Research Article
The Relation of Performance Parameters for a 150K Auto-Cascade Refrigeration System

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Abstract: The performance parameters of a single compressed and four-stage segregating auto-cascade refrigeration system were developed in this study. The temperature of the cryogenic tank went down relatively slow with the evaporating temperature and the refrigerant temperature for W. When the state of system is steady, the suction pressure of the compressor is 0.3 MPa, the discharge pressure is decreased slowly. When the temperature of cryogenic tank is below zero 118 °C, the discharge pressure is 1.34 MPa. The lowest temperature could reach-18°C and the refrigeration capacity was about 7 W.

Keywords: Auto-cascade refrigeration system, mixture refrigerant, zeotropic

INTRODUCTION

One compressor was employed in the auto-cascade refrigeration system, the principle was applying different compositions of mixture working substance under different pressure processing different vaporizing temperature and condensing temperature and multi-cascade system was achieved by higher boiling point composition condensing lower boiling point composition, therefore the refrigeration system was simplified overwhelmingly and easy to maintain. a wide range of cooling temperatures from -180°C to -40°C could be attained by the auto-cascade refrigeration system, which can be used in many applications, whether in the field of refrigeration technology or semiconductor industry, blood and medicines preservation in hypothermal medicine, cryopreservation for instrument, in the field of cryogenics such as gas liquefied.

Auto-cascade refrigeration of industrial application was extensive and a variety of subjects were developed by the scholars of countries. Li *et al*. (2001) put forward that the liquid molar volumes of nonazeotropic refrigerant mixtures, calculated with Peng Robinson equation, were compared with vapor-liquid equilibrium experimental data, When HBT (Hankinson-Brobst-Thomson) equation was joined with PR equation, the deviations are reduced to less than 1.5% for both R22+R114 and R22+R142b. Raja *et al*. (2009) studied experimentally the influence of nucleation on the flow boiling heat transfer coefficient of R134a/R290/R600a refrigerant mixture in a smooth horizontal tube of 12.7 mm diameter. Higashi (1999) determined the plane of

vapor-liquid criticality for ternary refrigerant mixtures of R32/R125/R-134a from data on the vapor-liquid coexistence curve near the mixture critical points. The saturated liquid viscosity of ammonia (NH3) and of the hydro fluorocarbons, R32 and R134a, was measured by Laesecke *et al*. (1999) in a sealed gravitational viscometer with a straight vertical capillary. Phase behavior data at temperatures and at pressures from are presented for D, L-lactide in hydro fluorocarbon solvents: R32, R23 and R134a. The liquid refrigerant supply, different cascade heat exchangers, elevated-pressure mixed-coolants, have effect on the performance parameters (Gurudath and Venkatarathnam, 2010; Maytal *et al*., 2006; Gong *et al.*, 2002). Other factors will influence the performance: the ejector is used to recover some available work to increase the compressor suction pressure (Walimbe *et al.*, 2010; Byung-Chul, 2003).

The performance parameters of a single-compressed and four-stage segregating auto-cascade refrigeration system were developed in this study. The relation of performance parameters between the operating temperatures for cryogenic tank and the temperature for the first, second, third and fourth evaporating, the outlet temperature for the condenser, the discharge and suction pressure of the compressor is discussed.

PERFORMANCE FOR AUTO-CASCADE SYSTEM

The characteristic of performance: The experimental system is shown in Fig. 1. In order to reach 150 K, one
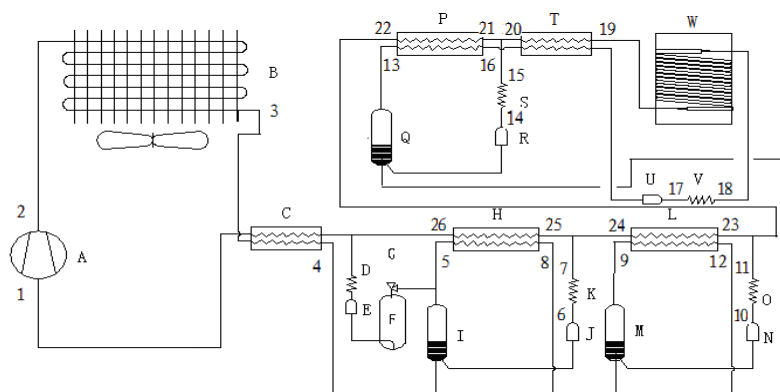
Fig. 1: Schematic diagram of ACR A: compressor ; B: air cooling condenser; C,T: regenerator; D: restriction tube; E,J,N,R,U: drier-filter; F: expansion vessel; G: safety-valve; H,L,P: condensing evaporator; I,M,Q: gas-liquid separator; K,O,S,V: capillary tube; W: evaporator.1, 2: the measuring point of temperature and pressure; 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17,18, 19, 20, 21, 22: the measuring point of temperature

compressor employed and four zeotropic mixture refrigerant R 134 a/R 23/R 14 /R 50 selected make up a complete four-stage auto-cascade refrigeration system, achieving high and low temperature self-cascade through evaporative condenser and gas-liquid separator separating different boil temperature of four refrigerants in turn and going into different refrigeration system.

