

## **A Study of Air Temperature Reduction before Entering the Condenser by Condensed Water of Evaporator Passing through Heat Exchanger**

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### **Abstract**

The aim of this research was to study the air temperature reduction before entering the condenser by condensed water of evaporator passing through heat exchanger. The experimental unit consisted of a vapor compression of 3.52 kW (12,000 BTU/hr) capacity with R-22 refrigerant and air cooled condenser. The heat exchanger was made of a copper u-tube bend tube with an external diameter of 6.35 mm, a length of 500 mm with 55 mm spacing between each tube. This copper tube bent into the shape with 7 turns. The results showed that the coefficient of performance was found to be 4.08, the power consumption of compressor of 866.25 W, and the heat transfer rate of condenser and evaporator were 4.40 and 3.54 kW, respectively. It also found that when the air flow passing through the heat exchanger, the average decrease of temperature was 2.1 °C.

**Keywords:** Heat exchanger, Air-conditioning system, Heat transfer, Condensation

### **1. Introduction**

Presently, the trend of using energy especially the power of nature such as petroleum, coal, etc. has been increased which may caused an energy shortage in the future. Especially, the electrical energy consumption of air conditioning system is a major concern because the rate of using energy has been increased. Split type air conditioning system is the most commonly used air conditioner for single room, building, resident and office. The split type air conditioning system has been widely used because of their ease of installation and inexpensive. Split type air conditioning system uses the air from the environment as heat transfer leave from the condenser. (Stoecker & Jones, 1982) It is well known that Thailand's climate all year around is more hot than cold, and the average temperature has a tendency to increase every year, this is the cause of the overload of air conditioner consumption which resulted in the decreasing of performance because lowly heat transfer rate of condenser.

Air temperature reduction before entering the condenser is the one method for increasing the performance and decreasing the energy consumption of air conditioning system. A review of prior studies indicates that researchers have tended to consider the development of air conditioning systems from the perspective of reduced energy consumption. Shah and Sekulic (2003) studied the heat exchanger device and heat exchanger design methodology including energy and heat transfer analysis. Juengjaroennirachon et al. (2006) examined the heat transfer performance of condenser using water and air. Hajidavalloo (2007) applied a new design with high commercialization potential that incorporated evaporative cooling on the condenser of

a window air conditioner. Lee et al. (2008), and Deamda and Yamtripat (1990) examined the air temperature reduction before entering the condenser. From the cycle of air conditioning system as shown that the air conditioner was turned on and the water was condensed by evaporator. These condensed water had low temperature enough to reduce the air temperature before entering the condenser. For these reasons, condensed water has been widely used in the form of heat transfer devices for enhancing the performance and reducing the energy consumption of air conditioning system.

The purpose of this research was thus to experimentally study the air temperature reduction before entering the condenser by condensed water of evaporator passing through heat exchanger. In order to increase the performance, decrease energy consumption, worthy energy using and decrease global warming.

## 2. Research Objectives

2.1 To design and build the heat exchanger for air temperature reduction before entering the condenser.

2.2 To study the efficiency of air conditioning system.

## 3. Literature Review

### 3.1 Principle of vapor compression refrigeration system cycle

In order to apply the heat exchanger from air conditioning system, it can be explain that when the air conditioner was turned on and the gas refrigerant was absorbed by compressor. The compressor compressed the high temperature and pressure refrigerant in order to cooling and condensed the liquid at the condenser before decreased the pressure at the capillary tube and then refrigerant flows to the evaporator. While the liquid refrigerant within the evaporator absorbed the heat from the air in order to decrease the air temperature, then evaporated to low pressure gas and flow to the compressor as the cycle as shown in Fig.1 (Stoecker & Jones, 1982).

