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SOLAR AIR-CONDITIONING SYSTEM AT THE UNIVERSITY OF INDONESIA

Hajime Yabase[1*], Kiyoshi Saito[1], Arnas Lubis[1], Idrus Alhamid[2], Nasruddin[2]

[1] *Waseda University, 1-104 Totsukamachi, Shinjuku-ku, Tokyo, 169-8050, Japan*
[2] *Fluid Mechanics Laboratory, Departement of Mechanical Engineering, Faculty of Engineering, Universitas Indonesia, Kampus UI Depok, Depok 16424, Indonesia*

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ABSTRACT

Indonesia's economic growth has continued at a steady rate of approximately 5% to 6% annually, and energy consumption in the entire country has been increasing year by year. Demand for air conditioning in buildings is expanding. In line with this expansion, a 239 kW solar air-conditioning system using a single-double effect combined absorption chiller was installed in a building at the University of Indonesia's Faculty of Engineering located in Depok city, near Jakarta, with the aim of reducing greenhouse gas emissions. We collected and analyzed data from this air-conditioning system to better comprehend its performance. We report the outline and the performance of the chiller and the air-conditioning system.

Keywords: Absorption chiller; Air-conditioning system; Indonesia; Model plant; Solar collector; Solar thermal

1. INTRODUCTION

Indonesia's economic growth has continued at a steady rate of approximately 5% to 6% annually, and energy consumption in the country has also been increasing year by year. Demand for air conditioning systems in buildings has also been expanding. Since most power is generated in coal-fired power plants, a large amount of sulfur dioxide, CO_2, and other harmful pollutants are exhausted into the air, which is becoming more polluted every year.

On the other hand, Indonesia has been taking positive countermeasures against climate change, and it is determined to reduce greenhouse gas emissions by 26% by 2020 with domestic efforts. Indonesia wants to introduce solar air-conditioning systems to reduce greenhouse gas emissions, and the Indonesian Ministry of the Environment and Forestry is supporting the initiative (MoE, 2015).

In light of this, we have installed a solar air-conditioning system that will effectively mitigate environmental pollution and reduce the greenhouse gas emissions of a building inside the University of Indonesia (Yabase, 2011; Nasruddin, 2015a). The power source of this system is the single-double effect combined absorption chiller (Hyodo, 2011; Kajii, 2011) incorporating a regenerator into which hot water obtained from solar heat is inputted. This aspect is shown in Figure 1. The absorption chiller uses natural gas as its driving source and the solar hot water is obtained from evacuated solar heat panels that can acquire hot water of 90°C.

We began the demonstration test in January, 2014, and the data was analyzed and evaluated jointly by the University of India and Waseda University. This paper reports the contents.

*Corresponding author's email: yabase@enet21.com, Tel. +81-90-87543219
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Figure 1 Aspect of solar absorption chiller

2. SYSTEM CONFIGURATION

2.1. Building Outlines

The demonstration facility for the solar air-conditioning system was installed in the Manufacturing Research Center (MRC) (6-story building of approximately 1,500 m^2 in total floor space) at the University of Indonesia's Faculty of Engineering. The university is located in Depok City in the southern area of the Special Region of Jakarta. Figure 2 shows a photograph of the MRC.

Figure 2 MRC at the University of Indonesia

2.2. System Outlines

Figure 2 shows the flow diagram of the solar air-conditioning system, and Table 1 shows its specifications. Solar heat (hot water in the temperature range of 75°C to 90°C) is inputted to the single-double effect combined absorption chiller (239 kW) to facilitate cooling. When the solar heat is insufficient, natural gas makes up the shortage (Nasruddin, 2015b).

Heat pipe type solar collectors made of evacuated glass tubes offer high efficiency even in the high-temperature area of 75°C to 90°C, and hot water is not brought into the evacuated tubes. Sixty-two solar heat collectors (180.04 m^2 in total) are installed on the roof.

The hot water storage tank is installed to absorb the flow rate difference between the solar heat collectors and the single-double effect combined absorption chiller, and it works as a temporary buffer when the sun radiation changes drastically.

The radiator is installed to prevent the hot water from boiling due to excessive heat collection.

