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The Study on the Performance Characteristics of NH_3 Refrigeration System using a Shell and Tube Type Heat Exchanger

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Abstract

Nowadays CFC and HCFC refrigerants are restricted because they causes to depletion of ozone layer. Accordingly, an experiment is apply to the NH_3 gas for refrigerant to study the performance characteristic and to improve the energy efficiency. An experiment are carried out for the condensed pressure in a range from 14.5bar to 16bar and for degree of superheat in a range from 0 to 10°C at each condensed pressure. As the result of experiment, when degree of superheat is 1°C and condensed pressure is 14.5bar, the refrigeration system showed the high performance.

Key Words : CFC(chlorofluorocarbon), HCFC(hydrochlorofluorcarbon), NH3, Degree of Superheat, Condensed Pressure, Heat Exchanger

1. Introduction

Refrigerating systems in chemical processing industry have been used for gas separation and liquefaction, separation of necessary matters from compounds, maintenance to prevent excessive pressure of refrigeration fluid and drying or removal of reaction heat(1).

There is a wide variety of refrigerants that can be applied for refrigeration, but for HCFC refrigerants, restrictions are imposed on their production because they are classified as materials that are harmful to earth environment. As alternatives for HCFC, HFC refrigerants have been marketed, but they have some problems such as low heat transfer rate and difficulty in selection of refrigerating oil and materials. In particular, they have high Global Warming Potential(GWP) and are not environmental, which causessuch problem as selection of refrigerants(2~4).

However, natural gases such as ammonia, propane, propylene and hydrocarbon are simple and cheap to obtain as well as environmental.

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In particular, as ammonia can be effectively applied at wide range of temperatures, it has been widely used for chemical processing so that it will be preferred in the future[5]. For ammonia refrigerating system, flooded evaporators are usually used. There also are two types of the flooded evaporators that are commonly used as follows: a chiller method and a direct refrigeration; for the one, brine is refrigerated using evaporating latent heat generated when refrigerating fluid is charged in a heat exchanger; and for the other, refrigerating fluid is charged inside and outside the reactor. However, while operating are changing, much wave of refrigerant fluid inside the evaporator for the flooded evaporator is found. And because it is very difficult to judge status change in vapors of refrigerants incoming into a compressor, operation may be ineffective and abnormal, which causes serious loss of energy and increase in operation expenses.

Therefore, this study conducted a performance experiment on degree of superheat according to compressed pressures using a shell & tube type compressor and a flooded evaporator to identify operation expenses and energy saving.

2. Experimental Equipment and Procedure

2.1 Experimental Equipment

Fig. 1 showed an outline of experimental system for performance study of refrigerators based on changing superheating depending on compressed pressure. This study used ammonia as working fluid for this system, which was composed of a compressor, a condenser, a receiver, a thermostat, an expansion valve and other accessories. Table 1 showed experimental condition.

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 standard to be not affected by external temperature. To measure the 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 in our laboratory to maintain the

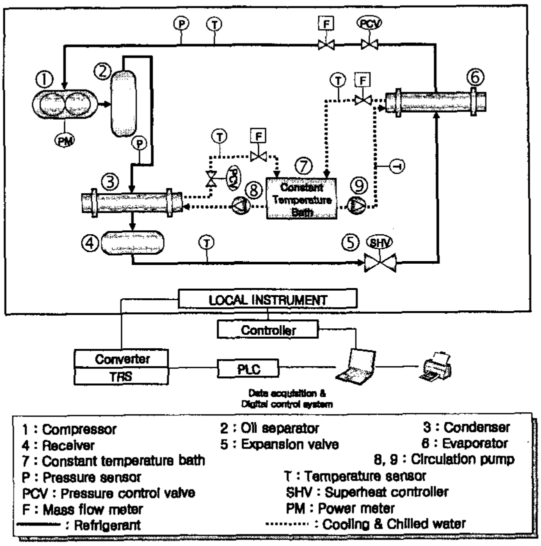

Fig. 1 The schematic of an ammonia refrigeration system

Table 1 Experimental condition

condensed pressure(bar)	14.5~16.0
Degree of superheat(℃)	0~10
Bath temperature(℃)	28
Ambient temperature(℃)	24
Chilled water flow(kg/h)	6800
Cooling & Chilled water	Demineralized water

