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Performance optimization of a hybrid cooler combining vapor compression and natural circulation cycles

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ABSTRACT

A hybrid cooler combining vapor compression and natural circulation cycles was developed for the cooling of telecommunication equipment in the cabinet-type base station of mobile communication. This hybrid cooler normally operates in the vapor compression mode at high ambient temperatures, but works in the natural circulation mode at low ambient temperatures by the thermosiphon principle. The performance of the hybrid cooler was measured according to the refrigerant charge, outdoor temperature, heat exchanger geometry, and the vertical distance between the condenser and the evaporator. The optimum design conditions for these variables are discussed with respect to the performance of the hybrid cooler in both operating modes. The difference in the optimum refrigerant charge between the two operating modes was solved by installing a liquid receiver. The temperature difference between the indoor and ambient air was introduced as a control parameter for use when changing the operating mode.

Optimisation de la performance d'un refroidisseur hybride alliant les cycles à compression de vapeur et les cycles à circulation naturelle

Mots clés : Refroidissement ; Composant ; Électronique ; Télécommunication ; Système frigorifique ; Système à compression ; Thermosiphon ; Expérimentation

1. Introduction

The rapid performance enhancement of electronic components has increased the amount of heat generation per unit area of electronic devices. In addition, since the electronic devices used in mobile communication are vulnerable to dust and humidity, a cabinet-type base station, which is generally located outdoors, should be tightly sealed and insulated from ambient

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Nomenclature

DB	dry bulb temperature (°C)
EER	energy efficiency ratio
m	mass (kg)
NC	natural circulation
OD	outside diameter (mm)
Q	cooling capacity (W)
RH	relative humidity (%)
T	air temperature (°C)
VC	vapor compression
W	power consumption (W)
x	quality (%)
ΔH	vertical distance between evaporator and condenser (mm)
ΔT	temperature difference between indoor and ambient air (°C)

Subscripts

a	actual
comp	compressor
e	evaporator
fan	fan
i	indoor
l	liquid
o	outdoor, ambient
v	vapor

air. Therefore, ambient air cannot be used directly to cool telecommunication equipment located inside the base station in the winter season even though the temperature is significantly lower than the indoor temperature of the base station. Therefore, for the cooling of the telecommunication equipment in the cabinet-type base station of mobile communication, a hybrid cooler combining vapor compression (VC) and natural circulation (NC) cycles was developed. The refrigerant flow in the natural circulation cycle is produced by the temperature difference between the indoor and ambient air without the operation of a compressor, and this type of refrigerant flow yielded high performance and reliability of the system in the winter season. However, proper system optimization between the vapor compression and the natural circulation cycle are essential for developing a high efficient hybrid cooler used in the cabinet-type base station of mobile communication.

Fig. 1 shows the schematic diagram of a hybrid cooler. The hybrid cooler has two operating modes of vapor compression and natural circulation. The hybrid cooler normally operates in the vapor compression mode in the summer season. The compressor circulates the refrigerant through a condenser, an expansion valve, and an evaporator. The evaporator absorbs the heat from hot indoor air. The heat is rejected to the ambient in the condenser. On the other hand, the natural circulation mode activates when the ambient air temperature becomes lower than a certain limit. The optimum temperature limit activating the mode change from vapor compression to natural circulation can be determined by comparing the actual cooling capacity with the design value. The natural circulation cycle, which consists of an evaporator, a riser, a condenser, and a downcomer, is based on the closed loop two-phase thermosiphon principle. It should be noted that the condenser is located at higher elevation than the evaporator. The terms ''riser'' and ''downcomer'' describe the flow direction through the connecting pipes in the natural circulation mode. The loop flow in the natural circulation mode is driven by the thermally generated density gradient between the condenser and the evaporator, generating a continuous unidirectional flow in the system. The application of the natural circulation cycle to the hybrid cooler can increase system performance and reduce the possibility of compressor failure at low ambient temperatures.

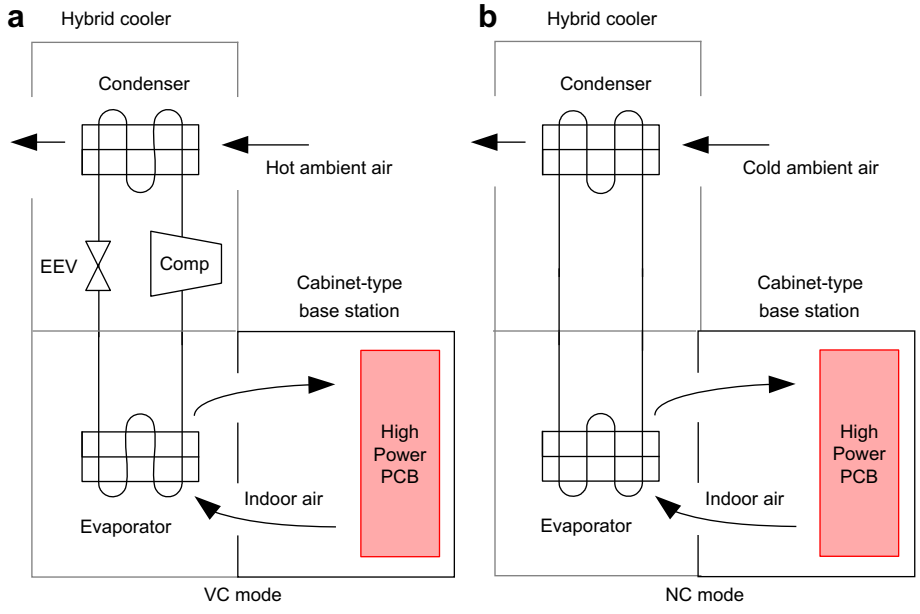

Fig. 1 – Schematic diagram of the hybrid cooler.