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The applied effect analysis of heat exchanger installed in a typical communication base station in Beijing of China

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Abstract

The high electric power consumption of air conditioning in communication base station needs to be solved urgently. This paper presents a new technology to discharge excess heat from a communication plant by utilizing the heat exchanger when the outdoor temperature is low enough. Then it compares the applied effects between two types of heat exchanger in a typical base station located in Beijing of China. It is found that this technology is feasible in Beijing of China. The plate heat exchanger can cool the station instead of air conditioning for about 5014 hours each year, and the corresponding electronic power saving rate reaches up to 29%. The plate heat exchanger applied effects are superior to the heat pipe heat exchanger.

*Keywords:*Heat exchanger; Air conditioning; Communication base station; Electric power saving;

1. Introduction

Communication base station is an important component of communication system. The indoor temperature, humidity and cleanliness not only have a direct influence on the reliable running and the service life of communication equipments, but also relate on the smooth and secure conduction of communication system. "The regulation of China communication mobile power supply and air-conditioning maintenance" rules that "the indoor temperature and relative humidity in communication base station should be separately maintained in the range of 10～30℃ and 15%～80%".

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Nomenclature

Q_c the heat exchanger capacity of the heat exchanger (W)

C_p the air specific heat at constant pressure (J kg^{-1} K^{-1})

G the air mass flow (kg s^{-1})

t_{h1} the inlet temperature of hot air (K)

t_{c1} the inlet temperature of cold air (K)

η the sensible heat exchange efficiency (%)

t_{h2} the outlet temperature of hot air (K)

P_a the annual electric power consumption of the air conditioning running independently (kWh)

P_h the annual electric power consumption of the air conditioning combined with the heat exchanger (kWh)

η_e the annual electric power saving rate (%)

The high heat dissipating capacity and high running load of communication equipments in the base station lead to the cooling load existing even if in winter, so the air conditioning would continually run to remove the extra heat [1], which brings a higher electricity bills.

However, when the outdoor temperature is lower, the cold energy of outdoor air can be utilized to cool the base station so as to cut running time of air conditioning and reduce electricity expenses [2].

The paper firstly presents the performance parameters of the two energy recycle equipments having been researched——plate heat exchanger and heat pipe heat exchanger, then analyses the annual cooling load of the base station, the serviceable time, electric power saving capacity and electric power saving rate when the two equipments applied in a typical communication base station in Beijing of China.

2. The heat exchanger

2.1. The working principle

Fig. 1. The working principle of heat exchanger applied in a base station

The working principle of air to air heat exchanger applied in a base station was shown in Fig. 1, both the outdoor air (the cold air) and the indoor air (the hot air) enters into the air to air heat exchanger, the heat transfers from outdoor air to the indoor air in the heat exchanger, after that, the outdoor air will be discharged to outside, and the indoor air will be sent into the room. For the two kinds of air are isolated, the cleanliness of base station will not be influenced. When the outdoor temperature is too high to cool, the air conditioning would start.

2.2. The performances

The authors had carried out the theoretical and experimental studies of the performances of both the plate heat exchanger and heat pipe heat exchanger [3]. The main performances of the two kinds of heat exchangers are shown in Table 1.

Table 1 The main performance parameters of the heat exchangers

	Rated airflow (m^3 h^{-1})	Total power (W)	The sensible heat exchange efficiency (%)
The plate heat exchanger	1680	600	55
The heat pipe heat exchanger	1000	400	76

3. The applied effects

3.1. The overview of a typical base station

The base station is located in Beijing of China. The building area is 25 m^2, and the floor height is 3.6 m. There are very few people in the room. The indoor temperature is set at 28℃, and the heat dissipating capacity of indoor equipment is 1200 W. The exterior envelope is insulated with expansion perlite, and its heat transfer coefficient is 0.753W/(m • K). the roof is insulated with aerated concrete, its heat transfer coefficient is 0.812 W / (m • K). An air conditioning with the rated refrigerating capacity for 7 kW is equipped in the base station. The lighting power is 30W.

3.2. The annual cooling load in the base station

The main electric power consumption equipment in the base station is the air conditioning. However, the power consumption of the air conditioning is related to the cooling load, which depends on the weather conditions, the thermal characteristics of building envelope, the internal heat source, etc. The whole year hourly dynamic cooling load of the typical base station has been calculated by using DEST(designer's simulation toolkits) developed by Tsinghua university. After date processing, the monthly average cooling load of communication base station and the monthly average outside air temperature in Beijing are shown in Table 2. As shown in Table 2, the average cooling load of each month is greater than zero even if the outside air temperature is very low. So we can conclude that the air conditioning needs to run for most of the time.

Table 2 The average cooling load of communication base station in Beijing

Months	1	2	3	4	5	6	7	8	9	10	11	12
Average cooling load (kW)	0.41	0.59	1.38	2.01	2.44	2.77	3.03	2.97	2.38	1.90	1.21	0.68
Average outside air temperature (K)	-3.83	-1.53	7.66	14.36	19.35	24.49	26.44	25.63	20.41	12.95	5.41	-0.47

3.3. The serviceable time of the heat exchangers a year

The heat transfer capacity of a heat exchanger depends on the difference between indoor and outdoor air temperature. Therefore, the proper outdoor temperature range at which a heat exchanger can start to cool should be calculated first, then the number of hours a year in this working temperature range in Beijing could be calculated, which is the serviceable time of the heat exchangers a year.