range of errors of measurements within temperature of ±0.1℃, pressure of ±0.1 bar, mass flow of ±0.1% and power of ±0.1%. We also employed 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 & Tube Type heat exchangers were used. As a fluid for refrigerant phase change, we used water. To maintain fluid temperature for refrigerant phase change at constant level, we installed a 1kW heater and a 3-way flow control valve and 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, it is 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 condensed pressure control, a pressure adjustment valve was used to automatically adjust flow of condenser cooling water 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 mass flow of refrigerants, a mass flow meter was installed at the outlet of the receiver and the evaporator.

2.2 Experimental Procedure

To maintain external conditions of the system at constant level before a test operation of the refrigerating system, in this study, we operated a thermo-hydrostat. To examine that chilled water flow of the evaporator was being maintained at constant level, it is 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 0.5bar in a range from 14.5bar to 16.0bar. For measurement of degree of superheat, were conducted every 1℃ in a range from 0 to 10℃.

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, it is conducted repetitive experiments, and as a result, experiment values were measured every two seconds through data acquisition system and data were analyzed using a computer.

3. Results and Discussion

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

3.1 Refrigerant Mass Flow

Fig. 2 showed that as condensed pressure and degree of superheat increased, mass flow decreased. If condensed pressure increases, 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 condensed pressure increases, refrigerant mass flow decreases because of decrease of volume efficiency. As degree of superheat increased, circulation of refrigerants within the evaporator decreased and refrigerant mass flow decreased. When condensed pressure was 14.5bar and degree of superheat was 1℃, mass flow increased most highly. When degree of superheat was 1℃, as condensed pressure was lower by, mass flow increased, and when degree of superheat was 1℃ rather than 0, mass flow increased more.

It was density of suction vapor and mass flow per volume taken to compressor increased as seen in Fig. 2 when suction pressure of the condenser increased.

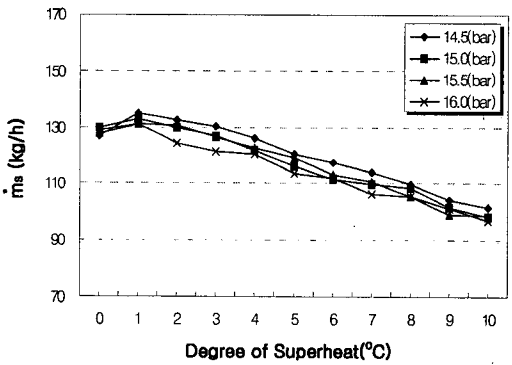

Fig. 2 The relations of refrigerant mass flow rate and degree of superheat at each condensed pressure

3.2 Suction Pressure of the Compressor

Fig. 3 showed the results of the experiment on suction pressure of the compressor. It was found that the lower condensed pressure and degree of superheat, the more suction pressure. When condensed pressure was 14.5bar, as degree of superheat was increased by, suction pressure was lower. And when the pressure was above 14.5bar, degree of superheat was higher, suction pressure was lower. However, there was an insignificant change in suction pressure according to change in condensed pressure.

When degree of superheat was 1℃ and condensed pressure was 14.5bar, the highest suction pressure was found. When degree of superheat was 0 rather than 1℃, suction pressure was low most because of sub-cooled boiling[7]. That is, as boiling occurred at the point where the outside of evaporator tube contacted refrigerant fluid, vapors were generated within the outside of the tube, and the vapors disappeared after they became far off due to heat transmitted to cold refrigerants.

