DEVELOPMENT OF A HIGH EFFICIENCY ABSORPTION CHILLER-HEATER AND A COMPACT ABSORPTION CHILLER-HEATER

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1. INTRODUCTION

Growing concern on the global warming has called for great necessity for energy saving. This applies very well to gas-fired absorption chiller-heaters, which need to be competitive to electric heat pump systems. Regulations to aim for strict energy conservation are expected to be severer in the future, requiring development of innovative absorption chiller-heaters. We started the development of a high efficiency gas-fired double-effect absorption chiller-heater using LiBr-H_2O to meet short or middle term target performance. The target performance has been set at cooling COP of 1.35 (on HHV), which is 0.35 higher than the COP of 1.0 for conventional machines in the market. This COP of 1.35 is believed to be very challenging, practically close to the maximum limit achievable by gas-fired double-effect absorption chiller-heater system using LiBr-H_2O.

Along with the development of a high efficiency machine, efforts have been put on the development of a compact gas-fired absorption chiller-heater suitable for renewal or replacement of existing old units. In Tokyo metropolitan area, for example, the stock-basis air-conditioning capacity for large-scale buildings (larger than 3,000m^2 in floor area) amounts to about 12×10^6 kW(3.4×10^6 USRT) in total, about 4.9×10^6 kW(1.4×10^6 USRT) of which is provided by electric system such as the centrifugal chillers. Considering that Tokyo area covers roughly one third of entire Japanese economy, there is huge potential market for replacing old chillers to new units. Since air-conditioning market for newly build buildings has substantially reduced due to recent economic recession in Japan, more attention has been targeted to the replacement of existing large-scale centrifugal chillers to compact absorption chillers. We started the development of a compact absorption chiller-heater with 50% reduction in volume. The new compact absorption chiller-heater requires almost the same installation space as centrifugal chillers, with its installation substantially simplified.

While having different targets, the two new absorption chiller-heaters are based on common key technologies principally applicable to the compact chiller-heaters as shown in Figure 1. Therefore the R&D has been conducted simultaneously.

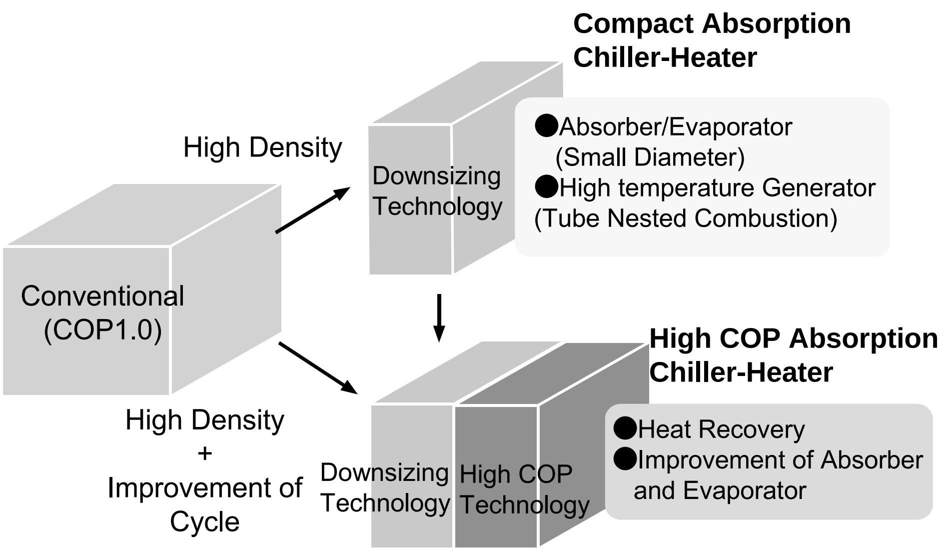


Figure 1. Relation of Each Development

2. Target Specifications

The target specifications of the developments are shown below.

(1) High efficiency absorption chiller-heater

・ COP: 1.35 (at cooling) and 0.88 (at heating)

・ Volume: equal to the conventional machine

・ Manufacturing cost: less than 110% of the conventional machine

・ Capacity: 100-500USRT

・ Commercialization time: Fiscal year of 2002

(2) Compact absorption chiller-heater

・ Volume: 50% of the conventional machine

・ COP: equal to the conventional machine (COP=1.0)

・ Manufacturing cost: less than 80% of the conventional machine

・ Capacity: 100-500USRT

・ Commercialization time: Fiscal year of 2002

3. Development of High Efficiency Absorption Chiller-Heater

3.1. High Efficiency Technology

Figure 2 shows the cycle flow of the high efficiency absorption chiller-heater. Technologies used in the development are classified into the following three categories.

