An Application of Optimum Heat Exchanger for the Grasp on Performance Characteristics of NH_3 Refrigeration System

Ok-Nam Ha[+], Il-Wook Kwon[++], Suck-Ju Hong*, Jae-Yeol Kim[+], Jong-In Lee[+++], Sang-Sin Jeon[++++], Kyung-Soo Ha[++++], Seung-Jae Lee[++++], Chan-Soo Park[++++], Song-Tae Jeong[++++]

(논문접수일 2004.12. 6, 심사완료일 2005. 2. 25.)

Abstract

Since the use of CFC and HCFC refrigerants is to be restricted due to the depletion of ozone layer, this experiment applies the NH_3 gas to study the performance characteristics from the superheat control for improving the energy efficiency. The experiments are carried out for the condensing pressure of refrigeration system from 1500kPa to 1600kPa by 50kPa and for degree of superheat from 0°C to 10°C by 1°C at each condensing pressure. As a result of experiment, 1) As degree of superheat increased, evaporating pressure of the compressor decreased so equilibrium temperature decreased. And specific volume of refrigerant vapors increased so refrigerant mass flow and heat load of the evaporator decreased. 2) An influence of change of condensing pressure on heat load of the evaporator was insignificant. 3) With the identical degree of superheat, change of compressed temperature was insignificant according to each condensing pressure, so there was little change in enthalpy. 4) when the degree of superheat is 0°C at each condensing pressure, the refrigeration system has the highest performance.

Key Words : CFC, HCFC, Degree of superheat, Condensing pressure

1. Introduction

The issue of ozone destruction has been recently a world-wide problem originated from the previous studies. Since then, production of specific Freon matters such as R-11, R-12 and R-502 that have been used as refrigerants of industrial refrigerating systems has been completely prohibited since January 1. 1996.

* Corresponding author, Department of Mechanical Engineering, Chosun University (sjhong@chosun.ac.kr)
Address : Department of Mechanical Engineering, Chosun University, #375 Seosuk-dong, Gwangju 501-759, Korea
+ Department of Mechanical Engineering, Chosun University
++ MYCOM Korea Chemical Plant Co., Ltd.
+++ Department of Automobile, Chosun College of Science & Technology
++++ Graduate School, Department of Mechanical Engineering, Chosun University

There are a wide variety of refrigerants that have been applied for refrigerating systems, but production and use of HCFC refrigerants have been controlled because they have been classified as matters that destruct earth environment. HFC refrigerants as developed alternatives of HCFC ones have been marketed, but they have a problem such as complicated selection of refrigerating oil and lowering of heat transfer rate. In particular, they are not environmentally-friendly because they have high GWP (Global Warming Potential), and further development to solve the problem is in progress[1~4]. The matters that can be used as refrigerants of those that have been frequently used in chemical manufacturing, oil refining, petrochemical industry and fertilizer production include ammonia, an mineral compound, propane and propylene as hydrocarbon. They are easy and cheap to obtain as they are natural gases, and in particular, environmentally-friendly.

Of them, an ammonia refrigerant has been widely used at a wide range of temperature. It has a high COP and heat transfer rate and because of its high critical temperature and pressure, it is superior as a refrigerant, but it has disadvantages such as toxicity, inflammability and explosiveness[5].

As heat exchangers that have been applied for ammonia refrigerating systems, a Shell & Tube type condenser and a flooded evaporator have been used, but because of their large size, large space for installation and more amount of refrigerants are needed.

Therefore, to solve the problem, this study conducted a performance test on change of degree of superheat according to condensing pressure using a Shell & Disk type optimum heat exchanger which can minimize the amount of a refrigerant and allow its minimum leakage.

Table 1 Experimental condition

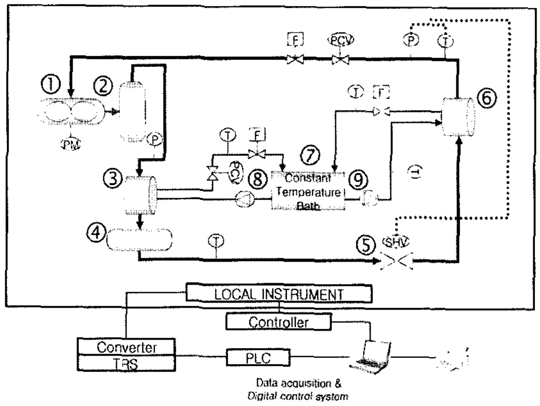
Condensing pres. (kPa)	1500~1600
Degree of superheat (°C)	0~10
Bath temp. (°C)	28
Ambient temp. (°C)	24
Chilled water flow (kg/h)	6800
Cooling & Chilled water	Demineralized water

Based on the results of the test, this study planned to improve energy efficiency, preserve earth environment, and seek industrial safety. And through reduction of installment area, economic value is expected.