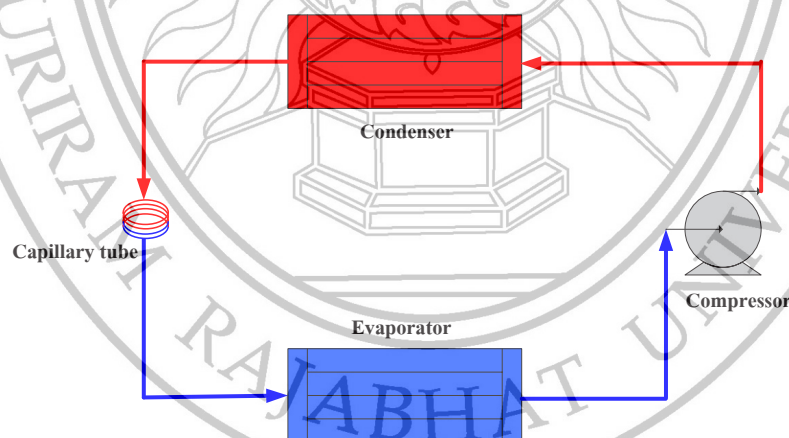


Figure 1. vapor compression refrigeration system cycle

Equations (1)-(4) were used to calculate the desired parameters. When considering the full speed of the compressor, pressure ratio compressor at both suction and compress sides of the compressor are related to the flow rate and



refrigerant temperature as shown in the following equation. The compressor power can be using by Eq. (1).

$$W_{comp} = \dot{m}_r (h_{comp,o} - h_{comp,i}) \quad (1)$$

Here,  $W_{comp}$  is the compressor power,  $\dot{m}_r$  is the mass flow rate of the refrigerant,  $h_{comp,o}$  and  $h_{comp,i}$  are the enthalpies at the compressor outlet and inlet of the system, respectively.

The heat transfer rate from the refrigerant in the condenser and evaporator can be using by Eqs. (2 -3) consequently.

$$Q_{cond} = \dot{m}_r (h_{cond,i} - h_{cond,o}) \quad (2)$$

Here,  $Q_{cond}$  is the heat transfer rate from the refrigerant in the condenser,  $h_{cond,i}$  is the enthalpy at the condenser inlet, and  $h_{cond,o}$  is the enthalpy at the condenser outlet.

$$Q_{evap} = \dot{m}_r (h_{evap,o} - h_{evap,i}) \quad (3)$$

Here,  $Q_{evap}$  is the heat transfer rate from the refrigerant in the evaporator,  $h_{evap,o}$  is the enthalpy at the evaporator outlet, and  $h_{evap,i}$  is the enthalpy at the evaporator inlet.

The performance analysis of vapor compression refrigeration system can be considered in terms of the system *coefficient of performance* as can be using by Eq. (4).

$$COP = \frac{Q_{evap}}{W_{comp}} \quad (4)$$

Here,  $COP$  is the *Coefficient of performance*

**3.2 Mechanism of heat transfer** There are three main ways that heat is transferred between substances or objects; thermal conduction, thermal convection and thermal radiation as shown in Fig.2. (Cengel & Boles, 2006)

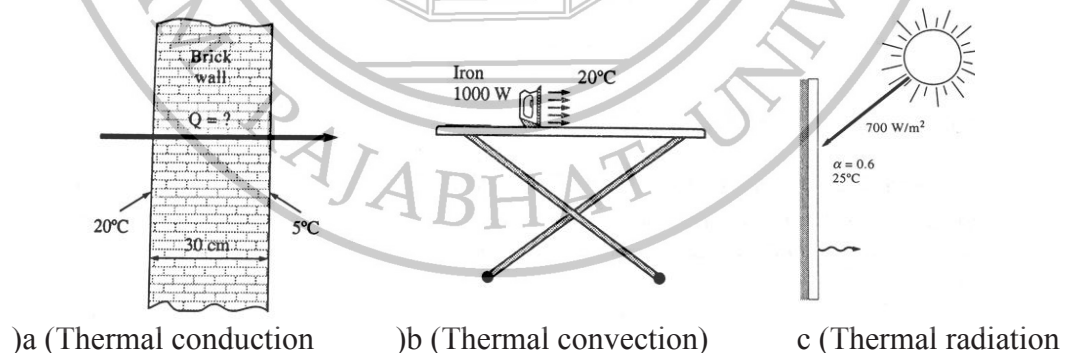


Figure 2. Mechanism of heat transfer

### *Thermal conduction*

Thermal conduction is the property of a material to conduct heat. The heat moves from a high temperature to areas with lower temperatures within the same or an intermediary between different adjacent. Which heat transfer is generated by the movement of molecules inside an intermediate as shown in Fig.2)a(.