(1) Heat recovery in the cycle

COP is increased by the improvement of the heat recovery efficiency of the following element in the cycle.

・ Improvement of the thermal efficiency of the solution heat exchanger

・ Installation of a refrigerant heat exchanger

・ Installation of a solution cooling absorber

(2) Improvement of absorber and evaporator

The following improvements of the absorber and evaporator increase the difference in the solution concentration and decrease the absorption solution circulation rate. The sensible heat loss in the cycle is reduced, improving COP.

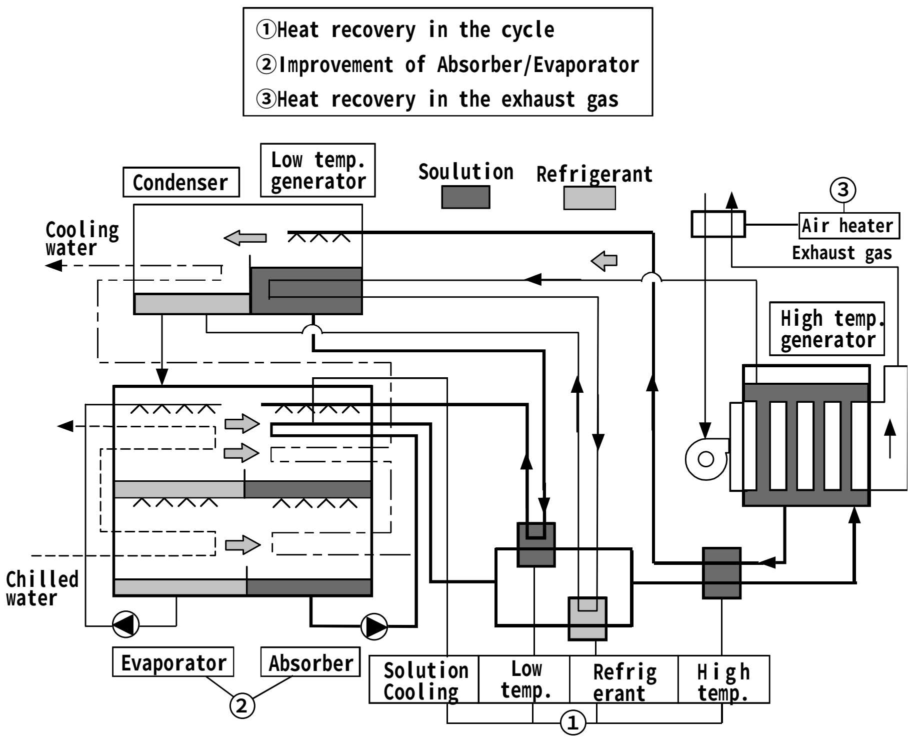


Figure 2. Cycle Flow of High Efficiency Absorption Chiller-Heater

・ Two stage absorption and evaporation

・ Improvement of the KA value of the absorber and evaporator (K: overall heat transfer coefficient, A: heat transfer area)

・ Large temperature difference between the inlet and outlet of the chilled water

(3) Heat recovery from the exhaust gas

COP is improved by preheating the combustion air or the absorption solution with the exhaust gas.

・ Installation of air preheater (New installation of solution preheater)

3.2. Setting of Target COP of High Efficiency Absorption Chiller-Heater

We have examined the limit of the COP of the double-effect absorption machine to which the above-mentioned high efficiency technologies is applied in order to set the target COP of high efficiency absorption machine. First, the COP of the machine to which the following technologies is applied maintaining the KA value of each component to the conventional value has been calculated by using the cycle simulation.

