STEAM GENERATION SYSTEM USING WASTE HOT WATER

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Abstract: By utilizing normally 80 to 90℃waste hot water as one of heat sources, we have developed and commercialized “Steam generation system”, which generates 0.3 to 0.6MPa(G) steam to be usable for a heat source of other processes. Low temperature hot water such as 80 to 90℃ discharged from factories or jacket cooling water from cogeneration system will be often wasted because its temperature is too low to utilize in factories for heating, drying and so on.
As a conventional technology, absorption heat pump can generate high temperature hot water or low pressure steam. However the pressure of the steam generated only by absorption heat pump is too low to utilize in various ways. On the other hand, low pressure steam can be raised by steam ejector that is driven by high pressure steam.
In this system, firstly absorption heat pump is driven by 80 to 90℃ hot water to generate 0.1 to 0.2MPa(G) low pressure steam, and then the low pressure steam is pressurized by steam ejector to 0.3 to 0.6MPa(G).
We EBARA cooperated with Tokyo Gas, MIURA for this development.

Key Words: Absorption cycle, Temperature boosting, Steam generating, Steam ejector

1 INTRODUCTION

In late years, utilization of the waste heat advances backed by the saving energy promotion of an industrial instrument and the system, and the high temperature waste heat is used for various processes by an exhaust gas boiler or an absorption refrigerator. On the other hand, the low temperature waste hot water less than 100℃ is often released without being used, because its temperature is too low to utilize in most industrial process of factories and it can be used only for air heating and preheating of the boiler feed water.
As a conventional technology using such a waste hot water effectively, the second kind absorption heat pump(Takada 1982) is known, and

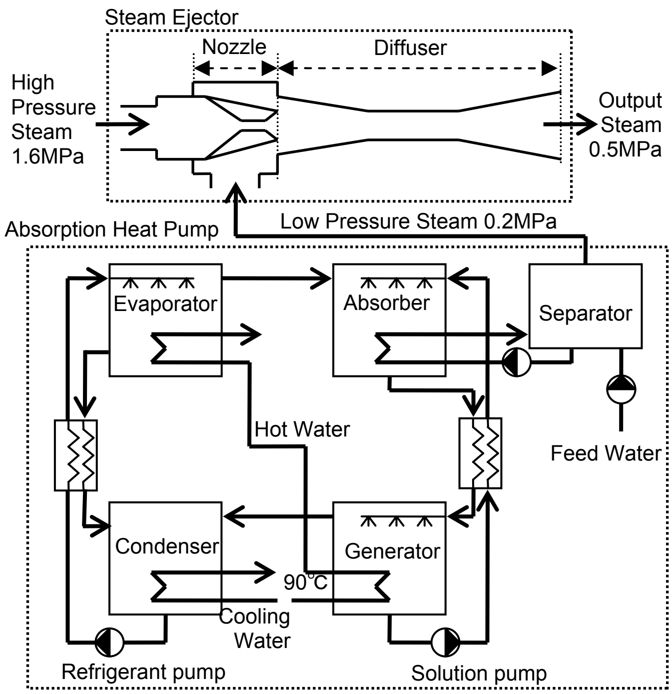

Figure 1: Schematic Diagram of Steam Generation System

the simulation about the specifications of the heat exchanger(Kashiwagi et al. 1986), the consideration of the heat pump which used solar heat(Nomura et al. 1989)(Nomura et al. 1990), optimization by theoretical analysis and the simulation for the cycle(Inoue et al. 2005), an experimental test and the analysis(Fukusumi and Inoue 2005) are reported.
However, the pressure of the steam generated by absorption heat pump using hot water of 80 to 90 ℃ is too low with 0.1 to 0.2MPa(G) to utilize in various ways.
In this system, firstly absorption heat pump is driven by 80 to 90℃ hot water to generate 0.1 to 0.2MPa(G) low pressure steam, and then the low pressure steam is pressurized by steam ejector to 0.3 to 0.6MPa(G). As steam of this pressure range has much demand in a factory process, it is intended to reduce fossil fuel used in a boiler.
In this paper, we explain the above-mentioned system, an example of the application, and a proof examination.
We EBARA cooperated with Tokyo Gas, MIURA for this development.