### *Thermal convection*

From Fig.2(b), heat energy transferred between a surface and a moving fluid at different temperatures is known as convection. Convection is the transfer of thermal energy from one place to another by the movement of fluids. Two types of convective heat transfer may be distinguished:

1. Forced convection: when a fluid is forced to flow over the surface by an external source such as fans, by stirring, and pumps, creating an artificially induced convection current.
2. Free convection: when fluid motion is caused by buoyancy forces that result from the density variations due to variations of thermal temperature in the fluid. At heating the density change in the boundary layer will cause the fluid to rise and be replaced by cooler fluid that also will heat and rise. This continue phenomena is called free convection.

### *Thermal radiation*

Thermal radiation is the transfer of heat energy without intermediate or radiation occurs without the involvement of a physical substance as the medium. The radiant heat will move in the form of electromagnetic wave motion which the radiation will be great on vacuum area such as the transfer of heat energy from the sun through the earth as shown in Fig.2)c(.

## **4. Experimental apparatus and methods**

The experimental unit consisted of a vapor compression of 3.52 kW (12,000 BTU/hr) capacity with R-22 refrigerant and air cooled condenser. The heat exchanger was made of a copper u-tern bend tube with an external diameter of 6.35 mm, a length of 500 mm with 55 mm spacing between each tube. This copper tube bent into the shape with 7 turns as shown in Fig.3.

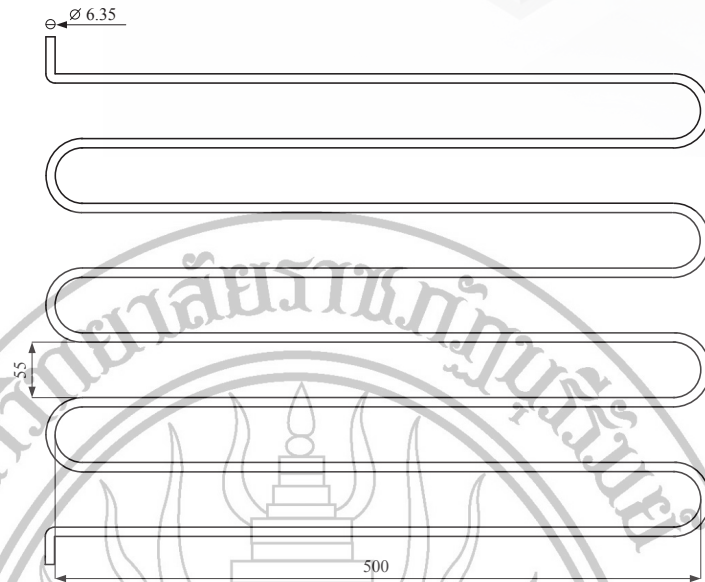


Figure 3. Heat exchanger device

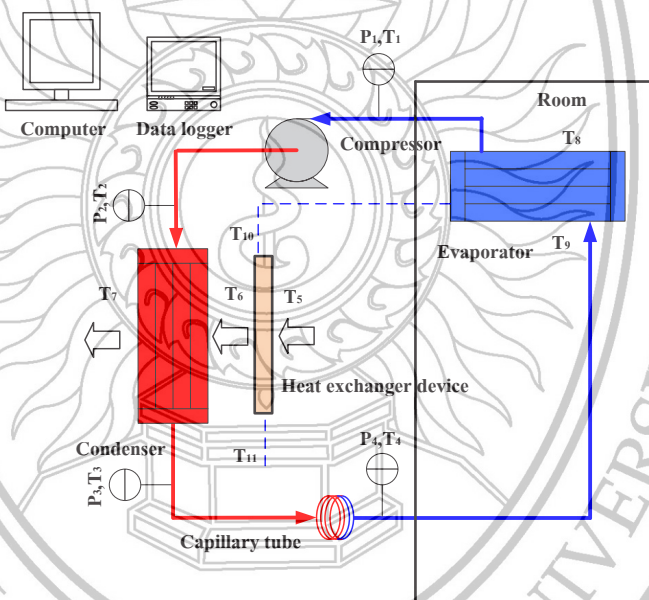


Figure 4. Schematic diagram for temperature and pressure measure points of air conditioning system

From Fig.4, the experiments were conducted over a period of 12 h, during which the relevant parameters were recorded every 30 min. The experimental data were recorded after a steady state condition was established. The temperatures of refrigerant, air and condensed water were recorded using type-K thermocouples. The air flow rates were recorded using anemometer. The temperatures were recorded at each position three times. The temperatures measured at each position were averaged over the time period.



