AMMONIA HEAT PUMP PACKAGE USING WASTE HEAT AS SOURCE

Shuji Fukano, Takanori Kudo, Noriyuki Arata

Mayekawa Mfg. Co.Ltd., 3-14-15 Botan,
Koto-Ku, Tokyo 135-8482, Japan.
Fax: 81-3-3642-8271, e-mail: shuji-fukano @mayekawa.co.jp

ABSTRACT

Not only environmental concerns that make ammonia, one of the oldest refrigerants in industrial use so attractive among old and new users, its excellent thermal properties enables design and installation of systems with high COPs as compared to HFCs. The main disadvantage of ammonia, however, is toxicity, smell and flammability. For this reason, most ammonia refrigeration systems are of indirect type using secondary refrigerants.

A lot of processes in industry as well as district heat supply centers that require heat between 65ºC. and 85ºC., use fossil fuels. Particularly, in industrial process, there is a lot of unused waste heat that can be reused as a heat source for heat pumps. Use of waste heat in heat pump applications not only reduces use of fossil fuel but also contributes to energy conservation.

This paper reports on the development and case study applications of ammonia heat pump packages that use heat sources such as condenser sink heat from existing refrigeration plants, exhaust heat from industrial plants, renewable geothermal energy among others to produce hot water with a maximum temperature of 85ºC.

1. INTRODUCTION

The use of natural refrigerants has attracted considerable interest in the past decade because of the environmental concerns associated with CFC, HCFC and HFCs.

Ammonia is one of the oldest refrigerants in industrial use today and its use will stay and always be of interest to engineers. This is because ammonia is a natural refrigerant with benign effect on the environment and has excellent thermal properties with a potential to offer systems with high COPs. The biggest disadvantage of ammonia, however, is toxicity, smell and flammability.

In order to increase use of ammonia in industrial refrigeration applications, a lot of effort and development have been advanced to reduce refrigerant charge, increase safety and reliability.

Also the heat pump application led to not only reduce use fossil fuel but also contribute to energy conservation, has attracted considerable interest because of environmental concerns.

A lot of processes in industry as well as district heat supply centers that require heat between 65ºC. and 85ºC., use fossil fuels. Particularly, in industrial process, there is a lot of unused waste heat that can be reused as a heat source for heat pumps.

This paper reports on the development and case study applications of ammonia heat pump packages with a motor power 125kW that use heat sources such as condenser sink heat from existing refrigeration plants, exhaust heat from industrial plants, renewable geothermal energy among others to produce hot water with a maximum temperature of 85ºC.

2. AMMONIA HEAT PUMP PACKAGE

2.1 Specification of ammonia heat pump package with a motor power 125kW

Table 1 shows specifications of ammonia heat pump package with a nominal power 125kW. These specifications are as water to water heat pump. This heat pump can be operated by heat source using of discharge gas from compressor in existing refrigeration plants, too.

Maximum producing hot water temperature is 85 ºC in case that heat source water is 45 ºC.

Heating capacity is controlled by rotation speed and number of piston so it keeps high COP operation and stable hot water temperature in set temperature in a condition of low heating demand.

Fig. 1 shows the package which mainly consists of a compressor, condenser, evaporator and surge drum.

Table 1 Specifications of ammonia heat pump package

Type			PH-W	
Refrigerant			Ammonia	
Outlet Hot Water Temperature		ºC	80	85
Capacity	Heating Capacity	kW	430	487
	Required Capacity of Heat source (Cooling Capacity)	kW	334	378
	Absorbed Power	kW	96	109
	COP heating		4.8	4.5
Compressor			Reciprocating Compressor Type: 6HK	
Motor	Type		IPM(open type)	
	Power	kW	125	
Condenser	Type		Shell and Plate	
Evaporator	Type		Shell and Plate	
	Temperature of water (inlet/outlet)	ºC	40/35	45/40
Lubrication oil			ISO-VG100(Immiscible oil)	
Dimension (W*L*H)		mm	1000*3795*2000	
Weight		kg	3600	