Table 1: Spec Example of Steam Generation System

Term		Summer	Other Season
Hot Water	Heat Sourse	Waste Hot Water Jacket Cooling Water of Cogeneration	
	Amount	305kW	377kW
	Inlet Temp.	90℃	
	Outlet Temp.	85℃	84℃
	Flow Rate	52.8m^3/h	
Cooling Water	Inlet Temp.	32℃	28.5℃
	Outlet Temp.	35℃	32.1℃
	Flow Rate	45.6m^3/h	
High Pressure Steam	Pressure	1.6MPa	
	Temp.	204℃	
	Flow Rate	790kg/h	
Output Steam	Pressure	0.5MPa	
	Temp.	159℃	
	Flow Rate	1005kg/h	1055kg/h
Feed Water	Temp.	60	
Electric Source		8.5kVA	

2 CONSTITUTION OF SYSTEM

This system is made up of absorption heat pump which produces low pressure steam from waste hot water, steam ejector which pressurizes the low pressure steam and control unit. There are example of the system specification in Table 1, internal flow in Figure 1, external drawing in Figure 2.
Hereinafter, we explain the second kind absorption heat pump and steam ejector which are the main constitution apparatus of this system.

2.1 Second Kind Absorption Heat Pump

The main constitution apparatus of the second kind absorption heat pump is the same as a general absorption refrigerator, it is an evaporator, an absorber, a condenser, a generator, a solution heat exchanger, a refrigerant heat exchanger, a solution pump and a refrigerant pump.
Below we explain the absorption heat pump cycle in detail. The solution is concentrated in the generator and the strong solution is pressurised with the solution pump and flow into the absorber via the heated side of the solution heat exchanger. The strong solution sprayed on

a heat exchanger tube of the absorber absorbs refrigerant vapor flowing in from the evaporator and generates absorption heat. The heat vaporizes the inside feed water of the heat exchanger pipe. The solution is attenuated in the absorber and the weak solution is pressurised with the solution pump and flow into the generator via the heating side of the solution heat exchanger. The weak solution sprayed on a heat exchanger tube of the generator is heated by waste hot water flowing in the tube, and the solution is concentrated with generating refrigerant vapor. Solution cycle goes around in this way. The refrigerant vapor generated in the generator flows into the condenser, and it is cooled off by cooling water in the heat exchanger pipe and condenses to refrigerant liquid. The refrigerant liquid is pressurized with the refrigerant pump and sprayed on a heat exchanger tube of the evaporator. Sprayed refrigerant liquid is heated and evaporated by waste hot water flowing in the tube, and refrigerant vapor flows into the absorber. The above-mentioned absorption heat pump cycle is expressed as during chart in Figure 3.

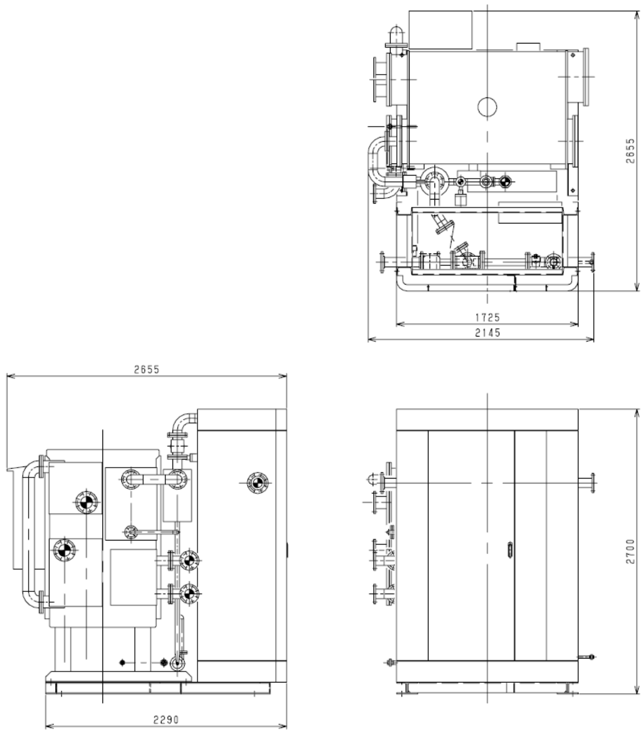

Figure 2: General View of the System

In this way, waste hot water is supplied to generator and evaporator, and cooling water is supplied to condenser, so that the absorber is increase in temperature and can generate steam.

