

# EXPERIMENTAL STUDY ON HEAT TRANSFER ENHANCEMENT OF A NEW HEAT EXCHANGER FOR A HEAT PUMP SYSTEM

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## ABSTRACT

We have designed experiment system of heat pump, and the heat transfer capability of R417a in corrugation inner wing heat exchanger was studied experimentally. Mechanism of the heat transfer enhancement was analyzed theoretically. The experimental results showed that heat transfer enhancement by corrugation inner wing heat exchanger improve heat transfer effect of the heat transfer, that the overall heat transfer coefficient of heat exchanger increase with the increasing of heat flux, that its overall heat transfer coefficient is higher than that of common shell and tube heat exchanger at the same specific rate of heat flow.

**Key words:** *heat transfer enhancement, heat pump system, heat exchanger, R417a.*

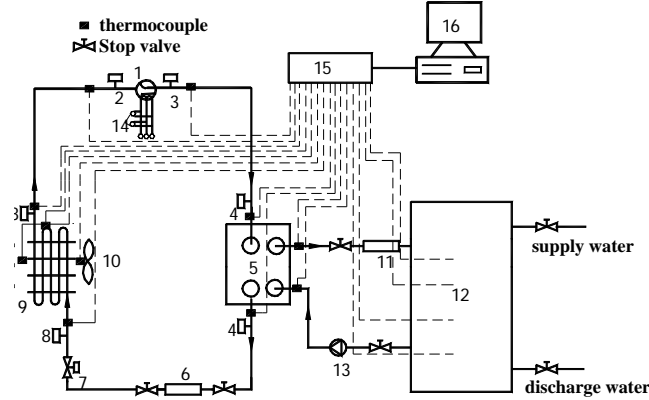
## 1 INTRODUCTION

At present, R22 is widely used as a working fluid in refrigeration & air-conditioning and heat pump system. Because R22 is a substance of HCFC which cause some destroy to the ozone layer and some greenhouse effects, and according the stipulation of “Montreal Protocol” in 1987, HCFC 's time limit is 2020 in developed countries and 2030 in developing countries. So another appropriate working fluid should be found out, it was indicated in the investigation to use R417a as replacement of R22 in heat pump system<sup>[1]</sup>. R417a can directly replace R22 in the refrigeration and heating system with an advantage of no replacing lubricant, but R417a is a ternary non azeotropic mixture refrigerant whose heat transfer characteristics is worse than R22, an appropriate heat transfer enhancement method should be adopted to improve the heat exchanger transfer heat characteristics. This paper studied R417a's transfer heat capability in a new heat exchanger with corrugation inner wing, and compared it with common shell exchanger. The results showed that overall heat transfer coefficient of corrugation inner wing heat exchanger is greater than that of common shell and tube exchanger at the same specific rate of heat flow.

## 2 EXPERIMENTAL DESIGNS AND EQUIPMENT

Experimental installation was shown as figure1. The low-temperature and low-pressure working fluid coming from evaporator was absorbed into compressor, it became the high-temperature and high-pressure gas after compression of compressor, then it flowed into heat exchanger while it became high-pressure liquid giving out heat energy in the heat exchanger. Its pressure decreased after passing through the throttle valve. It absorbed exhaust gas's heat and became into vapor in the evaporator, at last, returned into the compressor, thus repeated, and the heat pump cycle came into being. Cooling water cycle: in the loop of the water cycle, low-temperature water flowing out of the water tank for thermal storage had a high pressure, and then went into corrugation inner wing heat exchanger, exchanged heat energy with the heat pump working fluid in the exchanger. Water returned to the water tank for store heat with high-temperature after it absorbed condensation heat.

The experiment needs to measure the temperature during entrance and exit of evaporator, the working fluid's temperature, pressure, and volumetric flow rate during entrance and exit of heat exchanger, the water's temperature, pressure, and volumetric flow rate during entrance and exit of heat exchanger. Temperature and pressure may be measured and recorded by data collection system (combined with computer).



1. compressor; 2,3,4 and 8. pressure meter; 5. heat exchanger; 6,11. flowmeter; 7. throttle valve; 9. evaporator; 10. fan; 12. water tank for store heat; 13. water pump; 14. power meter; 15. 2700 data collection apparatus; 16. computer

**Fig. 1. Schematic diagram of experimental installment**

### 3 DATA PROCESSING METHOD

Heat load of heat exchanger may express in cooling water's quantity of heat, it may be expressed as

$$Q = C_p \cdot G \cdot \rho \cdot \Delta T / 3600 \quad (1)$$

where  $C_p$  = specific heat under constant pressure, 4.186kJ/kg·K is adopted in this paper.

