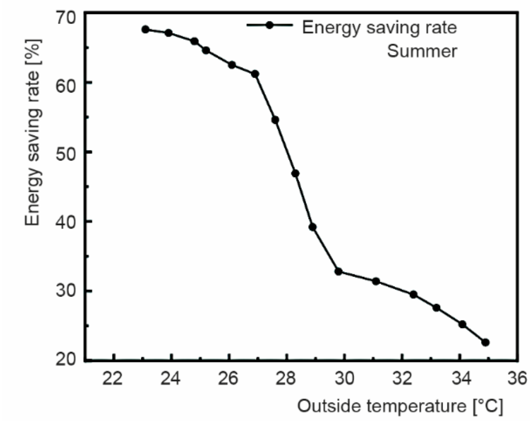


**Figure 3. Relation between outdoor temperature and energy saving rate in summer**

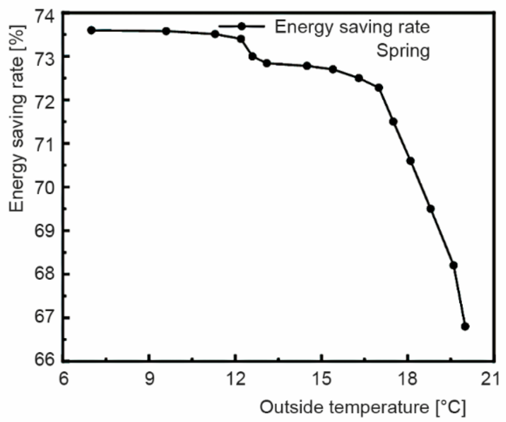


**Figure 4. Relation between outdoor temperature and energy saving rate in spring**

Figure 5 shows the effect of the energy savings rate of the air conditioning heat pipe composite system as the outdoor temperature changes in the fall. As can be seen in fig. 5, the energy saving rate of the base station decreases in varying degrees as the outdoor temperature increases in autumn from 12 °C to 28 °C. The energy saving rate is above 67% when the outdoor temperature is from 12 °C to 20 °C. After the outdoor temperature is greater than 25 °C, the energy saving rate of the base station decreases significantly to 17.8% when the outdoor temperature is 27.6 °C. The average energy saving rate in autumn is 60.2%. The reason of it is that when the outdoor temperature is lower than 25 ℃, the base station can cool down the initial return air through the heat pipe first, which greatly improves the energy-saving efficiency of the base station. When the outdoor temperature is greater than 25 ℃, the heat pipe's efficiency decreases which is affected by the temperature difference. In the meantime, the energy-saving rate of the base station also decreases significantly.

Figure 6 shows the effect of the energy saving rate of the air conditioning heat pipe composite system with the change of outdoor temperature in winter. As can be seen in fig. 6, the energy saving rate of the base station gradually decreases as the outdoor temperature increases in winter from –2 ℃ to 18 ℃, but the energy saving rate of the base station is above 66% in all cases, and the energy saving rate of the base station reaches more than 95% in winter when the outdoor temperature is at 0 ℃, which is calculated to be 74.1% on average in winter. The reason for the high energy saving rate in winter with air conditioning heat pipe composite technology is the use of a single heat pipe operation mode. By using the air outside the base station cabinet as a natural cooling source, the lower outdoor temperature in winter helps to achieve efficient heat dissipation from the base station, substantially improving the energy saving rate of the base station.