3.3 Cooling Water Flow Rate of the Condenser and Outlet Temperature

Figs. 4 and 5 showed cooling water flow of the condenser and outlet temperature. In examining a relationship between cooling water flow rate and outlet temperature, it was found that increased, outlet temperature decreased as cooling water flow rate. However, as flow decreased, outlet temperature increased. It indicates that

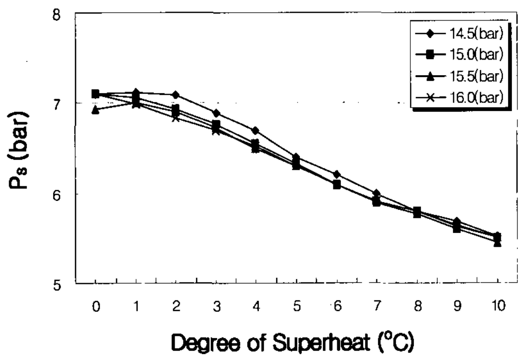

Fig. 3 The relations of suction pressure and superheat temperature at each condensed pressure

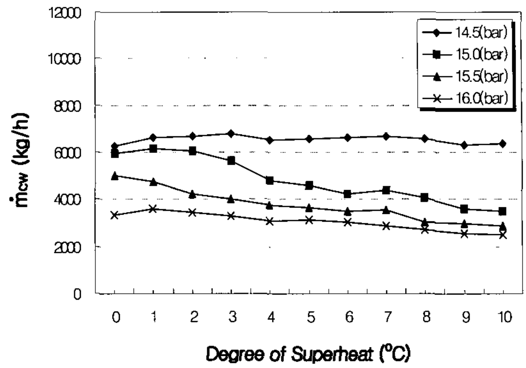

Fig. 4 The relations of cooling water mass flow rate and degree of superheat at each condensed pressure

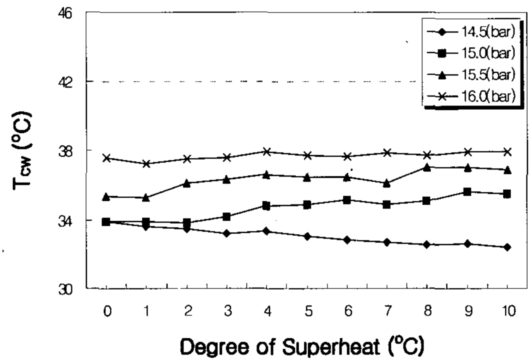

Fig. 5 The relations of cooling water outlet temperature and degree of superheat at each condensed pressure

it is involved with size of cooling area condenser. With 14.5bar and 16.0bar of condensed pressure, there was no significant difference in flow of cooling water and outlet temperature in spite of changing degree of superheat. With 15.0bar and 15.5bar of condensed pressure, and degree of superheat ranging from 0 to 4℃, the lower condensed pressure, the more mass flow of condenser increased. With a range from 4℃ to 10℃ of degree of superheat, though condensed 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.

3.4 Heat Capacity of the Condenser

Fig. 6 showed heat capacity of condenser measured by cooling water flow and outlet temperature. As condensed pressure and degree of superheat increased, heat capacity decreased. As heat capacity is proportionate to refrigerant mass flow and suction pressure, heat capacity of condenser increased in proportion to increase in refrigerant mass flow and suction pressure. It indicates that refrigerant mass flow and suction pressure influenced change of heat capacity of the condenser.

3.5 Chilled Water Temperature of the Evaporator Outlet and Heat Capacity of the Evaporator

Figs. 7 and 8 showed Chilled water temperature of the evaporator outlet and its heat capacity. As condensed pressure and degree of superheat were higher, the outlet temperature was higher and the capacity of the evaporator was lower. The reason of high cold water outlet temperature and low capacity was presented as follows: Refrigerant mass flow incoming into the compressor decreased because of the increased compression rate and the decreased volume efficiency.

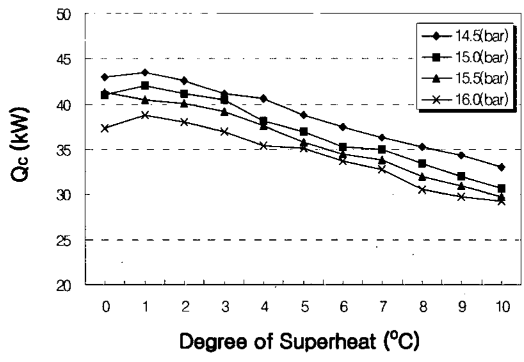

Fig. 6 The relations of condenser heat capacity and degree of superheat at each condensed pressure