The theoretical cycle is described as follows: a certain mass flow of mixture refrigerants R134 a/R 23/R 14/R50 is compressed by compressor A, then partly condensed going into condenser B for temperature variation, which of higher boiling-point constituent R134a and minor R23 dissolved in R134a is condensed into liquid and the rest refrigerant remain vapor. Vapor separates with liquid naturally through the action of gravity, in which R134 a and minor R23 is throttled by capillary tube K flowing through gas-liquid separator I, then evaporate to refrigerate in one stage condensing evaporator H, and vapor evaporated return to regenerator. Middle and low temperature working substance-gas mixture through loop from the top of gas-liquid separator I is condensed going into one stage condensing evaporator H, most R23 and minor R14 dissolved in R23 is condensed into liquid, however most R14 and R50 kept vapor. gas-liquid mixture coming from condensing evaporator H enter into second stage gas-liquid separator M, then separate with liquid and vapor naturally through the action of gravity, R23 and minor R14 liquid mixture throttled by capillary tube N through gas-liquid separator, then evaporate to refrigerate in second stage condensing evaporator L, R14 and R50 coming from the top of gas-liquid separator M is partly condensed in second stage condensing evaporator L going into third stage gas-liquid separator Q, most R14 and minor R50 separated with gas naturally through the action of gravity ,then evaporate refrigerating in third stage condensing evaporator P throttled by capillary tube and return to suction tube of compressor. R 50 from the top of gas-liquid separator Q is condensed yielding temperature

reduction in third stage condensing evaporator P, then evaporate refrigerating in evaporator V throttled by capillary tube U. finally after R50 gas from evaporator and R134a, R23, R14 from condensing evaporator were mixed, mixture refrigerant go into suction tube and return compressor, the complete cycle accomplish.

RELATION OF PERFORMANCE PARAMETERS

Variation of the evaporating temperature: The evaporator of coiled heat exchanger was put in the low temperature tank of 5L volume, which kept thermal insulating layer peripherally and was in direct touch with alcohol (secondary refrigerant), therefore the temperature for cryogenic tank is formulated by the alcohol temperature. the effect of the temperature reduction of the secondary refrigerant in the tank on the refrigerant temperature in the evaporator, first evaporating, second evaporating, third evaporating and fourth evaporating temperature was seen in Fig. 2,

It took nearly 4 h and 12 min for the temperature drop of secondary refrigerant in the tank from 290 K (15°C) to 150 K. Before 10 min of operation of auto-cascade system, the first, second and third evaporating temperature reduced sharply; moreover tend to keep stable swiftly. However the temperature drop of the second refrigerant in the low temperature tank went down relatively slow with the temperature decline of fourth stage, which kept just synchronous with the refrigerant for W shown in Fig. 2. the cause of condition arising that temperature after first, second throttling was lower than that after first, second throttling lied in the fact that in this stage the temperature of each exchanger was higher than the loss of refrigerating capacity in the heat exchanger, at the same time refrigerant was separated insufficiency, moreover the working substance of low boiling
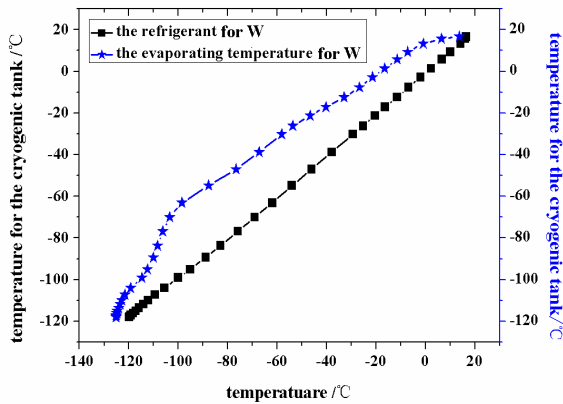
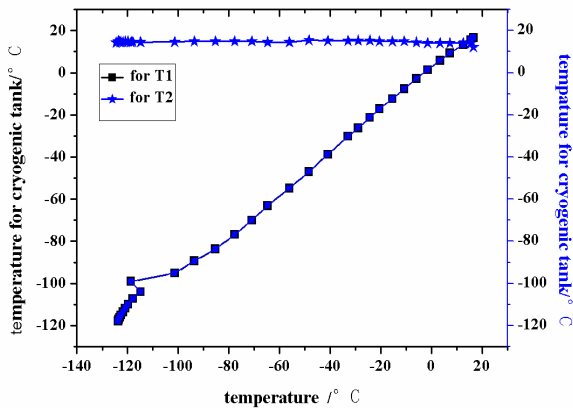Fig. 2: The change of the evaporating temperature