・ Two stage absorption and evaporation

・ Enlargement of temperature difference between the inlet and outlet of the chilled water (Chilled water temperature is changed from 12 - 7 ℃ to 15 – 7 ℃)

・ Installation of a refrigerant heat exchanger (Thermal efficiency = 0.95)

・ Installation of a air preheater (Boiler efficiency = 0.87)

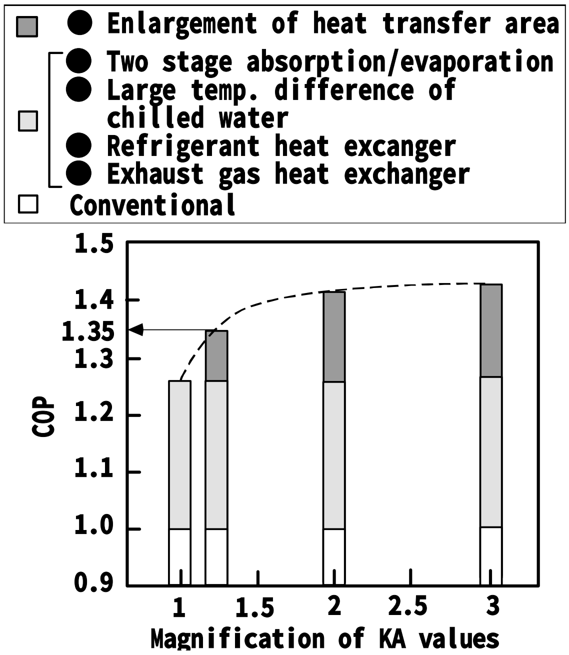


Figure 3. Effects of Increase of KA Value on COP

Next, the relation between the COP of the machine and the KA value of each component (absorber, evaporator, condenser, low-temperature generator, solution heat exchanger) has been examined. Figure 3 shows the result. The horizontal axis shows the magnitude of the KA value to that of the conventional machine. It is found that the limit of the COP is about 1.42 at which the COP hardly increases, and the rate of increase has slowed down from about 1.35. Therefore the target COP of the high efficiency absorption machine has been set as 1.35.

3.3. Effect of Each High Efficiency Technology

Figure 4 shows the result of comparing the effect of each high efficiency technology when COP of 1.35 is achieved. The effect of each technology classified into three categories of the above-mentioned is shown as follows. The value in parentheses shows the improvement rate of the COP.

(1) Heat recovery in the cycle (0.20)

・ Solution heat exchanger (0.12)

・ Refrigerant heat exchanger (0.06)

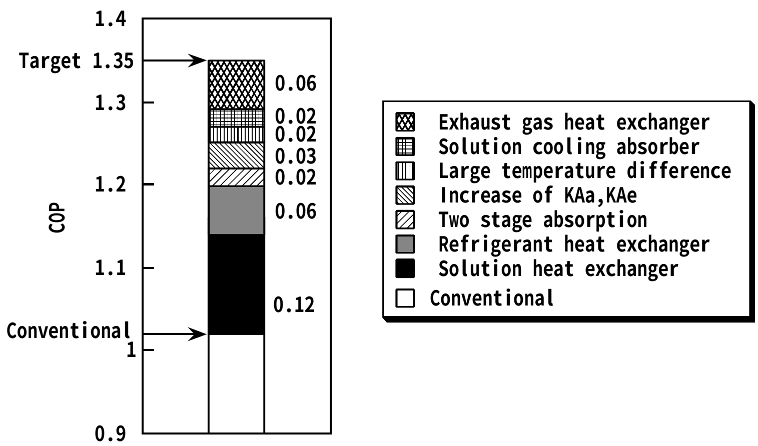


Figure 4. Effects of Each High Efficiency Technology

・ Solution cooling absorber (0.02)
(2) Improvement of absorber and evaporator (0.07)
・ Two stage absorption and evaporation (0.02)
・ Improvement of the KA value of the absorber and evaporator (0.03)
・ Enlargement of temperature difference between the inlet and outlet of the chilled water (0.02)
(3) Heat recovery from the exhaust gas (0.06)
・ Installation of air preheater (0.06)

As the result, it is found that the effect of the heat recovery in the cycle is the largest and the improvement of the thermal efficiency of the solution heat exchanger is very important. On the other hand, the effect of the improvement of the absorber and evaporator is also necessary to achieve COP of 1.35 though is less than that of the heat recovery in the cycle. Moreover, the improvement of the absorber and evaporator contributes to making of the solution heat exchanger compact due to the decrease of the solution circulation rate.

Though these technologies are expected to achieve the target COP, the downsizing technology is needed to make the volume of the high efficiency machine equal to that of the conventional machine. Next, the development of the compact technology is described.

4. Development of Compact Absorption Chiller-Heater

Absorption chiller-heater consists of six key components as shown in Figure 5. Three principal components, which occupy major volume of the unit, have been focused in the development of the compact machine.