2.3. Single-double Effect Combined Absorption Chiller

The element that uses solar heat as the driving heat source is added to the highly efficient double effect absorption chiller, which uses the combustion energy of COP 1.42 (JIS Standard) gas to make the single-double effect combined absorption chiller that can utilize solar heat. Solar heat is converted into hot water of 90°C or less to be used as the driving heat source. This chiller works as a single effect type chiller when driven by solar heat. Solar heat driving and gas driving can be performed at the same time in this chiller.

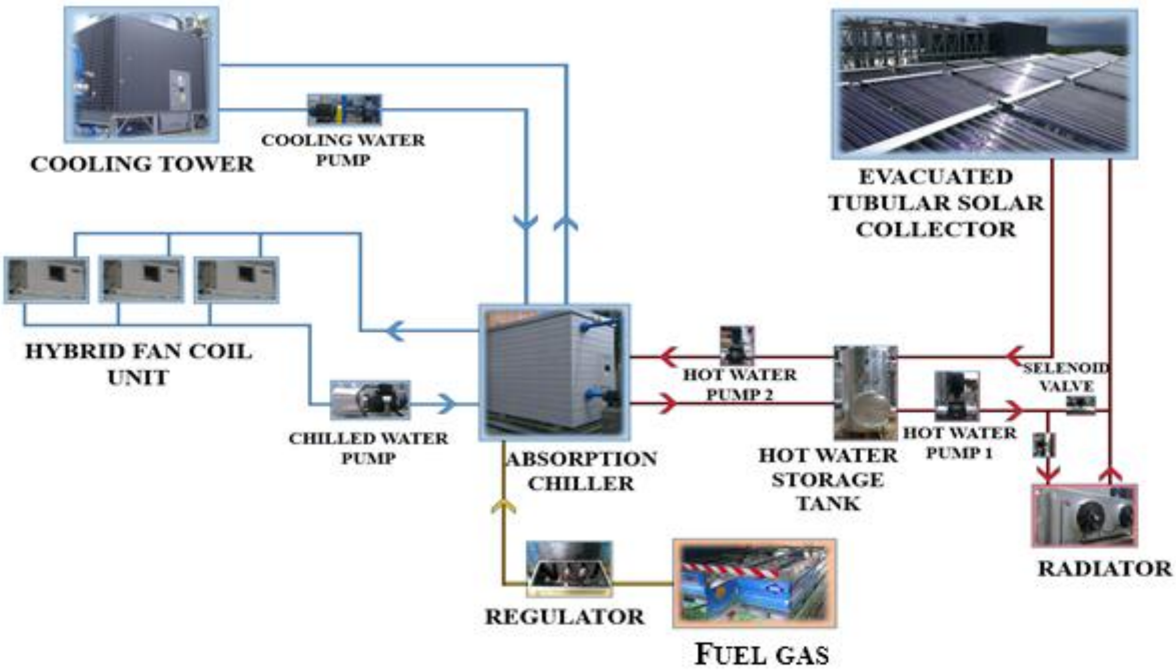

Figure 3 Flow diagram of solar air-conditioning system

The gas absorption chiller with auxiliary waste heat recovery (Gene-Link) is a conventional absorption chiller that can reduce fuel consumption during cooling by inputting hot water. Since the Gene-Link was designed to utilize waste heat hot water at a stable high temperature (83°C to 90°C) obtained in the cogeneration system, etc., it was also required in the utilization of solar hot water so that the system could be driven with hot water at lower temperatures.

The single-double effect combined absorption chiller introduced at this time can be driven with hot water as low as 75°C by the newly provided condenser only for the refrigerant regenerated by solar heat. If the cooling water temperature is low, this chiller can be driven with hot water of a lower temperature as described later.

Table 2 shows the specifications when the hot water temperature is 90°C and 75°C, and it also shows the specifications of the conventional Gene-Link for reference.

Table 1 Specifications of Solar Air-conditioning System

Absorption chiller	Solar absorption chiller × 1 Capacity 239 kW
Solar collector	Evacuated tubular type: Solar collector Directiom & angle: North, 15 degree Effective area 2.92 m^2/Unit × 62 unit