Here,  $P_1 - P_4$  are the measure points of refrigerant pressure,  $T_1 - T_4$  are the measure points of refrigerant temperature,  $T_5 - T_9$  are the measure points of air temperature, and  $T_{10} - T_{11}$  are the measure points of condensed water temperature.

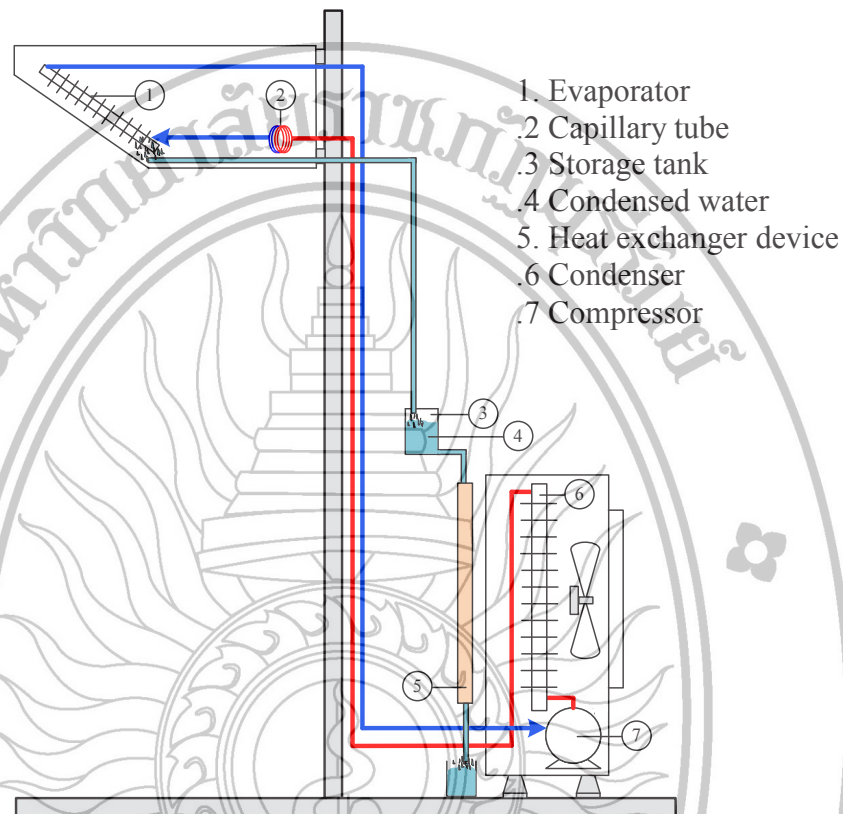


Figure 5. Experimental installation of air conditioning system

For the experiments in Fig.5, the water was condensed at evaporator section and this condensed water flowed through heat exchanger that was installed at the condenser inlet. When the air flowed through heat exchanger, the temperature was decrease in order to cooling the condenser.

## 5. Results and Discussion

The research results of the air temperature reduction before entering the condenser by condensed water of evaporator passing through heat exchanger show as follow.

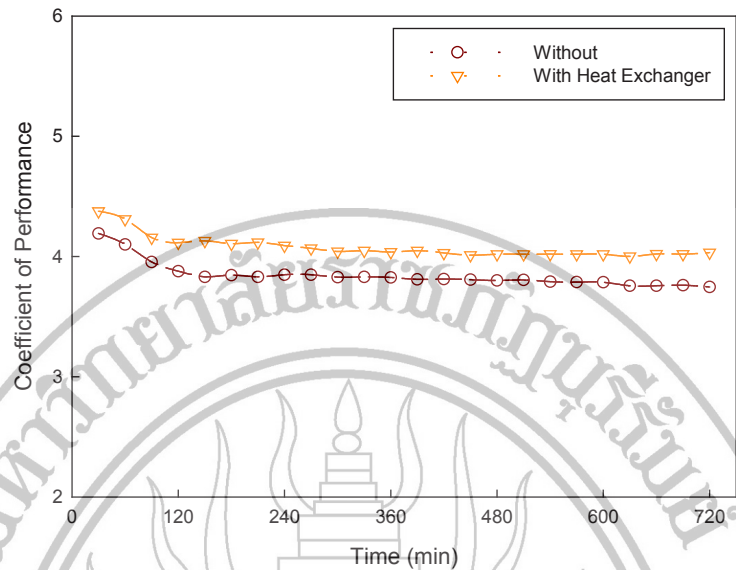


Figure 6. The comparison of coefficient of air conditioning system performance with time