The feature of the absorption heat pump is what can produce a high temperature by waste hot water itself as a drive source. Its theoretical coefficient of performance (steam generating heat output / waste hot water heat input) is about 0.5.

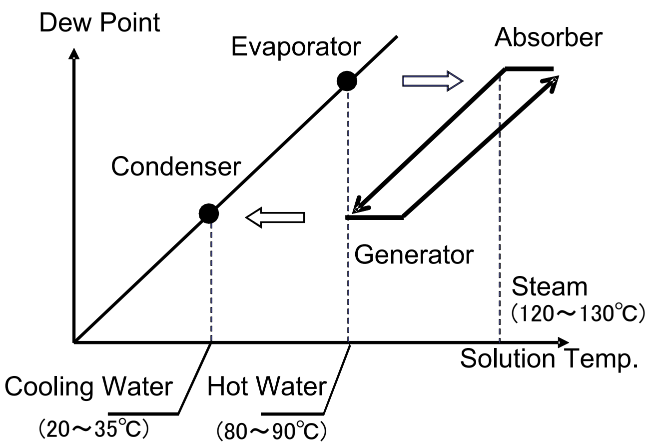

Figure 3: Dühring chart of Absorption Heat Pump Cycle

2.2 Steam Ejector

Steam ejector is constructed as a main part with a nozzle and a diffuser, and can pressurize low pressure steam by high pressure steam as a drive source. The high pressure steam is jetted at super sonic speed by a nozzle and suck in low pressure steam. Both steam is mixed in the diffuser and slow down as the cross-sectional area of the diffuser increases, and its pressure rises gradually. As a result, pressure of the output steam is rised higher than sucked low pressure steam. Steam ejector has the high durability and reliability for the simple structure that has no moving parts.

3 EXAMPLE OF APPLICATION

As this system can generate steam from waste hot water, a target is a customer who there is not a use of the hot water, and cannot make good use. There can get a hot water from the jacket cooling water of the gas engine cogeneration system, or steam drain. In addition, hot water can be gotten from downstream gas of the exhaust gas boiler, coolant of an industrial furnace and an industrial process. It is effective to make it steam to a use. There are example of system application and energy balance when assumed input of 100 in Figure 4 and Figure 5.