$G$  = volumetric flow rate,  $m^3/h$

$\rho$  = density of water,  $kg/m^3$

$\Delta T$  = difference in temperature during entrance and exit of heat exchanger,  $^{\circ}C$

In formula (1),  $Q$  may be also expressed as

$$Q = K \times A_o \times \Delta t_m \cdot (2)$$

where  $\Delta t_m$  is logarithm average difference of temperature,  $A_o$  is exterior area of base tube, it may be also expressed as

$$A_o = N \times \pi \times d_o \times l \quad (3)$$

$$\Delta t_m = [(t - t_i) - (t - t_o)] / \ln[(t - t_i) / (t - t_o)] \quad (4)$$

In formula(4),  $t$  is the condensation temperature of working fluid's vapor.

#### 4 EXPERIMENTAL RESULTS AND ANALYSIS

It can be seen from the figure2 that at the same specific rate of heat flow the overall heat transfer coefficient of corrugation inner wing heat exchanger is better than common shell and tube exchanger.

R417a(R125/R134a/R600, 47%/50%/3%) is a kind of non azeotropic mixture refrigerants whose glide temperature is about 6°C. Owing to different boiling points among non azeotropic mixture refrigerants (under ordinary atmospheric pressure, boiling point of R134a is -26.5°C, R125 is 48.6°C and R600 is -11.73°C), high-boiling point component condense at first, low-boiling point component condense later.

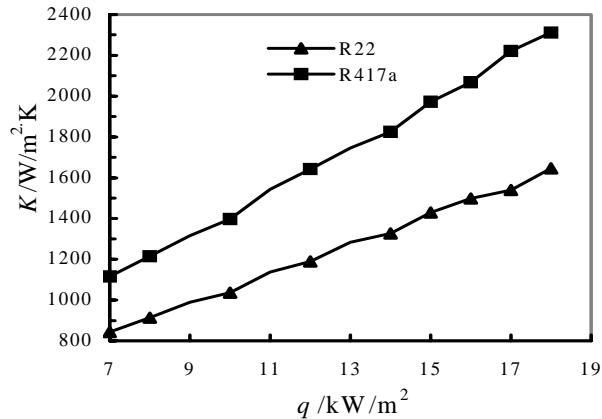


Fig. 2. The relationship between heat flux density and overall heat transfer coefficient

Low boiling point component will accumulate on the heat transfer surface forming gas phase resistance layer, only in the way of diffusion through gas resistance layer, high-boiling point component can get to the surface of heat transfer. Consequently, condensation heat transfer will be influenced seriously by the gas phase mass-transfer resistance layer so as to overall heat transfer coefficient of non azeotropic mixture refrigerants is much lower than that of single component. Non azeotropic mixture refrigerants R417a will form a thicker gas phase mass-transfer diffusive layer, which increase the heat transfer resistance to a great extent when it condenses around the tube. Owing to the structure of corrugation inner wing heat exchanger, the excited steam will flow fiercely when vapor of composite working fluid flow through the channels. It increases onflow degree under the low value of Re and increase the disturbance of gas film diffusive layer, then enhance the heat transfer of the gas and decrease the heat resistance. Velocity of refrigerants stream will increase with the specific rate of heat flow. So overall coefficient of condensation heat transfer will increase with the specific rate of heat flow, from the point of heat transfer enhancement on liquid film, the thickness of liquid film on the wall of the tube will be large along with the condensation process.

Owing to the structure of corrugation inner wing heat exchanger, action of condensation surface tension can be sufficiently utilized, making for condensation finished rapidly from the top to the bottom of the wings, consequently the thickness of the liquid film can be thinner. At the same time, overall heat transfer coefficient of the liquid film may be increase while using the coarse wings which destroy flow boundary lay of the liquid film. Furthermore, large velocity of the flow may be permitted due to decrease of pressure. Velocity of stream flow increases with specific rate of heat flow. It is centrifugal effect of the stream flow that can intermix gas and liquid phase uniformly, and let gas and liquid intermix better that is liquid membrane on the wall of tube can be destroyed by high velocity current, tiny liquid drop can be carried away easily by gas flow forming mist flow intermixed by gas and liquid phase. It accelerates gas

and liquid phase condensation in the mass consequently and greatly improves the heat transfer coefficient. But shell and tube heat exchanger usually improves the heat transfer coefficient depending on larger heating area with the disadvantage of great of pressure drop, and greater value with increase of velocity of the stream flow. The most important is that shell and tube heat exchanger is difficult to activate the rapid flow of the steam, that is, the increase of heat transfer coefficient is salience. So heat transfer coefficient of the shell and tube heat exchanger is not better than that of corrugation inner wing heat exchanger.

## 5 CONCLUSION

New corrugation inner wing heat exchanger can enhance the refrigeration working fluid (R417a) remarkably so as to solve the key problem in application of heat pump systems that influenced by the low overall coefficient of heat transfer, it be provided with a broad foreground to utilize R417a substituting for R22 in the field of heat pump system.

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