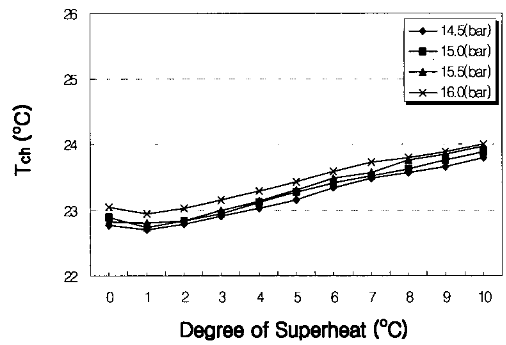

Fig. 7 The relations of chilled water outlet temperature and degree of superheat at each condensed pressure

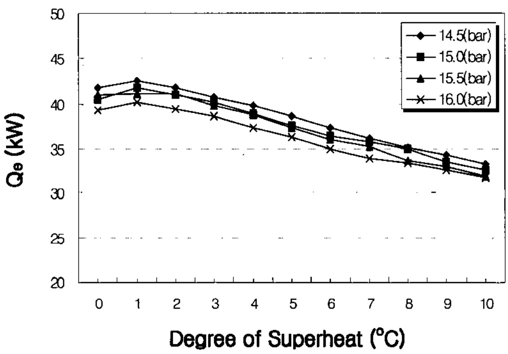

Fig. 8 The relations of evaporator heat capacity and degree of superheat at each condensed pressure

3.6 Power and COP

Fig. 9 showed consumption power of compressor. As condensed pressure and degree of superheat increased, power increased. As presented in Fig. 3, power increase is involved with compression ratio according to suction pressure of the compressor. 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 suction pressure incoming into the compressor decreased. Therefore, as compression rate of the compressor increased, power also increased.

Fig. 10 showed experimental results of COP. COP indicates a relation between heat capacity of the evaporator and power. As condensed pressure and degree of super-

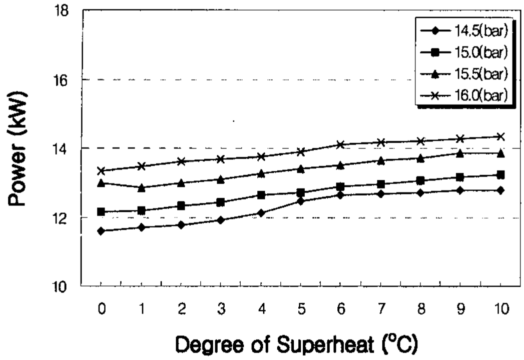

Fig. 9 The relations of power and degree of superheat at each condensed pressure

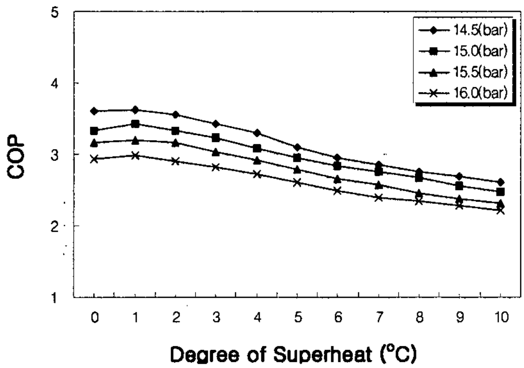

Fig. 10 The relations of COP and degree of superheat at each condensation pressure

heat increased, heat capacity of the evaporator decreased and power increased. With 4℃ to 10℃ of degree of superheat, COP decreased much because the power for compressor increased more than capacity.

4. Conclusions

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

(1) As condensed pressure and degree of superheat were higher, refrigerant mass flow decreased, which caused decrease in capacity of the evaporator.

(2) It was found that refrigerant mass flow and capacity of the evaporator decreased more when degree of superheat was 0℃ than when degree of superheat was 1℃ because of sub-cooled boiling.

(3) As degree of superheat increased, refrigerant mass flow incoming into the evaporator decreased and compression ratio and power increased, which caused much loss of energy.

(4) It was found that for the Shell&Tube Type flooded ammonia refrigerator, 1℃ of degree of superheat is an optimal condition to save operation expenses.

Acknowledgement

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