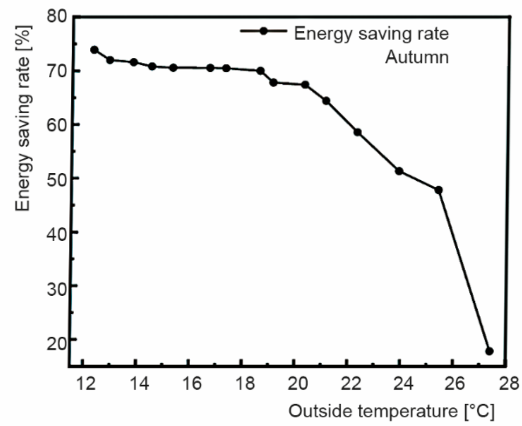


**Figure 5. Relation between outdoor temperature and energy saving rate in autumn**

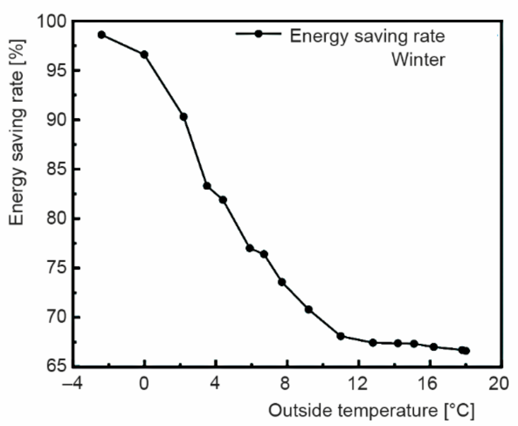


**Figure 6. Relation between outdoor temperature and energy saving rate in winter**

## Analysis of applicability by region

In order to study the applicability of air conditioning heat pipe composite technology in various regions of China, the areas involved in the study were classified by thermos-technical calculation. Changsha is selected as the hot summer and cold winter area, Nanning is selected as the hot summer and warm winter area, Guiyang is considered as mild area. Cold areas with the lower temperature, base station requires air conditioning heating when using heat pipe technology, which lead to excessive power consumption. Hence, the heat pipe air conditioning composite technology applicability analysis does not consider cold areas. For the energy saving analysis of the same type of communication outdoor base stations in three representative cities using air conditioning heat pipe composite technology, the DEST software is applied to find out the annual hourly meteorological temperature of Zhengzhou and the typical annual hourly meteorological temperature of the three representative cities. According to the annual hourly temperature of the representative cities, we can get the usable time of the heat pipe thermal management system, as shown in fig. 7. Figure 7 shows the distribution of each representative city below and higher than 25 ℃, the outdoor temperature of Zhengzhou is lower than 25 ℃ accounting for 81.2%, Nanning is lower than 25 ℃ accounting for 60.3%, Changsha is lower than 25 ℃ accounting for 72.5%, and Guiyang is lower than 25 ℃ accounting for 97.7%.

Three representative cities energy saving rate comparing with Zhengzhou's communication base station energy saving rate, as shown in fig. 8. The communication base station air conditioning heat pipe composite system in cold region reaches to 60.8% of annual energy saving rate in hot summer and cold winter region, Changsha annual energy saving rate reaches to 56.6%. In hot summer and warm winter region, Nanning's annual energy saving rate is 51.9%, in mild region, Guiyang annual energy saving rate is 63.5%. The air conditioning heat pipe composite system in cold region is not considered due to the heat pipe mode requires air conditioning heating with low regional temperature.

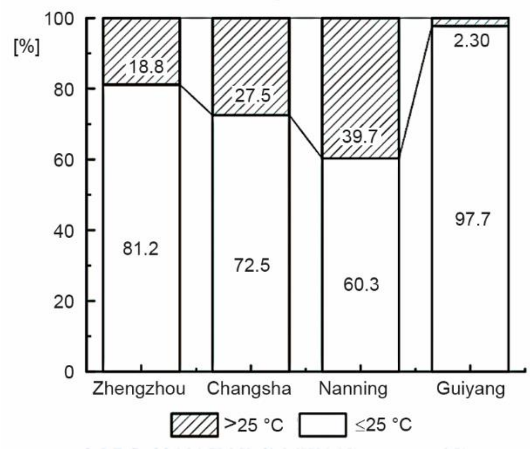


**Figure 7. Proportion of annual temperature in four cities**

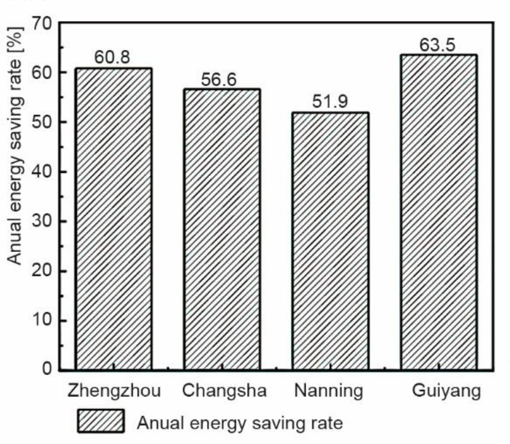


**Figure 8. Comparison of annual energy saving rates in four cities**

## Conclusions

The actual data analysis of the communication outdoor cabinet with air conditioning heat pipe composite technology was carried out, and the energy-saving impact of the system was tested under different outdoor temperature conditions throughout the year, as well as the applicability analysis in various regions of the country, and the following main conclusions were drawn.

- Comparing with the traditional base station air conditioning, Zhengzhou uses air conditioning heat pipe composite technology to improve the energy-saving effect of the base station. With the decreasing of outdoor temperature, the energy-saving rate increases significantly, especially in winter. The energy-saving rate in spring, summer, autumn and winter is 68.6%, 40.6%, 60.2%, 74.1%, respectively, thus, the system has a significant energy-saving effect.
- The applicability analysis of the system is carried out in different parts of the country according to the thermal zone. The annual average energy saving rate in cold region, hot summer and cold winter region, hot summer and warm winter region and mild region is 60.8%, 56.6%, 51.9%, and 63.5%, respectively. In cold region, due to the low outdoor

temperature, the system is not considered. It is worth promoting in the market. In the next step, the optimization of the composite system will be carried out, and field tests will be carried out in cold regions to further improve the applicability and economy of the system.

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