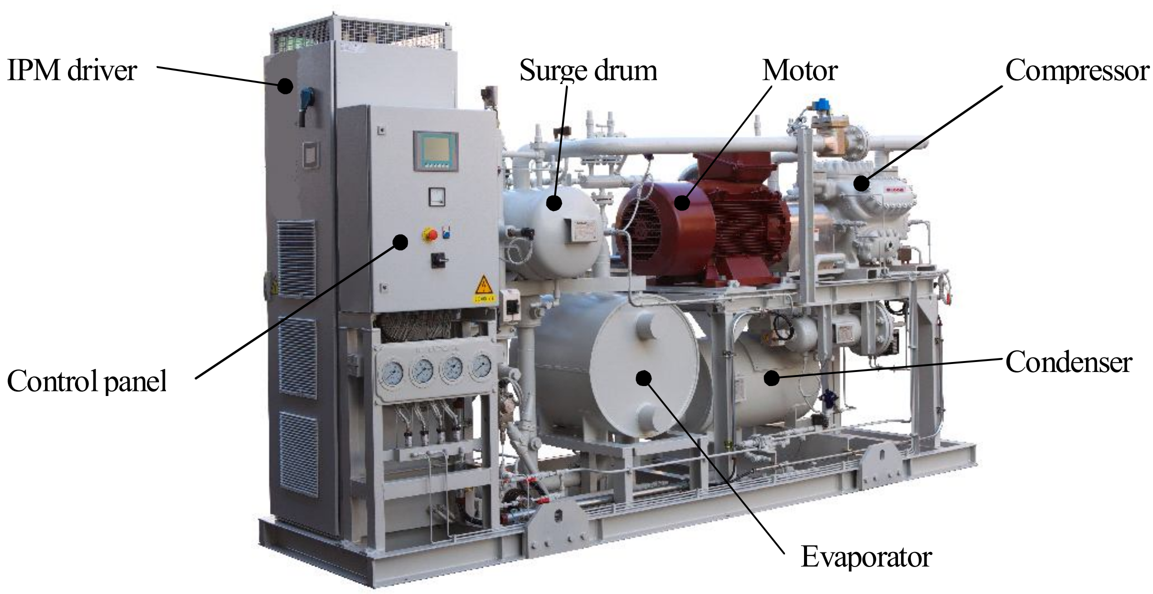

Fig.1 Ammonia heat pump package

Table 2 shows the operating limits of compressor. This compressor can be used up to 5.0 MPaG and in a wide range of pressure and speeds. This ammonia package with this compressor can operates in a wide range of water temperature as shown in Fig. 3.

Table 2 Operating limits of 6HK reciprocating compressor

Item	Limit Value
Maximum discharge pressure[MPaG]	5.0
Maximum suction pressure[MPaG]	2.0
Maximum differential pressure[MPaG]	3.5
Design pressure [MPaG] High / Low press. side	5.6/2.5
Maximum discharge temperature[ºC]	140
Max./Min. rotation speed [rpm]	900/1500