Table 2 Basic specifications of solar absorption chiller

			Solar absorption chller-heater		(reference)
			Inlet tenmp. of hot water: 90°C	Inlet tenmp. of hot water: 75°C	Conventional Gene-Link
Coefficient of performance (COP)	With hot water	-	1.91	1.43	1.72
	Without hot water	-	1.30	1.30	1.29
Heating efficiency		-	0.86	0.86	0.84
Chilled water	Inlet-Outlet temp.	°C	15.0→7.0	15.0→7.0	12.0→7.0
	Flow rate	m^3/(h-RT)	0.378	0.378	0.605
Cooling water	Inlet-Outlet temp.	°C	32.0→37.6	32.0→37.2	32.0→37.6
	Flow rate	m^3/(h-RT)	1.00	1.00	1.00
Hot Water	Inlet-Outlet temp.	°C	90.0→79.5	75.0→71.9	90.0→80.0
	Flow rate	m^3/(h-RT)	0.115	0.115	0.096
Heat recovery rate		kW/RT	1.40	0.41	1.12
Energy saving rate		%	32	9	26
Max. Cooling capacity only hot water heating		%	55	28	45

3. PERFORMANCE TEST

3.1. Test Outline

The performance test was initiated by operating the system for 8 hours a day from 08:00 to 16:00 from Monday to Friday except on days when the system could not be operated because corresponding days were holidays or because some other works were being performed. However, the insolation and outside air temperature were recorded all day long.

The measurement data was collected by the I/O unit for data collection, and then accumulated and processed in the data collection and display unit. Figure 4 shows the I/O unit for data collection, and Figure 5 shows the data collection and display unit.

3.2. Test Result

The performance test commenced in January, 2014, and data has been collected continuously since then. As representative examples, Figure 6 shows the operation data on February 14, Figure 7 shows the operation data on March 20, and Figure 8 shows the operation data on April 17.

In each data set, the upper graph shows the insolation, collected solar heat, and cooling load (cooling capacity), while the lower graph shows the fuel (natural gas) consumption, solar heat input amount (solar thermal utilization amount), solar chiller inlet temperature, and outside air temperature (ambient temperature).

Figure 4 I/O unit for data collection

Figure 5 Equipment for data collection and display

It can be seen from the collected data that solar heat is utilized with priority for the required cooling load. We have confirmed that the backup function using natural gas operated properly, and the whole system functioned well. The solar heat was collected efficiently in proportion to the insolation.

(1) February 14

The maximum outside air temperature was 30°C, the mean cooling load rate was approximately 35%, and the gas reduction amount was 26.5%. The chiller was driven at the hot water temperature of 60°C to 70°C because the chiller was designed to enable driving if the refrigerant can be regenerated even if the solar hot water temperature does not reach the required temperature. Since the mean cooling load rate was low, solar heat was easily utilized.

(2) March 20

The maximum outside air temperature was 32°C, the mean cooling load rate was approximately 35%, and the gas reduction amount was 27.9%. The chiller was driven at the hot water temperature of 60°C to 67°C.

(3) April 17

The maximum outside air temperature was 34°C, the mean cooling load rate was approximately 35%, and the gas reduction amount was 39.7%. The chiller was driven at the hot water temperature of 55°C to 69°C.

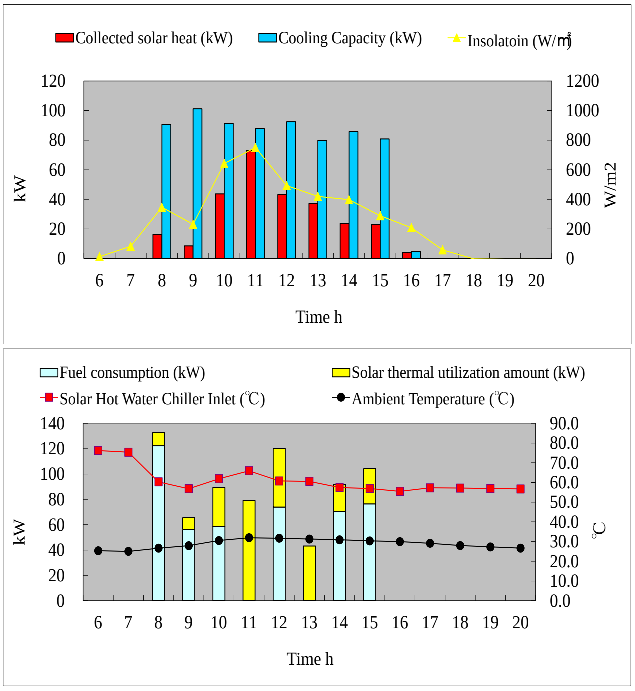

Figure 6 Operation data (February 14, 2014)

