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EXPERIMENTAL STUDY ON A NOVEL HYBRID COOLER FOR THE COOLING OF TELECOMMUNICATION EQUIPMENTS

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ABSTRACT

A hybrid cabinet cooler, which has operating modes of vapor compression and natural circulation, is designed for the cooling unit of an outdoor telecommunication system. The performance of the system in the both operating modes was measured by varying refrigerant charge and operating conditions. Since each operating mode shows different optimal charges, it is required to control refrigerant charge amount based on the mode change. The natural circulation cycle yielded approximately 95% of cooling capacity of the vapor compression cycle. The instability of the natural circulation cycle was observed, which should be considered as an important design parameter.

1. INTRODUCTION

The rapid development of electronic components increased the heat dissipation of electronic devices. The high density integrated technology can not be applied without solving the heat dissipation problem. Therefore electronic devices need cooling devices to dissipate high heat fluxes effectively. Similarly, a hybrid cooler was developed for the cooling of mobile equipments in a cabinet. The mobile equipments include the systems for CDMA, PCS, and other wireless communications. The hybrid cooler was designed to work at two operating modes by using cold ambient air. The electronics, which are vulnerable to dust and humidity, can not be exposed directly to the cold ambient air. Therefore, the ambient air can not be directly used in the cooling of the electronic components. The cabinet cooler normally operates in the vapor compression mode. However, when the ambient air temperature becomes lower than a certain limit, the cabinet cooler works in the natural circulation mode in which the working fluid is naturally circulated due to the temperature difference between the indoor and outdoor of the cabinet without operating the compressor.

Figure 1 represents a schematic of the hybrid cabinet cooler. For the vapor compression mode, a compressor circulates the refrigerant flow through a condenser, a TXV, and an evaporator. The evaporator absorbs the heat generated from the electronic components during the evaporation process. The heat is rejected to the ambient in the condenser. On the other hand, the natural circulation mode activates when the ambient temperature is relatively low. The natural circulation cycle works based on the thermosyphon principle. For the natural circulation mode, the working fluid is circulated by the density difference between the vapor and the liquid. Therefore, no external power is needed for the fluid transport. The liquid flows from the condenser to the evaporator by using gravity force. The only necessary requirement is that the evaporator must be located below the liquid level in the condenser. The application of the hybrid cooler can save the energy and reduce the possibility of compressor failure for the cooling at low ambient temperatures.