Fig.2 6HK reciprocating compressor

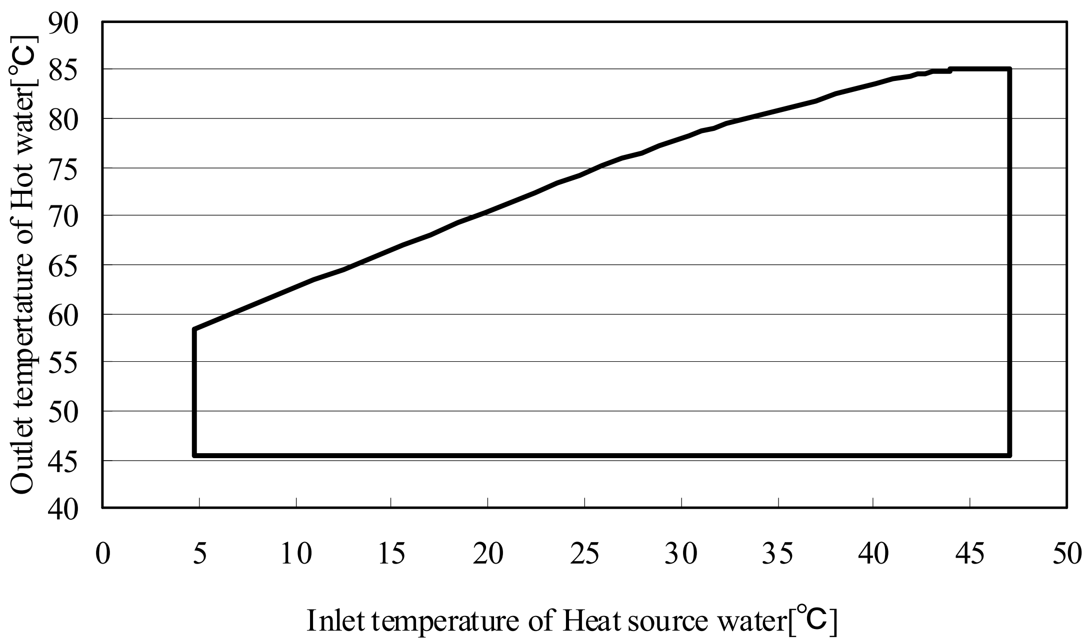

Fig.3 Operating range of ammonia heat pump package

2.2 Influence on heating performance by with/without oil separator

In view of safety improvement, minimisation of components in the heat pump package is one of the effective methods. It was tested influences on performance of heat pump by with and without oil separator. Compared conditions are as follows.

1) Running condition of outlet hot water temperature : 65 ºC
2) Running condition of inlet heat source temperature : 20 ºC, 35 ºC and 40 ºC
3) Flow rate of hot water and heat source water is adjusted to keep 5 ºC differences between inlet and outlet temperature.

Fig.4 shows comparison data of with and without oil separator. Ratio is on the basis of data of with oil separator. .Data of motor power in case of without oil separator is from 1 to 2 % less than with oil separator. And data of heating capacity in case of without oil separator is same or higher than with oil separator.

This result leads in case that oil recovery system from evaporator to compressor works properly, it's not necessary to install any oil separator.

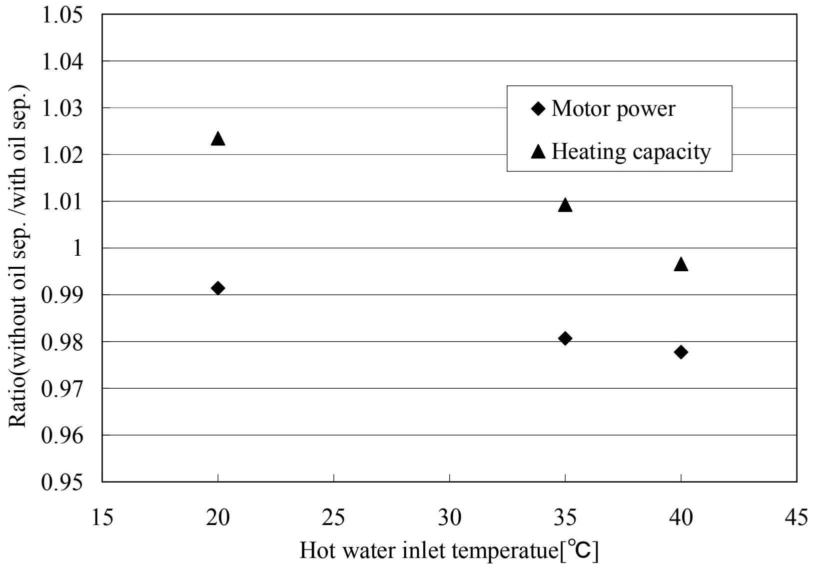

Fig.4 Comparison data of without oil sep. and with oil sep.

3. APPLICATION OF USING WASTE HEAT AS SOURCE

A lot of processes in industry as well as district heat supply centers that require heat between 65ºC and 85ºC, use fossil fuels. Particularly, in industrial process, there is a lot of unused waste heat that can be reused as a heat source for heat pumps. This section reports on annual energy efficiency assessment with application of ammonia heat pump package that use heat sources with condenser sink heat from existing refrigeration plants in food processing factory.

3.1 Flow of the system

In this factory, some chiller package were installed for supplying cold water and secondary refrigerant to such as cold storage room, freezing rooms and air conditioning packages. These condenser sink heat that is continuously more than 500kW is cooled by a cooling tower. Hot water of 65 ºC is consumed about 100m^3 per day for processing, washing equipments and so on. Makeup water is heated by a gas boiler.

One set of water to water ammonia heat pump system using heat sources with condenser sink heat is applied as a substitute for this hot water supply system. Fig. 5 shows this heat pump system which mainly power equipments of a heat pump, water pump between cooling tower and heat pump, water pump between heat pump and heat exchanger and water pump between heat exchanger and hot water storage tank.