Figure 6 illustrates the  $COP$  for the air conditioning systems with and without the heat exchanger. This figure shows that the  $COP$  of the air conditioning system with the heat exchanger is higher than that of the system without heat exchanger. This is because the more subcooled refrigerant exit from condenser, more refrigerant quantity flows through evaporator, and more aerosol therefore the heat transfer rate of evaporator is increased, as indicated by Fig. 7, which shows the heat transfer rates of evaporator were 3.40kW and 3.54kW, respectively. Therefore, the result shows that the  $COP$  and heat transfer rate of evaporator of the air conditioning system with heat exchanger is higher than that of the system without heat exchanger.

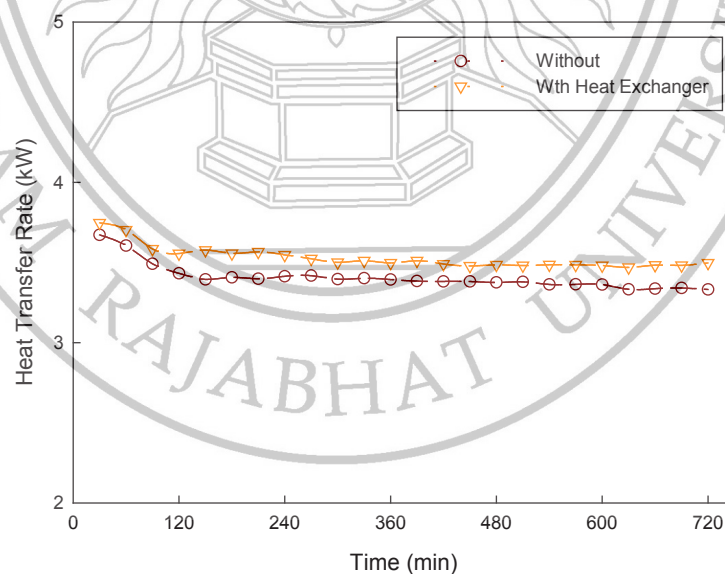


Figure 7. The comparison of heat transfer rate of evaporator with time

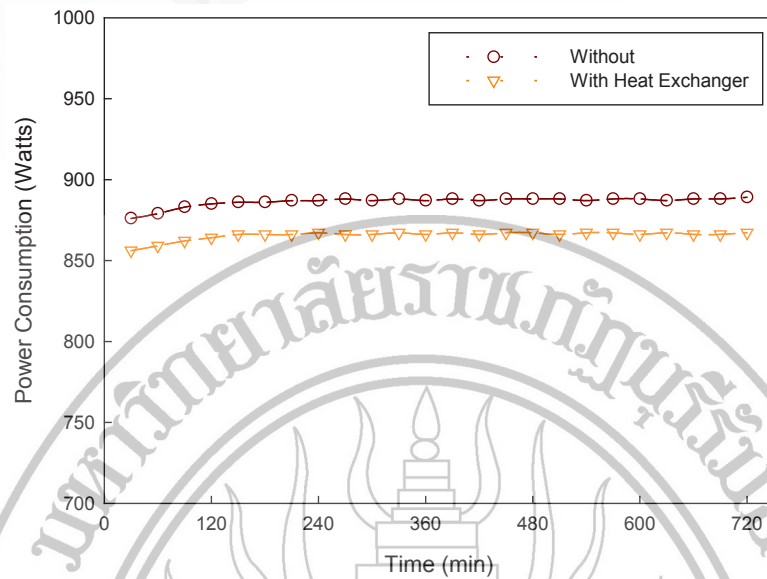


Figure 8. The comparison of power consumption with time

Figure 8 shows the comparison of the power consumption with time for the air conditioning systems with and without the heat exchanger. The figure shows that the power consumptions of the air conditioning system were 866.75 W and 888.75 W, respectively. The power consumption of the air conditioning system with heat exchanger is lower than that of the systems without heat exchanger, this is because the heat transfer rate of condenser is higher. As a result, the lower power consumption obtained from refrigerant heat transfer leads to energy savings for the air conditioning system.

