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High efficiency H_2O/LiBr double effect absorption cycles with multi-heat sources for tri-generation application

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HIGHLIGHTS

- A high-efficiency absorption cycle using multi-heat sources is developed trigen application.
- HX 2-2 cycle with two heat exchangers (SDHHX and DHX) is recommended as the best candidate.
- $T_{Hotwater}$ has much more significant effect on the COP and $\dot{Q}_E$ than T_{steam} in the HX 2-2 cycle.
- The most important UA to affect the COP is UA_{LG} while that to affect $\dot{Q}_E$ is UA_A.

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ABSTRACT

The objective of this study is to develop a high-efficiency double effect absorption cycle using multi-heat sources for tri-generation (trigen) application. The trigen system produces electricity, heating and cooling loads at the same time. The double-effect absorption refrigeration system consists of two generators, condensers, solution heat exchangers, expansion valves, an absorber and an evaporator. The cycle simulation is carried out for the H_2O/LiBr double effect absorption cycle with multi-heat sources for parallel, serial, reverse, revised serial and revised reverse flow patterns. The absorption refrigeration system uses the high temperature steam and hot water as the multi-heat sources. A new high-efficiency cycle is selected depending on the arrangements of additional heat exchangers. This study recommends HX 2-2 cycle with two additional heat exchangers (SDHHX and DHX) as the best candidate for trigen application. It is concluded that $T_{Hotwater}$ has much more significant effect on the COP and $\dot{Q}_E$ than T_{steam} in the HX 2-2 cycle. It is also found that the most important UA to affect the COP is UA_{LG} while that to affect $\dot{Q}_E$ is UA_A.

1. Introduction

With the increasing demand for cooling energy, concern is rising over blackouts in summer due to the electric peak. Accordingly, interest in energy demand dispersion and cooling systems that use alternative energy sources has been paid attention. Cooling systems that use heat sources other than electricity are needed to reduce the electric-peak demand in summer. The conventional vapor compression refrigerating systems use electric energy. On the other hand, the absorption refrigerating systems consume very little electric energy because the refrigerant is compressed in a liquid state and the system is driven by thermal energy. For this reason, the development of highly efficient tri-generation systems is required to mitigate the electric peak in summer, to facilitate distributed power generation, and to stimulate the propagation of gas cooling systems that use other heat sources [1,2].

The tri-generation(trigen) system is a total energy system that simultaneously generates electricity and cooling/heating thermal energies from one system. Furthermore, it recovers heat discharged from the power generation. The trigen system is regarded as highly energy-efficient because it uses technology that can save more energy and reduce more greenhouse gas emissions than the conventional system. At present, methods of recovering hot steam and water, which are waste heat (unused energy) from the power generation systems, are being evaluated, and interest in absorption cooling systems that use the waste heat is increasing [3]. Due to their advantages of efficient energy use, the absorption refrigerating systems are being recognized for their higher economic values than those of other refrigerating systems. Furthermore, they can be used to comply with international environmental regulations and resolve the power demand imbalance problem in summer [4,5].

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Nomenclature

COP	coefficient of performance	*L*	low temperature
E	evaporator	*H*	high temperature
h	enthalpy, kJ/kg	*HS*	heat source
$\dot{m}$	mass flow rate, kg/s	*T*	total
P	parallel	*HC*	high temperature condenser
$\dot{Q}$	cooling capacity, kW	HG	high temperature generator
R	ratio, reverse	LG	low temperature generator
S	series	in	inlet flow
T	temperature, °C	out	outlet flow
U	overall heat-transfer coefficient, W/m^2 °C		
$\dot{W}$	pumping power, kW	*Abbreviations*	
X	concentration of LiBr, %	*HHX*	high heat exchanger
η	efficiency	*LHX*	low heat exchanger
		AHX	additional heat exchanger
Subscripts		*ASHHX*	additional steam high heat exchanger
B	base	*ASLHX*	additional steam low heat exchanger
E	evaporator	*LMTD*	log mean temperature difference
A	absorber		
C	condenser		
G	generator		

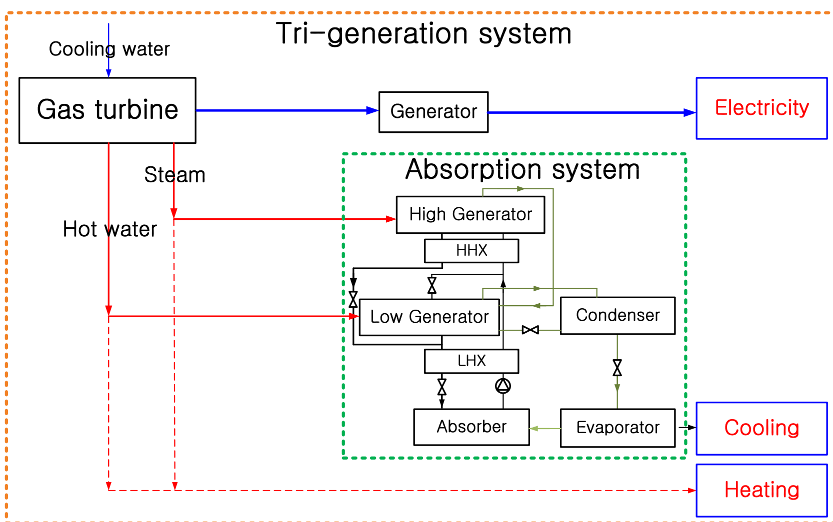

Fig. 1. Schematic diagram for the tri-generation system.

Fig. 1 shows the schematic diagram of a trigen system. The exhaust gas (hot steam) discharged from the gas turbine is used as the heat source for the high-temperature generator, and the coolant (medium-temperature water) discharged from the gas turbine is used as the heat source of the low-temperature generator. Electricity is the main production energy of the system, and heating and cooling thermal energies are additionally obtained from the waste heat according to the demand (in winter or summer). In particular, the cooling capacity is obtained from the absorption system [6–8]. Fig. 2 shows the schematic diagram of the energy efficiency of the trigen system. The conventional power plants that only produce electricity has 30–40% energy efficiency, but the trigen systems that produce cooling and heating thermal energy has an 85% or higher energy efficiency [9].

Because the absorption refrigerating systems can use various types of waste heat and solar energy, the low-temperature absorption systems that use exhaust gas heat from industrial furnaces or incinerators are being developed. Especially for cogeneration, a gas or diesel engine can use a coolant or exhaust gas to drive an absorption refrigerator. Furthermore, if a gas turbine is used for power generation, the absorption refrigerator can be driven using the exhaust gas; and if fuel cells are used for power generation,

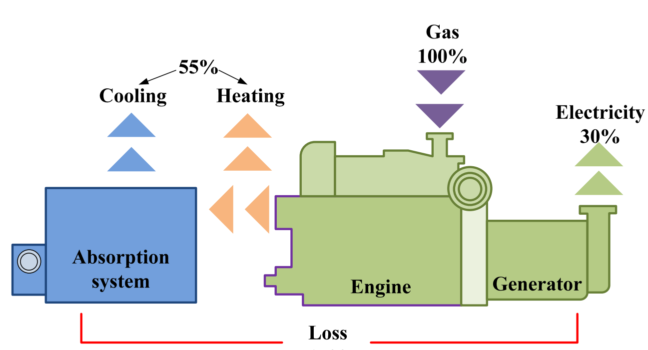

Fig. 2. Schematic diagram for efficiency of the tri-generation system.