2. Experimental apparatus and test procedure

2.1 Experimental Equipment

Fig. 1 shows an outline of experimental system for performance study of the refrigerator based on changing degree of superheat depending on compressed pressure. This study used ammonia as working fluid for this system, which was composed of a compressor, a condenser, an evaporator, an expansion valve and other accessories. And we gave a great care on minimization of pressure loss when designing the inside of the system. Its low-pressure part was insulated based on the KS



① Compressor ⑤ Expansion valve
② Oil separator ⑥ Evaporator
③ Condenser ⑦ Constant temperature bath
④ Receiver ⑧, ⑨ Circulation pump
P : Pressure sensor PCV : Pressure control valve
PM : Power meter SHV : Superheat controller
F : Mass flow meter T : Temperature sensor
—— : Refrigerant —— : Cooling & chilled water
····· : Electric signal

Fig. 1 The schematic of Ammonia refrigeration system.

standard not to be affected by external temperature. To measure phase change of working fluid within the system, we installed a pressure gauge, a thermometer, a mass flow meter, a superheating controller, a pressure adjustment valve, and a power meter in the system. And we installed a thermo-hydrostat to maintain the range of errors of measurements within temperature of ±0.1°C, pressure of ±10kPa, mass flow of ±0.1% and power of ±0.1%. We used a screw compressor of 30RT capacity for an experiment under a constant load, and fixed a slide to maintain the load at a constant level. For a compressor and an evaporator, Shell & Disk type heat exchangers were used. Fig. 2 shows a Shall & Disk type heat exchanger which has advantages of plate heat exchanger as well as make up for disadvantages such as difficulty to use at high pressure or high temperature and reaction between working fluid and rubber gaskets. As a fluid for refrigerant phase change, we used water. To maintain fluid temperature for refrigerant phase change at constant level, we installed a thermostat for automatic control of temperature. For constant maintenance of chilled water in the evaporator, an inverter circulation pump and a flow control valve were installed. To control degree of superheat, we calculated degree of superheat according to suction temperature and pressure of each sensor attached to the outlet of the evaporator and used an electronic expansion valve(6) which automatically controls opening of the valve through PID control to achieve a set-up value. For condensing pressure control, a pressure adjustment valve was used to automatically adjust cooling water flow of the condenser according to set-up pressures through input value of pressure sensor of the top of the condenser, and a flow meter was installed to measure the amount of cooling water flow of the condenser. And, for measurement of refrigerant mass flow, a mass flow meter was installed at the outlet of the receiver and the evaporator.

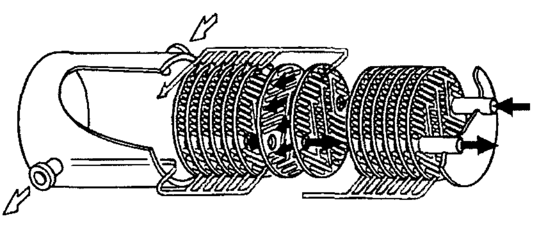


Fig. 2 Details of flow direction in the Disk shell type heat exchanger

2.2 Test Procedure

To maintain external conditions of the system at constant level before a test operation of the refrigerating system, this study operated a thermo-hydrostat and to examine that chilled water flow of the evaporator was being maintained at constant level, we operated a circulation pump for flow check. Before operation of the system, this study compared the value of each measuring instrument attached to the system with the measured value transmitted on-line to check errors, and then monitored operation using a monitoring program. When the operation was stable, the experiments were conducted at every 50kPa in a range from 1500kPa to 1600kPa. For measurement of degree of superheat, experiments were conducted every 1°C in a range from 0°C to 10°C. The degree of superheat was set up using an electronic expansion valve in the beginning of operation, and then a passive expansion valve was used to maintain the exact set-up value at constant level. To improve accuracy of experimental data value, we conducted repetitive experiments, and as a result, experiment values were measured every two seconds through data acquisition system and data were analysed using a computer.

3. Results and Discussion

This study compared COPs based on power and refrigerating capacity according to heat load of condenser, heat load of evaporator, refrigerant mass flow, evaporating pressure, cooling water mass flow and chilled water outlet temperature under each condensing pressure mentioned above and 0~10°C of degree of superheat.