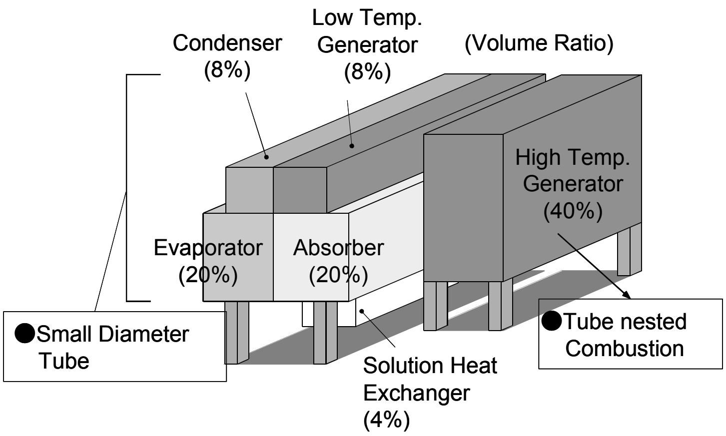


Figure 5. Components of Absorption Chiller-Heater

4.1. Absorber and Evaporator

Downsizing technology as shown in Figure 6 has been proposed to make conventional shell-and-tube absorber and evaporator compact.

The outline of downsizing technology is shown as follows.

(1) Small diameter tube type

Figure 7 shows the concept of the small diameter for measurement of the heat transfer performance. The point of this type is as follows:

・ Reduction of the volume of channels for chilled and cooling water
・ Enhancement of heat transfer by high performance tubes
・ Denser arrangement of tubes by the reduction of tube pitch and the plover arrangement

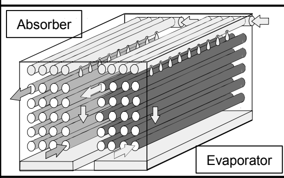
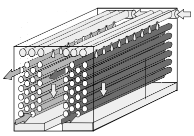
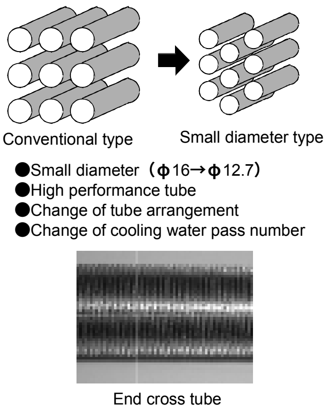
Type	Conventional (Shell&Tube)	Small Diameter Tube
Structure		
Shape	Φ16 Conventional Tube	Φ12.7 End cross tube
Heat transfer performance	100%	120〜150%
Volume	100%	45%

Figure 6. Comparison of Downsizing Technology of Absorber and Evaporator

Figure 8 shows heat transfer performance of the absorber and the evaporator. The evaluation of compactness is examined by using the K value enclosed with circle in this figure.

The reduction in the volume has been evaluated as shown in Figure 8. This technology is expected to reduce the volume by more than 50%.



■Small diameter tube

Figure 7. Small Diameter Type Absorber and Evaporator

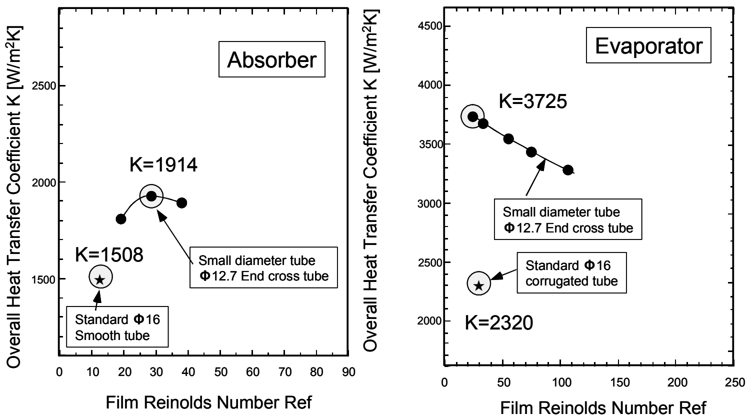


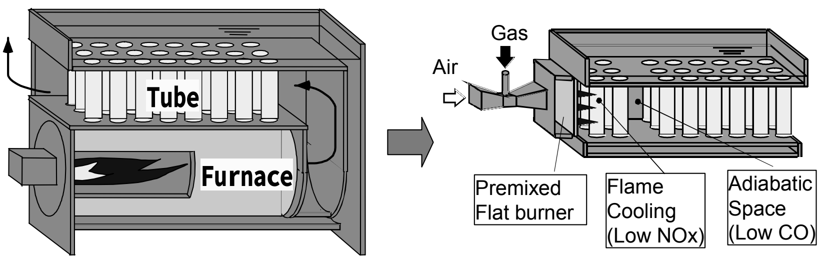
Figure 8. Heat Transfer Performance of Absorber and Evaporator