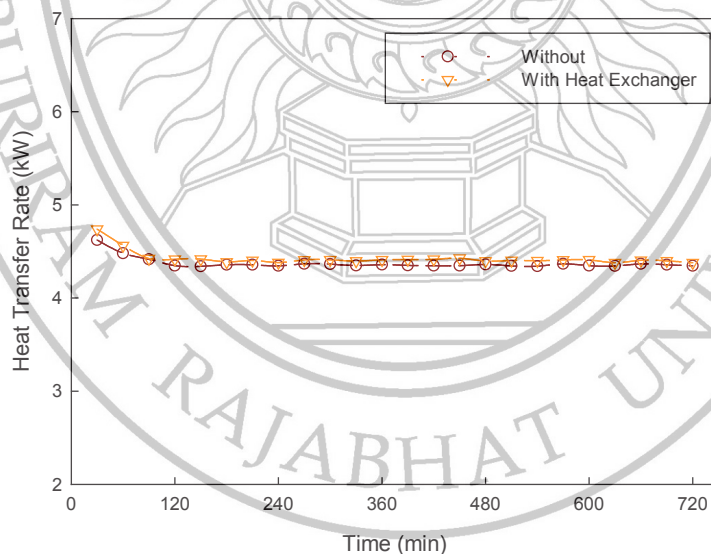


Figure 9. The comparison of heat transfer rate of condenser with time



Figure 9 shows the comparison of heat transfer rate of condenser with time for the air conditioning systems with and without the heat exchanger. The results show that the heat transfer rates of condenser were 4.40 kW and 4.34 kW, respectively. This is because the more subcooled refrigerant before passing through the condenser thus the heat transfer is increased as shown in this figure.

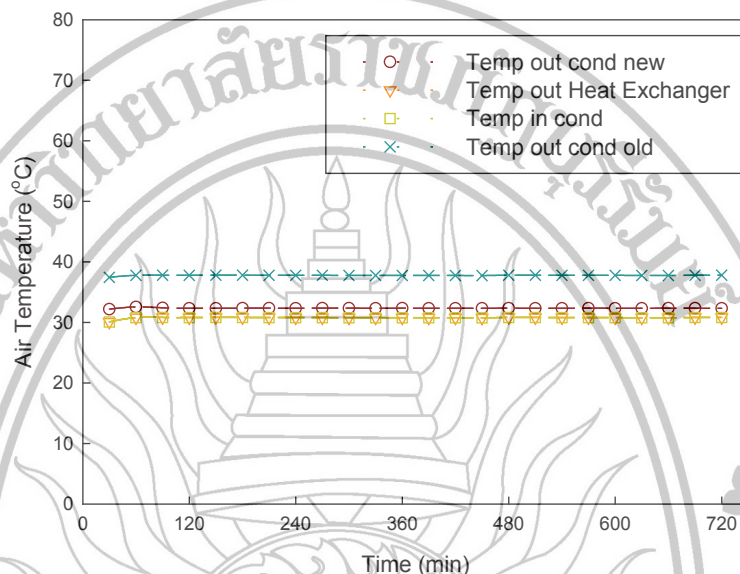


Figure 10. The comparison of air temperature with time

Figure 10 shows the comparison of air temperature with time for the air conditioning systems with and without the heat exchanger. The result shows that the air temperature before entering through heat exchanger was 32.2 °C, then the air conditioning system with heat exchanger could reduce the air temperature to 2.1 °C.

## 6. Conclusion

The aim of this research was to study the air temperature reduction before entering the condenser by condensed water of evaporator passing through heat exchanger. The experimental unit consisted of a vapor compression of 3.52 kW (12,000 BTU/hr) capacity with R-22 refrigerant and air cooled condenser. The results showed that the coefficient of performance (*COP*) of the system was 4.08, the power consumption of compressor was 866.25 W, the rate of heat transfer in condenser and evaporator were 4.40 and 3.54 kW, respectively. And the air conditioning system with heat exchanger could reduce the air temperature to 2.1 °C.

## 7. Recommendations

Future research should emphasize the increasing of heat transfer area on the application of heat exchanger device that affected the heat transfer rate of heat exchanger device.

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