3. 1 Refrigerant mass flow and evaporating pressure

Fig. 3 shows the result that as condensing pressure and degree of superheat increased, refrigerant mass flow decreased.

If condensing pressure increases under the same degree of superheat, compression ratio increases and actual volume of refrigerant vapors discharged by the compressor per hour decreases and volume efficiency of the compressor decreases, which causes decrease of actual mass of the refrigerant vapors discharged per hour by the compressor. Therefore, if condensing pressure increases, refrigerant mass flow decreases because of decrease of volume efficiency.

Fig. 4 shows a result that as degree of superheat increased, evaporating pressure of the compressor decreased. As evaporating pressure of the compressor decreased, equilibrium temperature decreased, accompanied by increased specific volume and decreased volume efficiency, which caused decrease of refrigerant mass flow as seen in Fig. 3. When condensing pressure is increased under the identical degree of superheat, the difference of refrigerant mass flow and evaporating pressure of the compressor was insignificant. It indicates that change of condensing pressure did not have a great influence on refrigerant mass flow and evaporating pressure.

3. 2 Cooling water flow of the condenser and Outlet temperature

Figs. 5 and 6 show cooling water flow of the condenser and outlet temperature. In examining a relation between cooling water flow and outlet temperature, it was found that as cooling water flow increased, outlet temperature decreased. However, as flow decreased, outlet temperature increased. It indicates that it is involved with size of cooling area of condenser.

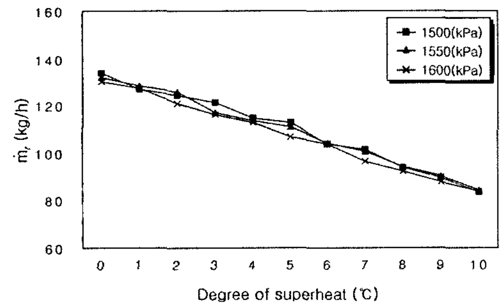


Fig. 3 The relations of refrigerant mass flow and degree of superheat at each condensing pressure

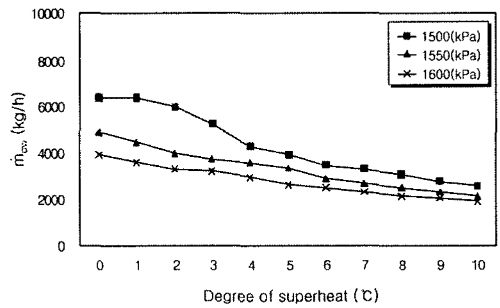


Fig. 5 The relations of cooling water mass flow and degree of superheat at each condensing pressure

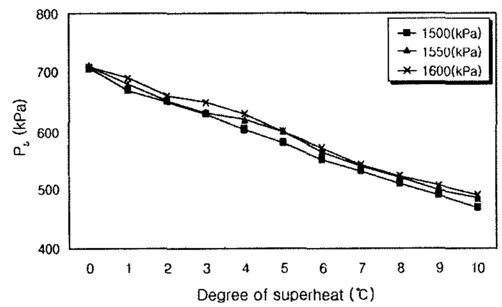


Fig. 4 The relations of evaporating pressure and degree of superheat at each condensing pressure

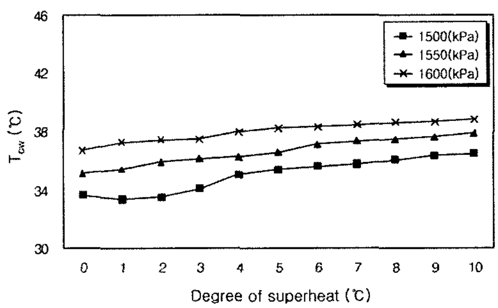


Fig. 6 The relations of cooling water outlet temperature and degree of superheat at each condensing pressure

Fig. 5 shows that as condensing pressure and degree of superheat were lower, cooling water mass flow of the condenser increased. It is because cooling water mass flow increased as mass flow of refrigerants increased.

The degree of superheat ranging from 0°C to 4°C, the lower condensing pressure, the more cooling water flow increased. With a range from 4°C to 10°C of degree of superheat, though condensing pressure decreased, mass flow did not increase much. It is believed that with increase of degree of superheat, enthalpy of refrigerant vapors discharged from the compressor increased and then more mass flow increase should be expected. However, the reason of less increase in spite of its wider range of degree of superheat was that the area of heat resistance of the condenser was wider.

3. 3 Heat load of the condenser

Fig. 7 shows heat load of the condenser measured by cooling water flow and outlet temperature.