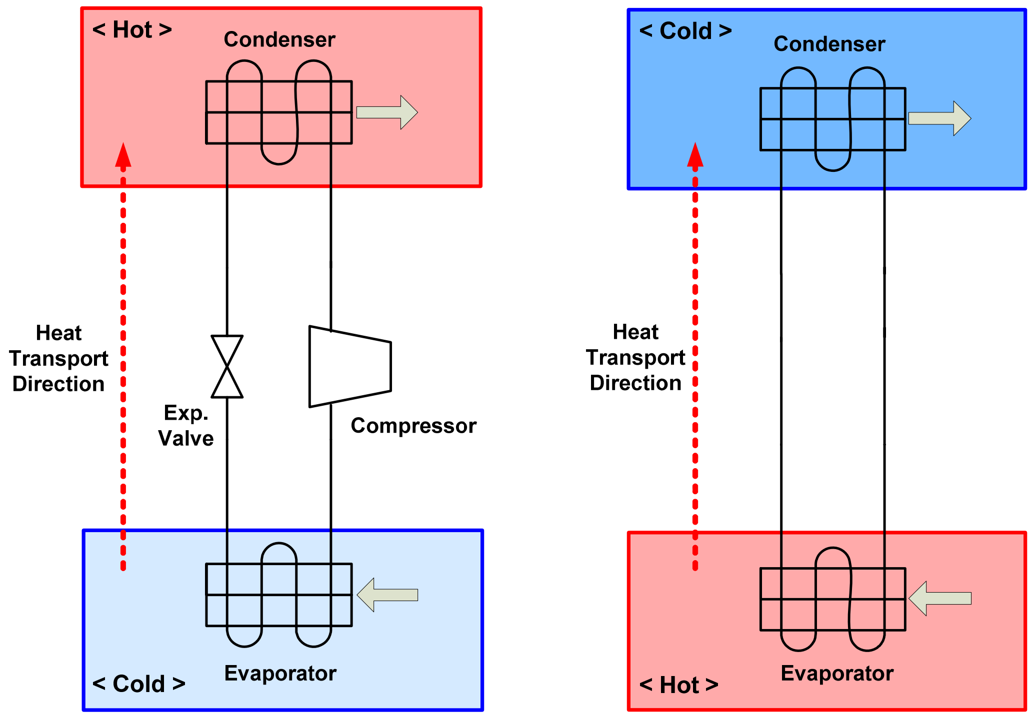


Figure 1 : Schematic of hybrid cooler.

The objective of this study is to investigate the performance of the hybrid cooler in accordance with the refrigerant charge, vertical distance between the condenser and the evaporator, and outdoor temperature. After presenting some design considerations in the hybrid cooler, experimental evaluations were carried out and then a field test was performed.

2. EXPERIMENTS

2.1 Hybrid Cooler

There are some design considerations for the proper operation in the natural circulation mode. The condenser was installed in the upper part of the cabinet, while the evaporator was located in the lower part. In addition, it was necessary to minimize the pressure loss in the tube circuit because there was no external work input in the natural circulation mode. Therefore, the main path of working fluid was designed for the natural circulation mode without passing the expansion valve and compressor. Besides, the inlet port of the evaporator was located at the lower location than the outlet port of the evaporator to help easy flowing of vapor into the condenser. In the same manner, the inlet port of the condenser was located at the higher location compared with the outlet port of the evaporator to help easy flowing of liquid into the evaporator.

Figure 2 shows a layout of the hybrid cooler. As previously mentioned, the main path was designed for the natural circulation mode. If the mode was converted, the flow path of working fluid was altered by four solenoid valves to make the compressor and expansion valve work properly in the cycle. The capacities of the condenser and evaporator were 2.8 kW and 2.0 kW, respectively. The detailed design configurations of the heat exchangers are specified in Table 1. The compressor used in the cabinet cooler for the vapor compression cycle was reciprocating type with a capacity of 0.7 RT. A TXV was used as an expansion valve and centrifugal-type fans were used. The refrigerant was R-134a and the tube had 9.52 mm outside diameter.

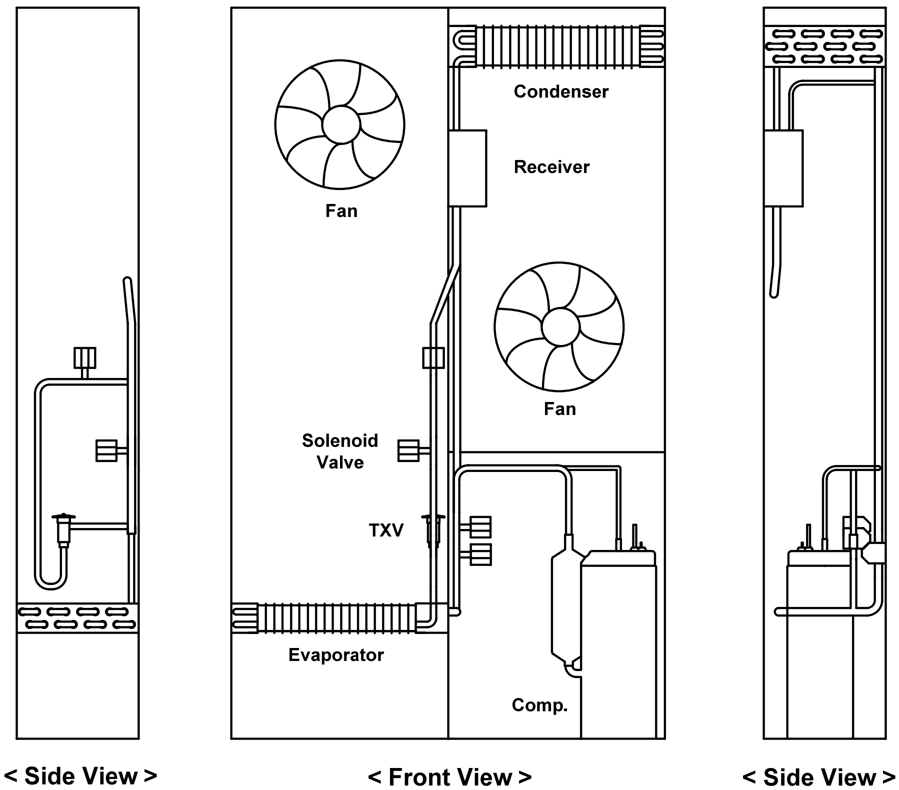
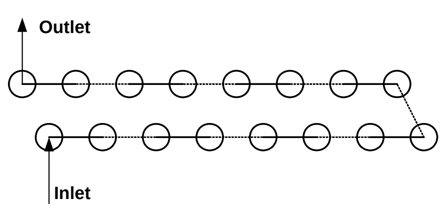
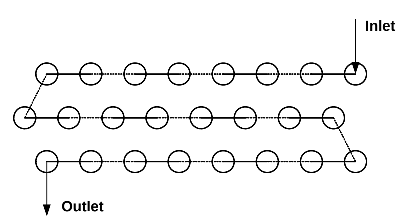