In addition, this application is indirect system with heat exchanger between heat pump and hot water storage tank at the same time direct system is also available depends on safety system for ammonia.

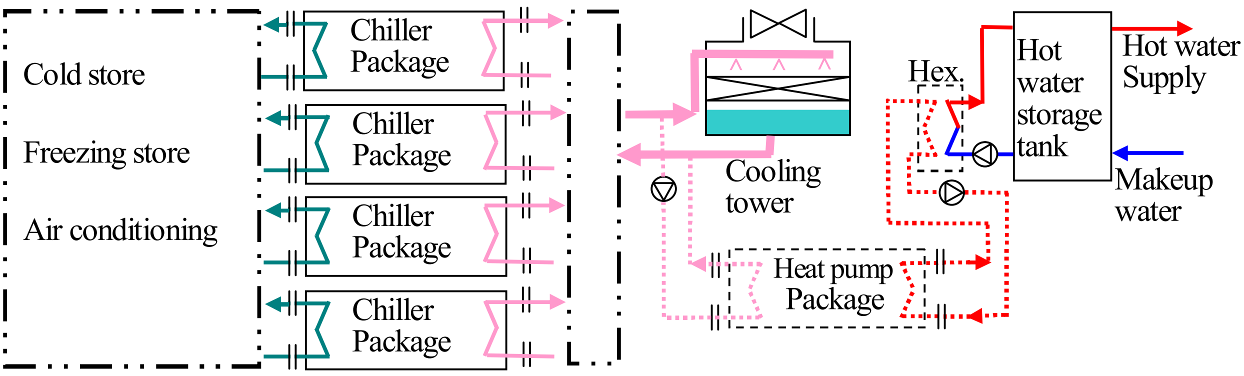

Fig. 5 Water to water ammonia heat pump system using heat sources with condenser sink heat

3.2 Condition

Table 3 shows condition of existing cooling and heating system.

Fig. 6 shows hourly consumption of hot water. This data leads heat pump must run more capacity than demand in night time and break time and storage hot water tank so as to cover the peak of hot water consumption.

Table 3 Condition of existing system

Hot water consumption [m^3/day]	100
Hot water temp. [ºC]	65
Makeup water temp. [ºC]	15
Annual working days [days]	264
Condenser sink heat of chiller packages [kW]	500 or more
Gas boiler efficiency	0.95
Gas calorific value [MJ/Nm3]	40.63

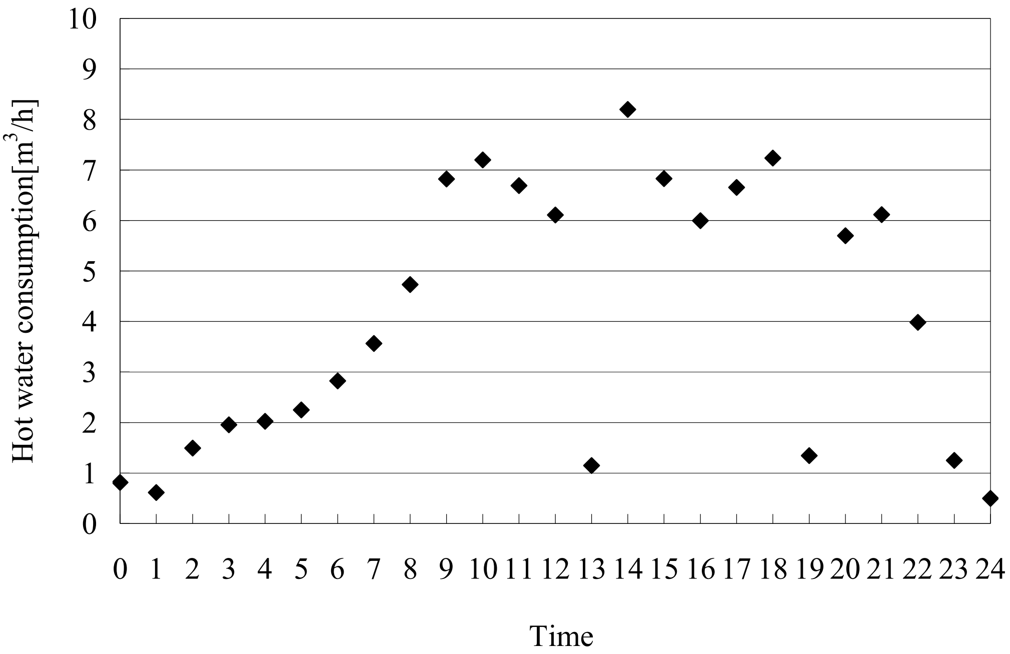

Fig. 6 hourly consumption of hot water

Table 4 shows running condition of heat pump. Inlet and outlet heat source water temperature is assumed same as outlet and inlet water temperature of existing chiller packages.