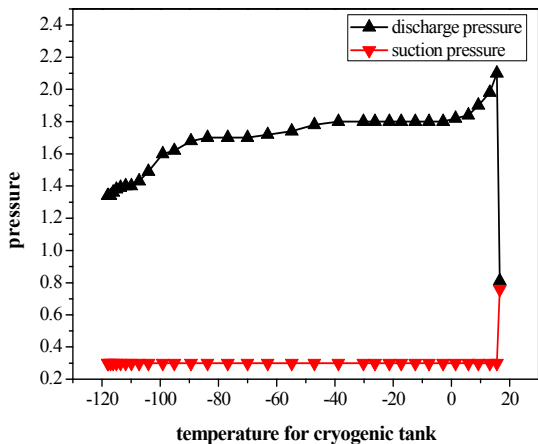Fig. 3: The temperature change of the outlet for the condenser

Fig. 4: The pressure change of compressor

temperature was only condensed by refrigerating capacity which working substance of high boil temperature was evaporated refrigerating, then caused temperature drop refrigerating. So that, in initially shorter time, there was a lag that junior of temperature drop compared with superior (Andrey and Naer, 2009).
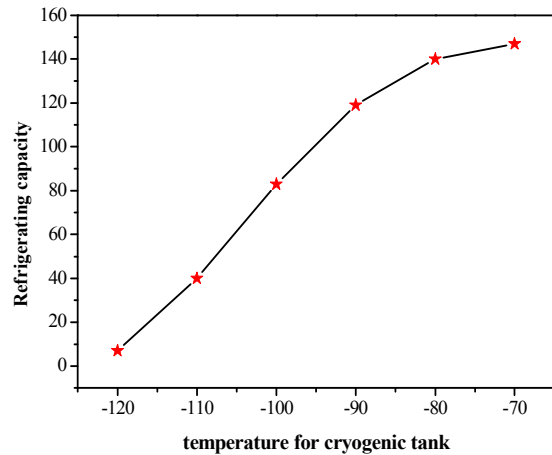

Fig. 5: The change of the refrigerating capacity

Variation of the outlet temperature of the condenser
As is shown in Fig. 3, the outlet temperature for the condenser fluctuated slightly from 12.1°C to 15.2°C. The temperature of the fourth return pipe was the outlet temperature of the evaporator, the outlet temperature for the evaporator and the temperature difference decreased with the decline of the temperature for cryogenic tank. When the temperature for cryogenic reach -118°C, the temperature of the outlet for the evaporator is minimum. The decline of the outlet temperature for the evaporator was synchronous with the decrease of the temperature for cryogenic tank. Heat transfer between the evaporator and cryogenic tank is diminished with the decline of the temperature difference between the inlet and the outlet of the evaporator. When the temperature of cryogenic tank was below zero 118°C, the temperature of the outlet temperature of the evaporator reach -123.8 °C.

Variation of the pressure of the compressor: Figure 4 shows the change of the suction and discharge pressure of the compressor. At the initial stage the discharge pressure of the compressor increases rapidly, the suction pressure is almost stable. the constituent of high boiling point temperature initiates to condense, but the constituent of the lower boiling temperature could be condensed, as a result the constituent of high boiling temperature is accumulated and the liquid of the refrigerant has not yet evaporated in the condenser, the lower boiling temperature constituent has not been condensed, the constituent of the inferior for the high boiling temperature is more condensed. So that the discharge pressure increases rapidly at the start of the system. When the system goes into the stable condition, the discharge pressure decreases slowly with the condensation of each stage of the constituent. The temperature for the cryogenic tank declines when the refrigerants are liquefied continuously, the pressure of the system is reduced as for the condensation of the

refrigerants of lower boiling point, the discharge pressure is decreased slowly, the pressure reaches stable finally. When the state of system is steady, the suction pressure of the compressor is 0.3 MPa. When the temperature of cryogenic tank is below zero 118℃, the discharge pressure is 1.34 MPa.

Variation of cryogenic tank on refrigerating capacity: Figure 5 shows the change of the refrigerating capacity. When the temperature of the cryogenic tank is -70°C, the refrigerating capacity is 147 W. The lowest temperature could reach -118°C and the refrigeration capacity was about 7 W. The refrigerating capacity decreased with the temperature drop for the cryogenic tank.

CONCLUSION

The performance parameters of a single compressed and four-stage segregating auto-cascade refrigeration system were developed in this study. the temperature of the cryogenic tank went down relatively slow with the evaporating temperature and the refrigerant temperature for W. When the state of system is steady, the suction pressure of the compressor is 0.3 MPa, the discharge pressure is decreased slowly. When the temperature of cryogenic tank is below zero 118 °C, the discharge pressure is 1.34 MPa. The lowest temperature could reach-118°C and the refrigeration capacity was about 7 W.

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