The upper temperature limits for the heat exchangers. By analyzing the hourly dynamics cooling load calculated by DEST, there are an outdoor temperature and a building cooling load corresponding to an hour. The heat exchanger capacity equation of the heat exchanger is shown in Eq.1:

$$Q_c = C_p \times G \times (t_{h1} - t_{c1}) \times \eta \qquad (1)$$

If the building cooling load is equal to the heat exchanger capacity of the corresponding moment, the outdoor temperature of this moment is the maximum temperature for the heat exchanger to cool instead of the air conditioning. The upper temperature limits for the plate heat exchanger and the heat pipe heat exchanger are respectively 19 ℃ and 18 ℃.

- The lower temperature limits for the heat exchangers
  When the air flow is constant, the outlet indoor air temperature will reduce with the outdoor air temperature reducing. In order to ensure that the air supply temperature is above the dew point temperature of indoor air, the outdoor inlet air temperature must be higher than a certain value, which is the lower temperature limit for the heat exchanger. Supposed that the indoor air temperature is 21℃, the relative humidity is 40%, so the dew point temperature of indoor air is 6.9 ℃. Then according to the sensible heat exchange efficiency equation (shown in Eq.2) calculate the minimum inlet outdoor air temperature t_{c1}.

$$\eta = \frac{t_{h1} - t_{h2}}{t_{h1} - t_{c1}} \qquad (2)$$

  When the inlet temperature of hot air (t_{h1}) is 21℃, the outlet temperature of hot air (t_{h2}) is 6.9 ℃, according to Eq.2, the minimum inlet outdoor air temperatures (t_{c1}) for the plate heat exchanger and the heat pipe heat exchanger are respectively -4.64℃ and 2.45℃.
- The serviceable time
  By analyzing Beijing meteorological data, the serviceable time of the plate heat exchanger (-4.64℃< outdoor air temperature<18℃) is 5014 hours, and the serviceable time of the heat pipe heat exchanger (2.45℃<outdoor air temperature<19℃) is 3307 hours.

3.4. Energy saving analysis

This section will calculate the electric power consumption before and after installed the heat exchanger, and then comparatively analyze the electric power saving effects when installed the two types of heat exchanger.

- Methodology
  Firstly, calculate the annual electric power consumption of the air conditioning running independently according to Eq.3.

$$P_a = \sum_{\tau=1}^{8760} \text{the electric power of air conditioning} \times \frac{\text{the hourly cooling load}}{\text{the refrigeration capacity}} \quad (3)$$

  Secondly, calculate the annual electric power consumption of the air conditioning combined with the heat exchanger. P_h is equal to the sum of the electric power consumption of air conditioning and heat exchanger.
  Finally, calculate the annual electric power saving rate η_e according to Eq.4.

$$\eta_e = \frac{P_a - P_h}{P_a} \times 100\% \quad (4)$$

- Summary
  According to the methodology and the hourly cooling load, the annual cooling electric power consumption of the base station before and after installed the heat exchanger has been calculated and analyzed, the annual electric power saving effects has also been analyzed. Table 3 and Table 4, respectively, show the electric power consumption before and after installed the plate heat exchanger and the heat pipe heat exchanger in the communication base station in Beijing. The annual electric power saving, annual electric power saving rate and the corresponding comparisons of two types of heat exchanger are shown in Table 5. The heat exchanger applied effects in the communication base station in Beijing are remarkable, the annual electric power saving rate is more than 23%, and the applied effects of the plate heat exchanger are superior to heat pipe heat exchanger.

Table 3 The electric power consumption when installed the plate heat exchaners

Mode of operation	t_{c1} (℃)		Total cooling load (kW)	Rated refrigeration capacity (kW)	The electric power (kW)	P_a/P_h (kWh)
Air conditioning running	—		15944.7	7	2.5	5694.6
Plate heat exchanger combined with air conditioning	Air conditioning running	$t_{c1}<-4.64$, and $t_{c1}>19$	8928.0	7	2.5	3188.6
	Plate heat exchanger running	$-4.64<t_{c1}<19$	7016.7	$Q_c = C_p \times 1680 \times (t_{h1} - t_{c1}) \times 55\%$	0.6	857.0

Table 4 The electric power consumption analysis of applied the heat pipe heat exchaners

Mode of operation	t_{c1} (℃)		Total cooling load (kW)	Rated refrigeration capacity (kW)	The electric power (kW)	P_a/P_h (kWh)
Air conditioning running	—		15944.7	7	2.5	5694.6
Heat pipe heat exchanger combined with air conditioning	Air conditioning running	t_{c1}<2.45, and t_{c1}>18	10480.2	7	2.5	3742.9
	Heat pipe heat exchanger running	2.45<t_{c1}<18	5464.5	$Q_c = C_p \times 1000 \times (t_{h1} - t_{c1}) \times 76\%$	0.4	638.1

Table 5 The comparisons of electric power saving effect applied the two types of heat exchangers

	The electric power consumption in air conditioning mode(kWh)	The electric power consumption in the mode of air conditioning combined with heat exchanger (kWh)	Annual electric power saving (kWh)	Annual electric power saving rate (%)
Installed the plate heat exchanger	5694.6	4045.7	1648.9	29.0%
Installed the heat pipe heat exchanger	5694.6	4381.1	1313.5	23.1%

4. Conclusions

According to the analysis above, in Beijing city, the applied effects of both the plate heat exchanger and the heat pipe heat exchanger are good. Due to the serviceable time of the plate heat exchanger is longer than the heat pipe heat exchanger, the energy saving rate of the plate heat exchanger is higher. The plate heat exchanger can cool the station instead of air conditioning for about 5014 hours each year, and the corresponding electronic power saving rate reaches up to 29%. For Beijing is a typical city of cold region in China, it can be conclude that the technology of heat exchanger applied in the base station in cold region of China to cool is feasible.

Acknowledgements

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