There are three seasonal running conditions of heat pump since the outlet water temperature from cooling tower has seasonal variations.

Table 4 Running condition of water to water ammonia heat pump

	Hot water temp. / Inlet of heat pump [ºC]	62
	Hot water temp. / Outlet of heat pump [ºC]	67
Winter season (January, February, December)	Heat source water temp. / Inlet of heat pump [ºC]	25
	Heat source water temp. / Outlet of heat pump [ºC]	20
	Heating capacity [kW]	290.7
	Electric power incl. water pumps and etc. [kW]	80.6
Summer season (June, July, August)	Heat source water temp. / Inlet of heat pump [ºC]	35
	Heat source water temp. / Outlet of heat pump [ºC]	30
	Heating capacity [kW]	408.3
	Electric power incl. water pumps and etc. [kW]	86.4
Mild season (March, April, May, September, October, November)	Heat source water temp. / Inlet of heat pump [ºC]	30
	Heat source water temp. / Outlet of heat pump [ºC]	25
	Heating capacity [kW]	346.4
	Electric power incl. water pumps and etc. [kW]	84.1

3.3 Results

Table 5 shows results of application of water to water ammonia heat pump system. Annual running hour is 4566h. Running hour in a day has seasonal difference since heating capacity of heat pump is depending on outside air temperature. This application leads 1240102 kWh of waste heat form cooling tower to atmosphere in a year transfer to hot water. Furthermore high annual performance factor can be achieved.

Table 6 shows comparison of annual primary energy consumption and CO_2 emission. Annual gas consumption of boiler is calculated by based on 100 m^3 per day as same condition as heat pump system. This application can be achieved 37% reduction of primary energy consumption and 61% reduction of CO_2 emission.

Table 5 Results of application of ammonia heat pump system

Running hour per day in winter season [h/day]	20
Running hour per day in summer season [h/day]	15
Running hour per day in mild season [h/day]	17
Annual running hour [h]	4566
Annual calorie for heating[kWh]	1566128
Annual calorie of heat recovery from chilling packages [kWh]	1240102
Annual electric power consumption include water pumps etc. [kWh]	381431
Annual Performance Factor[-]	4.11

Table 6 Comparison of annual primary energy consumption and CO_2 emission

Gas consumption of boiler [Nm^3]	146068
Primary energy consumption of gas boiler [MJ]	5934735
CO_2 emission by use of gas boiler [kg-CO_2] *1	319889
Primary energy consumption of heat pump system [MJ] *2	3722763
CO_2 emission by use of heat pump system [kg-CO_2] *3	123584
Primary energy reduction ratio by heat pump system[%]	37
CO_2 emission reduction ratio by heat pump system [%]	61

*1: Gas CO2 emission value 2.19 kg-CO_2

*2: Electricity primary energy 9.76 MJ/kWh

*3: Electricity CO2 emission value 0.324 kg-CO_2

4. CONCLUSIONS

This paper reports on the development and case study applications of water to water ammonia heat pump packages that use heat sources as condenser sink heat from existing chiller packages.
This ammonia package with the reciprocating compressor which can be used up to 5.0 MPaG and in a wide range of pressure and speeds has various applications to hot water supply system. Also this package can use a lot of and various heat sources.

Moreover, ammonia heat pump which uses natural refrigerant will contribute to further reduce environmental impact by improvement of efficiency, safety and reliability.

5. REFERENCES

1. N. Arata, Technical report of high temperature ammonia heat pump package, 2010, Japan
2. N. Mugabi, Ammonia Refrigeration Technology of IIR International Conference, Semi hermetic and hermetic ammonia compressor packages, 2009, Macedonia
3. A Publication of the International Institute of Ammonia Refrigeration, Condenser, November 2009, Industrial heat pumps, 4-7p. and 23-26p.