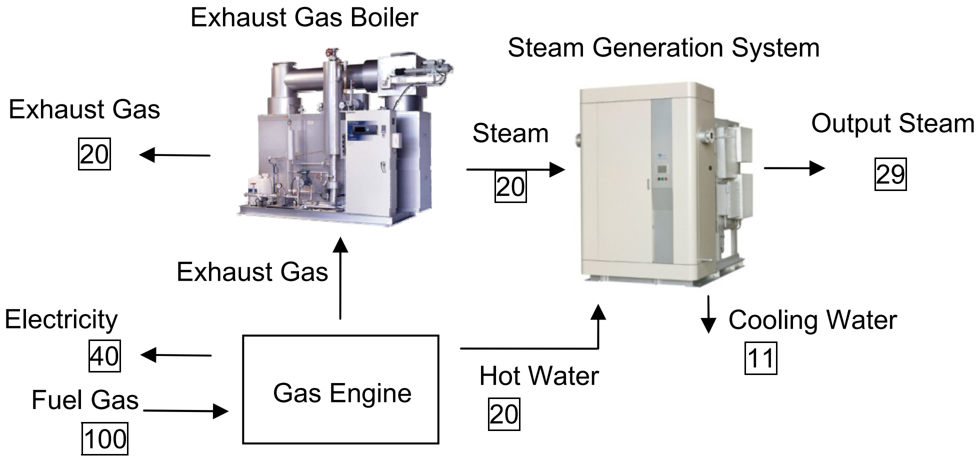

Figure 4: Schematic Diagram of Cogeneration System

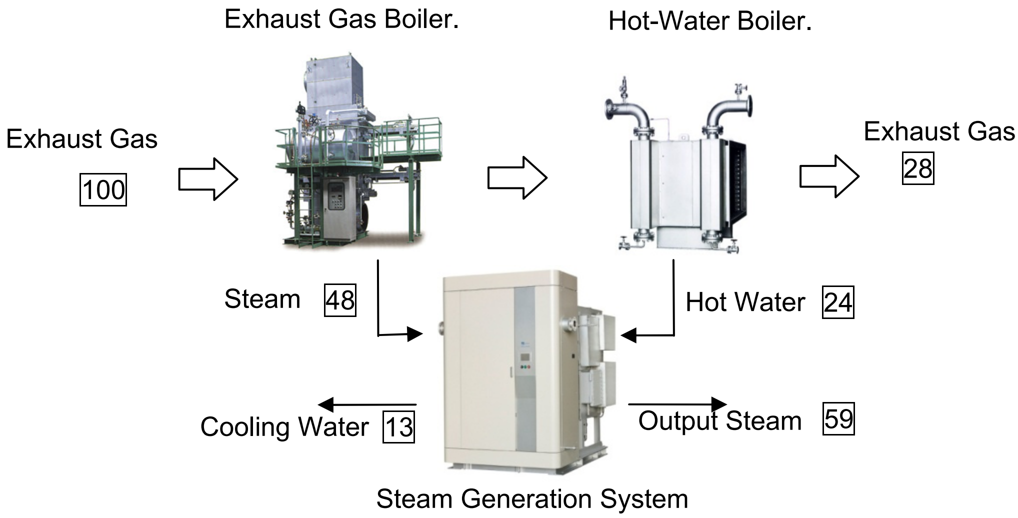

Figure 5: Schematic Diagram of Waste Gas Recovery System

4 PROOF EXAMINATION

4.1 Performance Test

We produced the testing equipment of this system and carried out a performance test in-house. There are the design specifications of the system and the result of the performance test with the actual machine in Table 2. Through the test, we confirmed that the performance of this system met design specifications. The dryness of output steam was more than 99% and it was kept even when the cooling water temperature was fluctuated by start or stop of the cooling tower. In addition, this design specification is decided to the condition of steam, hot water, the cooling water in the field test to mention later.

Table 2: Design Spec and Experimental Results of Testing Equipment

Term		Design	Experiment
Hot Water	Amount	484kW	534kW
	Inlet Temp.	86℃	86.3℃
	Outlet Temp.	75.8℃	75.1℃
	Flow Rate	42m^3/h	42.2m^3/h
Cooling Water	Inlet Temp.	20℃	19.2℃
	Outlet Temp.	25.3℃	24.9℃
	Flow Rate	45.6m^3/h	41.3m^3/h
High Pressure Steam	Pressure	1.1MPa	1.08MPa
	Temp.	188℃	188℃
	Flow Rate	983kg/h	1062kg/h
Output Steam	Pressure	0.3MPa	0.3MPa
	Temp.	144℃	143℃
	Flow Rate	1322kg/h	1426kg/h

4.2 Field Test

We put the above-mentioned testing equipment to Ibaraki Plant of Tsumura & Co. that is a manufacturer of medicinal chemicals, and started a field test from April 2010 and are continuing now. The absorption heat pump has the characteristic that quantity of output steam changes by the temperature of the waste hot water and cooling water. By this field test, we confirmed that this system did not have any problem in a change of such a temperature condition and load, and the real use situation including the start stop functionally. In addition, we confirmed the durability and the reliability of devices constituting a system and measure quantity of output steam and inspect the fuel reduction effect by having introduced this system. There are photographs in the testing equipment setting situation in Figure 6, and the flow diagram of field test in Figure 7.