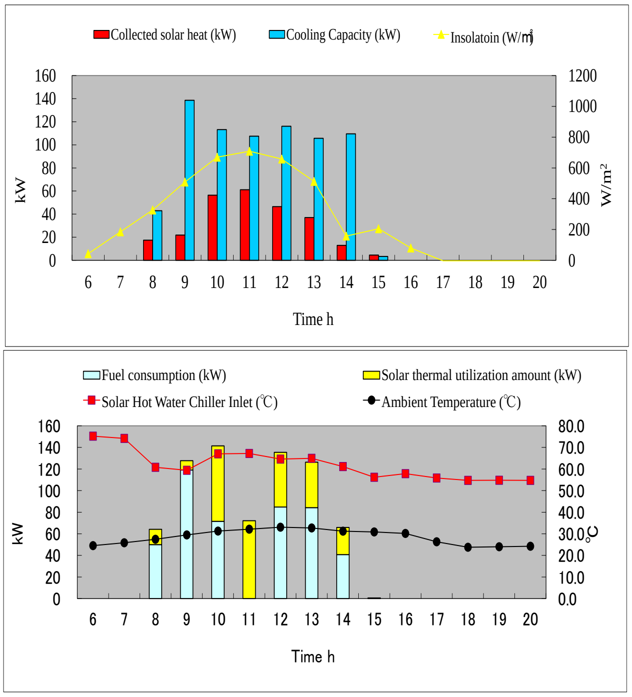

Figure 7 Operation data (March 20, 2014)

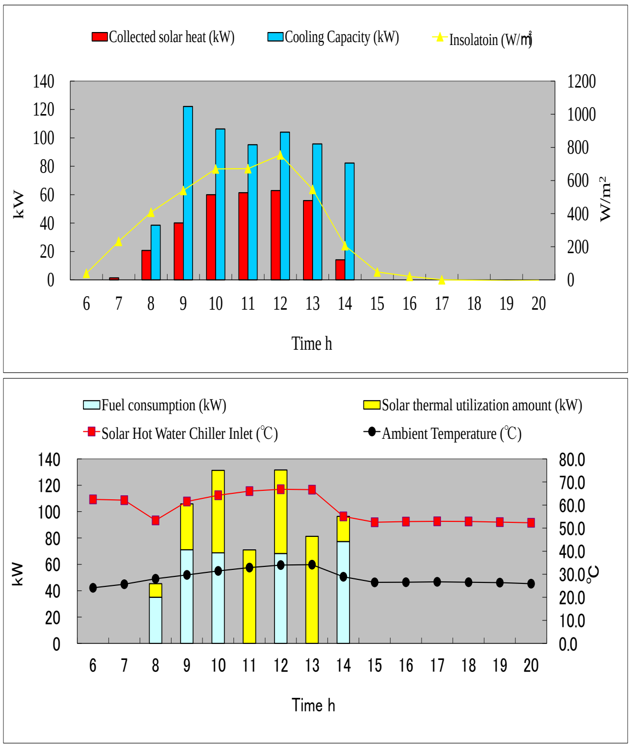

Figure 8 Operation data (April 17, 2014)

The test results described above show representative days when solar heat was collected relatively steadily. It can be seen from the above test results that the air temperature was almost constant throughout the year, and changes in the air temperature on any given day are small in Indonesia. As a result, the air-conditioning load was stable all through the year.

The gas reduction amount seems to be quantitatively smaller as the hot water driving temperature was lower. However, the cooling load rate was as low as 35% in the air-conditioning target building because the operation rate was insufficient. To evaluate the solar heat utilization effect in a more practical way, it is necessary to collect data with the cooling load range of approximately 60% or perform simulation for supplement.

We will continuously collect data, perform simulations, and evaluate the solar heat utilization effect.

4. CONCLUSION

The solar air-conditioning system installed at the University of Indonesia confirms that solar heat was utilized with priority, that the backup function using natural gas operated properly, and the whole system functioned well.

The gas reduction amount by solar heat was 25% or more, but the cooling load rate was as low as 35%. In order to practically evaluate the solar heat utilization effect, it is necessary to collect data with the cooling load rage of approximately 60% or perform a simulation for supplement.

It is confirmed that the solar air-conditioning system could operate even if the solar temperature of the hot water was as low as 60 to 70°C, and that the gas reduction amount tended to increase as the temperature of the hot water was reduced (as far as the solar air-conditioning system could operate).

5. ACKNOWLEDGEMENT

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