As condensing pressure is lower under the same degree of superheat, heat load of the condenser generally increased. It is because volume efficiency of the compressor and refrigerant mass flow increased as condensing pressure was lower. The result was that the higher degree of superheat, heat load of the condenser tended to decrease. The reason of the decrease is presented as follows: as degree of superheat increased, enthalpy of refrigerant vapors discharged from the compressor increased so sensible heat to be removed from the condenser per hour increased, but refrigerant mass flow decreased as seen in Fig. 3.

3. 4 Chilled water temperature of the evaporator outlet and heat load of the evaporator

Figs. 8 and 9 show chilled water outlet temperature of the evaporator and its heat load.

As degree of superheat increased, chilled water temperature increased and heat load of the evaporator generally decreased. Under the identical degree of superheat, when condensing pressure was changed, the difference of outlet temperature and heat load of the evaporator change was insignificant. As condensing pressure increased, heat load of the evaporator decreased accompanied by decreased actual refrigerating effect. The difference in the decreased amount was insignificant. And as condensing pressure increased, refrigerant fluid temperature of the con-

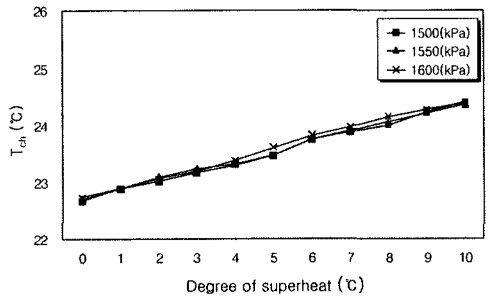


Fig. 8 The relations of chilled water outlet temperature and degree of superheat at each condensing pressure

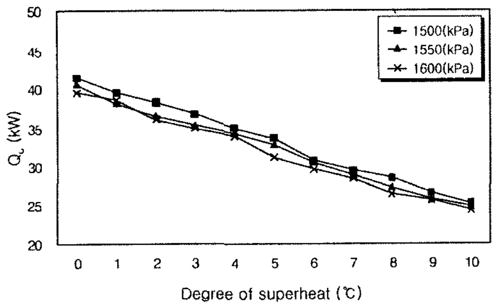


Fig. 7 The relations of condenser heat load and degree of superheat at each condensing pressure

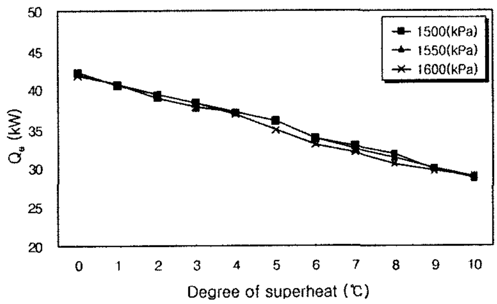


Fig. 9 The relations of evaporator heat load and degree of superheat at each condensing pressure

denser outlet increased, but it was found that temperature difference of refrigerant fluids was very insignificant. Therefore, insignificant difference of enthalpy at the evaporator inlet indicates that change of chilled water outlet temperature and heat load of the evaporator was insignificant. It was believed that temperature difference of refrigerant fluids was insignificant because refrigerant fluid was compressed because of prolonged heat exchange after phase change of refrigerant vapors discharged from the compressor.

3. 5 Power and COP

Figs. 10 and 11 show power and COP. As condensing pressure and degree of superheat increased, power increased. As presented in Fig. 4, power increase is involved with compression ratio according to evaporating pressure. When pressure of the compressor was maintained at constant level and as degree of superheat was increased, refrigerant mass flow evaporated from the evaporator decreased and also evaporating pressure decreased. Therefore, as compression ratio of the compressor increased, power also increased.

Fig. 11 shows experimental results of COP. COP indicates a relation between heat load of the evaporator and power. As condensing pressure and degree of superheat increased, heat load of the evaporator decreased and power increased. Therefore, COP was decreased.

4. Conclusions

Through a study on performance of an ammonia refrigerating system by change of degree of superheat according to condensing pressure, the following results were obtained:

(1) As degree of superheat increased, evaporating pressure of the compressor decreased so equilibrium temperature decreased. And specific volume of refrigerant vapors increased so refrigerant mass flow and heat load of the evaporator decreased.

(2) An influence of change of condensing pressure on heat load of the evaporator was insignificant.

(3) With the identical degree of superheat, change of compressed temperature was insignificant according to each condensing pressure, so there was little change in enthalpy.

(4) With 0°C of superheat, COP was the highest.

Acknowledgement

This study was supported by research grant of Chosun University, 2004

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