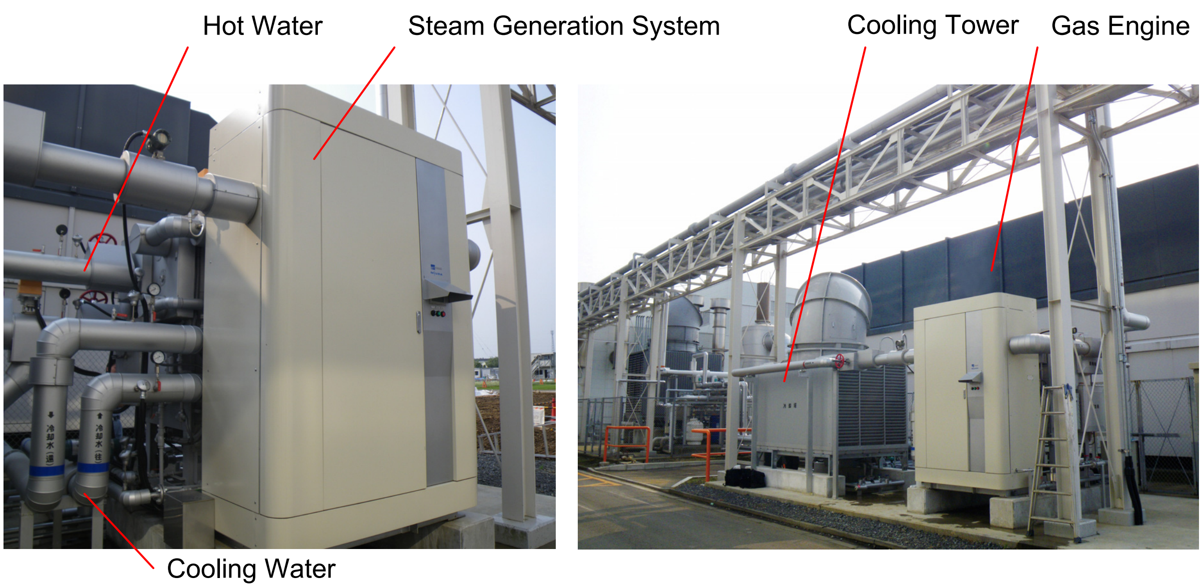

Figure 6: Photo of Field Test

This testing equipment used waste hot water of gas engine cogeneration system as a heat source. The hot water had been used only for boiler feedwater preheat before this device was introduced, but further energy saving and CO_2-saving were planned by converting it into steam this time. There is a graph of introduction effect in Figure 8. Because of some factors that temperature of the hot water was lower than an assumption for adjustment of the facilities that was not caused by the testing equipment itself, and driving time of gas engine cogeneration system was short, the quantity of 4-month steam output was less than an assumption from a proof start. The quantity of steam output was as expected, except influence of the gas engine cogeneration system driving time, and, after August when a hot water temperature condition was improved, the precision of the effect calculation before the introduction was confirmed. Even if driving time passes more than 2,000 hours, there is neither decrease in performance nor the corrosion in steam output department. For start stop of gas engine cogeneration system, and change of hot water temperature and the cooling water temperature, it was confirmed that operation was stable.