4.2. High Temperature Generator

Downsizing Technology has been proposed to make conventional furnace-and-tube type high temperature generator compact as shown in Figure 10. The concepts are shown as follows:

(1) Tube-nested combustion type

・ High intensity combustion generated by premixed flat burner



■Furnace & tube type (Conventional) ■Tube-nested combustion type

Figure 9. Compact High Temperature Generator

・ Low NOx emission by rapid flame cooling created by the front tubes

・ Low CO emission by enhanced oxidation in the adiabatic space

Combustion performance was tested and exhaust gas pressure loss and the maximum temperature of the heat transfer surface were measured. Table 2 shows the results. This technology is expected to meet the target performance in terms of the maximum temperature of the heat transfer surface and compactness. The tube-nested combustion type generates relatively high pressure loss across the furnace, requiring a high pressure air blower and a venturi-mixer to accommodate the low-pressure supply gas of 1.5kPa. Later phase of the development will focus on the solution of various problem identified.

Table 1.Comparizon of Downsizing Technology of High Temperature Generator

Type	Conventional (Furnace and tube)	Tube-nested combustion
Turn down ratio / NOx	1:4 / 60ppm	1:4 / 30ppm
Pressure loss	1.2kPa	3.3kPa
Max temp. of heating surface	≦ 200℃	186℃
Volume	100% (Conventional=100)	50%

※Upper limit temp.of corrosion against LiBr solution

5. R&D Schedule

Table 2 shows R&D schedule of this project. This R&D is a joint project collaborated by Tokyo Gas, Osaka Gas, Toho Gas and several manufacturers(Hitachi Industries and Sanyo Electric Air

Conditioning). The development of key components described in this paper was completed in the fiscal year of 1999. Demonstration tests and durability tests for prototype machines were completed in the fiscal year of 2000 and 2001. And the high efficiency type machine and the compact type machine were commercialized in the fiscal year of 2002 respectively.

Table 2 R&D Schedule

	Themes	1998	1999	2000	2001	2002
High Efficiency Type And Compact Type	Fundamental Development (Simulation & Component)	→	→			
	Development of Prototype Model(Phase 1)			→		
	Development of Prototype Model(Phase 2)				→	
	Durability Test				→	→
	Commercialization					▲

6. Specification of Products

Table 3-4 show specification of products.

Table 3 Specification of High Efficiency Type Machine

Manufacturer	Hitachi Co., Ltd.	Sanyo Electric Air Conditioning Co., Ltd.
Cooling Capacity	422～1055kW 7 series	352～2813kW 14 series
COP(Cooling)	1.35	
COP(Heating)	0.88	
Volume	Equal to the conventional machine	
Chilled Water Temperature	15→7℃	
Cooling Water Temperature	32→37℃	
NOx emission	60 ppm (@O_2=0%)	

Table 4 Specification of Compact Type Machine

	Hitachi Co., Ltd.
Cooing Capacity	422～1055kW 7 series
COP(Cooling)	1.01
COP(Heating)	0.86
Volume	60% of the conventional machine
Chilled Water Temperature	12→7℃
Cooling Water Temperature	32→37.5℃
NOx emission	60 ppm (@O_2=0%)

7. Conclusion

The following results were obtained by using the high efficiency technology and the downsizing technology in the development of the high efficiency absorption chiller-heater and the compact absorption chiller-heater.

(1) The limit of the COP of the double-effect absorption chiller-heater has been examined by using the cycle simulation, and the target COP has been set as 1.35.

(2) COP1.35 has been achieved by test machines which have the same volume as the conventional machine.

(3) It has been found that the volumes of the absorber, the evaporator, and the high temperature generator which occupy major volume of the unit are reduced to 50% by applying the downsizing technology. Moreover, it is expected that this technology can make the volume of the high

efficiency machine equal to that of the conventional machine.

(4) The volume of a test machine has been able to be downsized to 60% of the conventional machine.

It is hoped that the commercialization of high efficiency and compact type absorption chillers will promote energy conservation and increase sales in the air-conditioning market.

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