Figure 2 : Layout of the tested cooler.

Table 1 : Specifications of the heat exchangers

	Evaporator	Condenser
Tube spec.	3/8", 8R*2S*250 mm	3/8", 8R*3S*280 mm
Fin spec.	0.13 mm, 10 FPI	0.13 mm, 10 FPI
Coil spec.		

2.2 Experimental Setup

Temperatures, pressures and electric power were measured in the system. The temperatures on the refrigerating circuit, ambient and indoor air were measured using T-type thermocouples. The pressures were measured in the refrigerating circuit: one in the condenser outlet and the other in the compressor inlet. Finally, the voltage, the current and the phase angle were measured to estimate the electric power of the compressor and fans. All the signals were sent to the DAQ system. The experiments were performed in a psychrometric chamber that was designed to test household refrigerators. The chamber was capable of providing ambient temperatures ranging from -10 to 50°C. Table 2 shows the test conditions in the both modes.

Table 2 : Test conditions in each mode

		Vapor compression mode	Natural circulation mode
Indoor air	**Dry bulb temperature (℃)**	27	30
	Wet bulb temperature (℃)	19.5	-
Ambient air	**Dry bulb temperature (℃)**	35	8, 6, 4, 2, 0
	Wet bulb Temperature (℃)	24	-
Refrigerant charge (g)		350, 450, 550, 650, 750, 850, 950, 1050, 1150	350, 450, 550, 650, 750, 850, 950, 1050, 1150
Vertical distance (mm)		500, 800, 1100	500, 800, 1100

3. RESULTS AND DISCUSSION

3.1 Effects of Refrigerant Charge

The cooling capacity of the hybrid cooler was measured at different charges in each mode while the vertical distance was fixed at 1100 mm. Figure 3 shows the effects of the refrigerant charge. As the refrigerant charge increased, the cooling capacity of the system increased and then remained nearly constant after the peak value. This indicated each mode had optimal refrigerant charge. The peak values, which determined optimum refrigerant charge of the cabinet cooler, were 650 g and 1050 g for the vapor compression and natural circulation mode, respectively. The problem was that the two modes had different optimal charges. This problem was solved by using a receiver tank in the condenser outlet. Figure 4 represents the effects of refrigerant charge on the performance of the system with a receiver. As expected, optimal charges was approximately 1050 g.

3.2 Effects of Operating Condition

When the indoor temperature was 30°C, the cooling capacity of the natural circulation mode was analyzed with the decrease of outdoor temperatures. The decrease of outdoor temperature means the increase of the temperature difference between the indoor and outdoor. As shown in Figure 4, as the temperature difference between the indoor and the outdoor of the cabinet increased, the cooling capacity significantly increased. In addition, the cooling capacity of the natural circulation mode was approximately 95% of that of the vapor compression mode. This means the natural circulation mode yields reliable operations when the temperature difference between indoor and outdoor is sufficiently large. Therefore, the temperature difference between indoor and outdoor can be a important parameter for the determination of the mode change.