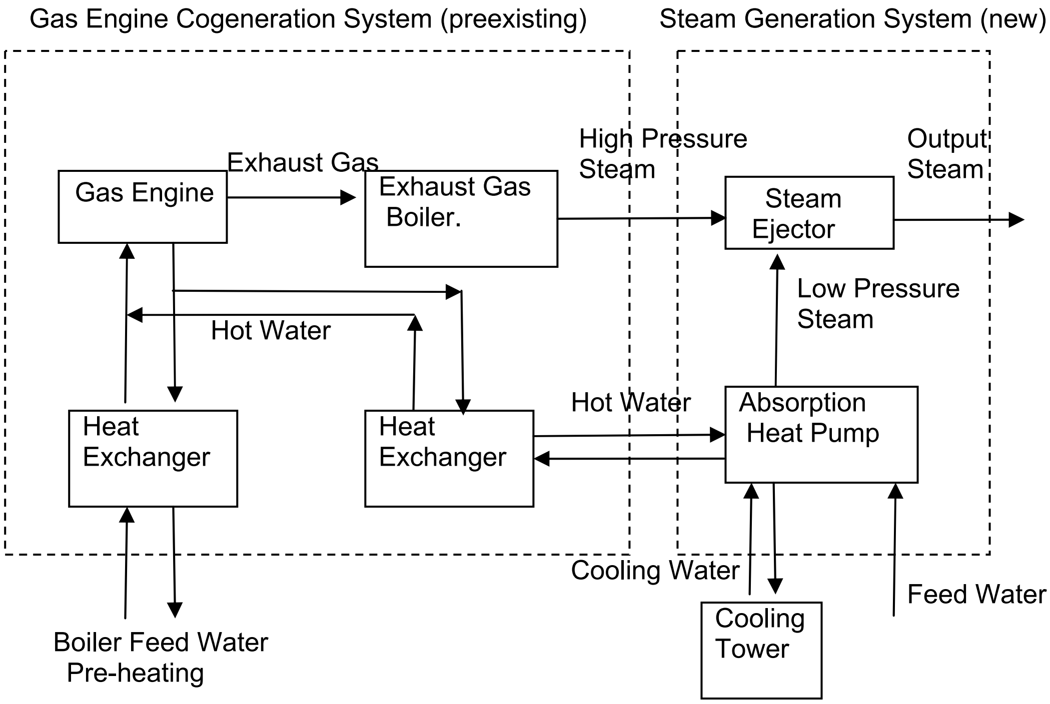

Figure 7: Schematic Diagram of Field Test System

5 CONCLUSIONS

We developed and launched sales of the system that firstly absorption heat pump is driven by 80 to 90℃ hot water to generate 0.1 to 0.2MPa(G) low pressure steam, and then the low pressure steam is pressurized by steam ejector to 0.3 to 0.6MPa(G), and confirmed performance by the performance test. We confirmed operation state and excess properties by the field test and are inspecting it about a fuel reduction effect now. Other than the system which this report introduced, we are going to increase a model having the output of approximately 2 times for a lineup in 2011. We push forward suggestion as new energy-saving apparatus.

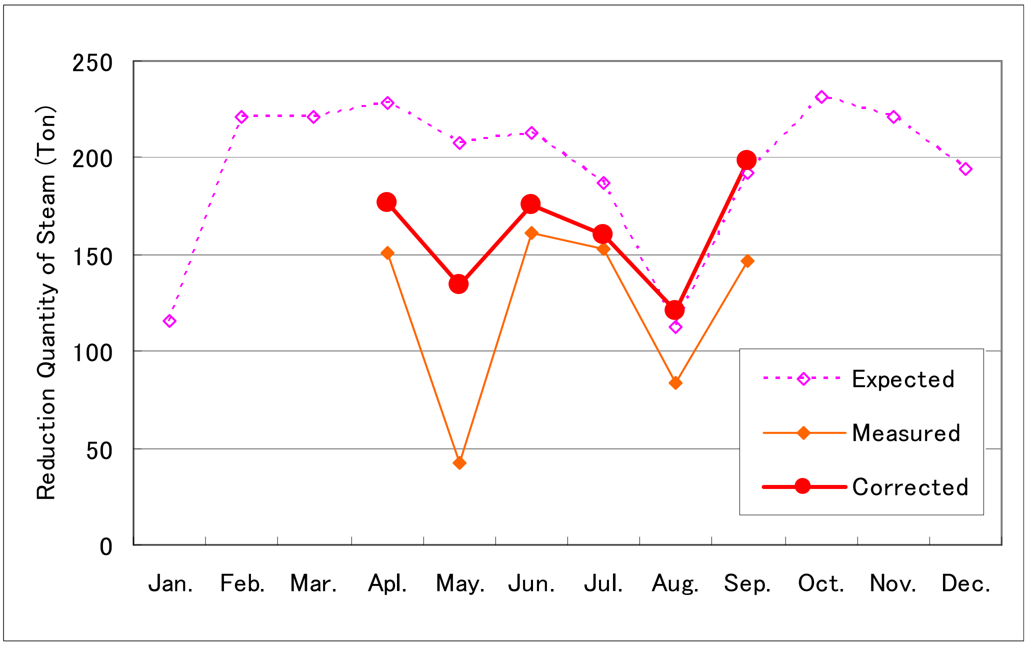

Figure 8: Effect of Field Test

6 ACKNOWLEDGMENT

To Ibaraki Plant of Tsumura & Co. having great cooperation, we express gratitude on carrying out the field test that this report introduced.

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