3.3 Effects of Vertical Distance

In the natural circulation mode, the working fluid was circulated naturally without external power input. The driving force for the liquid return to the evaporator is a gravity force. Therefore, the evaporator must be located below the condenser. In addition, the larger vertical distance between the evaporator and condenser was, the stronger the driving force was. To show the effects of vertical distance, the tests were carried out with refrigerant charge. Due to the reduction in the size of outdoor mobile cabinet, the vertical distance was limited to 1100 mm. As shown in Table 5, the cooling capacity increased with the increase of the vertical distance.

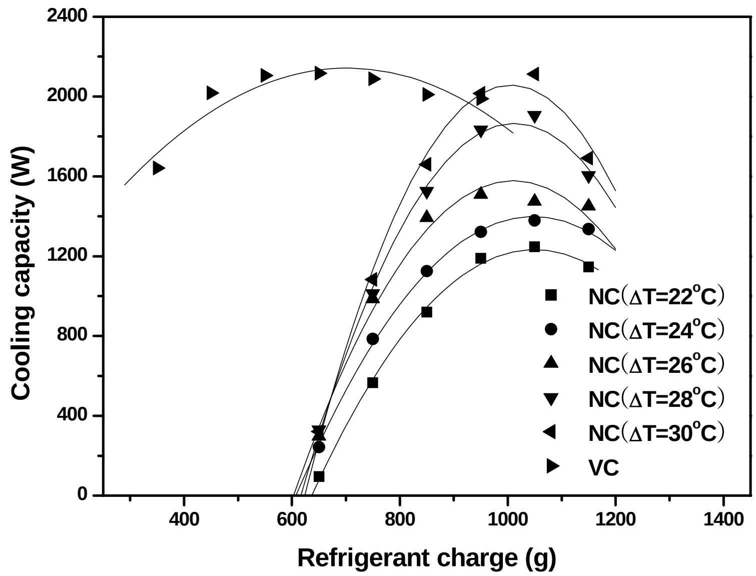


Figure 3 : Effect of the refrigerant charge without receiver.

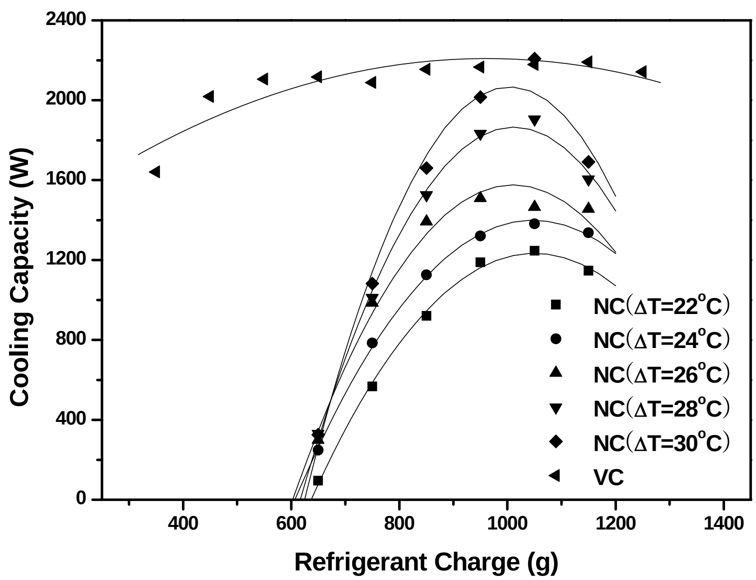


Figure 4 : Effect of the refrigerant charge with receiver.

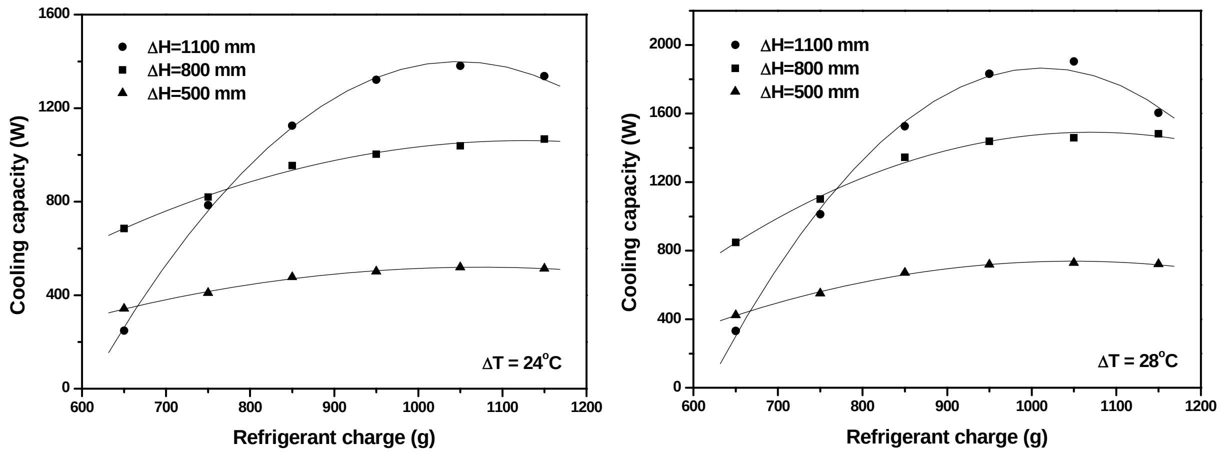


Figure 5 : Effect of the vertical distance.

3.4 Results of Field Tests

The field tests for the hybrid cooler were performed in a mobile cabinet. The electronic components, which were heat sources, were replaced with 2000 W heater. The indoor temperatures were measured at eight points inside the cabinet. The ambient temperature was maintained at 0°C. Figure 6 shows the results of the field tests. When the system temperature was 40°C, the cooler was turned on. After 15 min, the indoor temperature reached a steady-state condition, which was approximately 20°C. Then the mode was converted to the natural circulation mode. The indoor temperature increased rapidly, and then reached a steady-state condition, which was approximately 20°C.

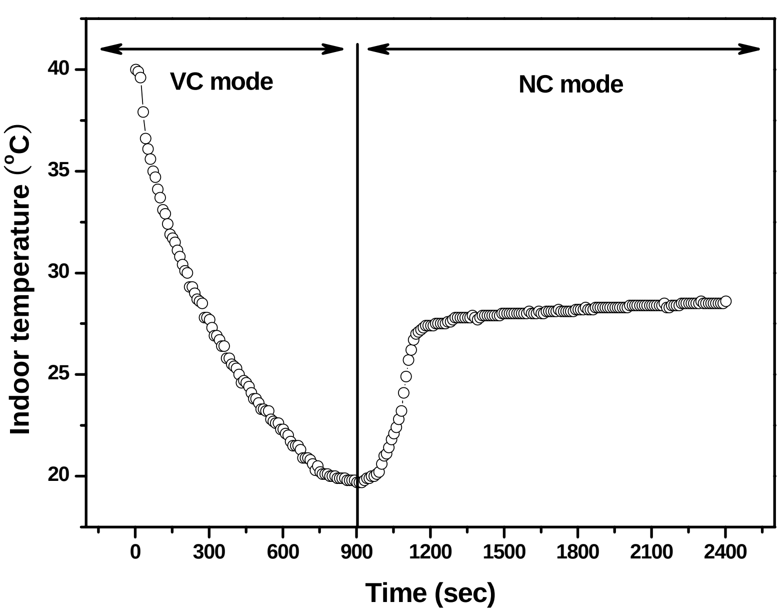


Figure 6 : Results of the field test.

5. CONCLUSIONS

A hybrid cooler having vapor compression and natural circulation modes was tested by varying refrigerant charge and operating conditions. The cooling capacity of the hybrid cooler in the natural circulation mode was 95% of that in the vapor compression mode when the temperature difference between indoor and outdoor of the cabinet was sufficiently large. The cooling capacity of the hybrid cooler in the natural circulation mode increased with refrigerant charge. However, it showed peak value at an optimal charge. Since the optimal charge for each operating mode was different, a receiver tank was applied to compensate this difference. The temperature difference between indoor and outdoor air was important parameter for the mode switch. The field test verified that the hybrid cooler showed good performance in the both modes.

NOMENCLATURE

NC	natural circulation mode	
VC	vapor compression mode	
ΔT	temperature difference between indoor and outdoor air	(°C)
ΔH	vertical distance between evaporator and condenser	(mm)

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