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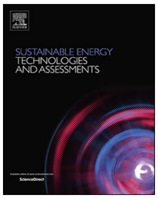

Original article

Effect of operating variables on performance of an absorption chiller driven by heat from municipal solid waste incineration

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ABSTRACT

This study presents an experimental analysis for a lithium-bromide/water waste steam driven parallel flow double effect absorption chiller evaluation. The absorption chiller analyzed is allocated at Bali refuse incineration plant for air conditioning system. This unit can supply a cooling capacity [400 USRT], [1406 kW]. A set of mathematical equations have been developed to estimate coefficient of performance (COP) of the chiller for each component. Theoretical analysis shows that increasing of the low temperature and high temperature heat exchangers effectiveness, decreasing temperature of absorber and condenser, increasing temperature of high pressure generator, and increase loading factor of the system improved the COP. The entire cycle is optimized by Engineering Equation Solver (EES) software from the standpoint of maximizing the COP via applying the direct experimental method. The optimization result of COP is obtained by the thermodynamic cycle.

Introduction

Bali Refuse Incineration Plant was built and operated in Bali District, New Taipei City, Taiwan since 2007. This plant is equipped with 3 sets of incinerator, mechanical mixing burning type; each set is designed to handle refuse burning 450 tons per day, which amounts to 1350 tons per day in total as 3 sets of incinerators are put into service. Heat energy recovery is realized by utilizing the heat generated from refuse burning to heat up the water in boiler that generates superheated steam for turbine propulsion. At boiler full load condition the main generator can produce power of about 35 MW; if the capacity of emergency generator set is also included, total power generation amounts to an even higher figure of about 41 MW. The total thermal efficiency of the cogeneration in Bali refuge incineration plant is about 87 ± 5% which means 13 ± 5% waste heat loss. The high temperature exhaust gas recovered by the air-cooled chiller for refrigeration and the pass through heat exchanger can heat water up to 80 °C. The sources of waste heat are abundant and thermal energy is cheap, which needs to be carefully used to improve energy efficiency to create economic value. Air-cooled chiller of Bali refuge incineration plant is the heart of the central air-conditioning system which illuminates about 60% the total power consumption. At the same evaporator and condenser temperature, the water cooled condenser is capable of providing higher refrigeration capacity and COP of an evaporative cooling condenser 31% and 14.3% higher when compared with air-cooled condenser, respectively [1,2].

At part load engine operation, Jayasekara et al. [3] instituted the conventional fixed flow waste heat recovery into the modulating flow cascade heat recovery system (CHRS) for increasing a percentage over 13% in COP at 50% engine load to promote the COP of the absorption chiller. Sedigh et al. [4] investigated the effect of a boiler and a cooling tower different cycle parameters on a series flow double effect water-Lithium bromide absorption chiller system. They noted mass and energy conservation laws controlling the system, and computed COP, exergy efficiency of the system, and exergy destruction (loss) of each component. Li et al. [5] elaborated a transient model to motivate the operation process of a lithium bromide – water absorption chiller. As regards heat source temperature, they evaluated heat input, cooling capacity, COP, and presented the chiller operates the best COP when the hot water temperature rise from 95 °C to 100 °C for a typical cooling tower conditions of tropical countries. She et al. [6] compared among the PM-1 mode of the low pressure and the high pressure generator have the same inlet temperature heat source, the low pressure generator has a relatively higher inlet temperature heat source, the PM-2 mode of the high pressure generator has a relatively lower inlet temperature heat source, and the traditional double-stage LiBr-H_2O absorption system (TDS) mode. At small ranges working conditions, they presented that the PM-1 mode has 26.7% COP improvement than the

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Nomenclature

COP	coefficient of performance, -
Eff	effectiveness, –
Q	heat loading, kW
h	enthalpy, kJ/kg
m	mass flowrate, kg/s
T	temperature, °C

Subscripts

ab	absorber
cd	condenser
ev	evaporator
gh	high temperature generator
gl	low temperature generator

TDS mode and the PM-2 mode improved 35% COP under wider ranges. Hussain et al. [7] compared the performance of air- and water- cooled condensers in ammonia vapor absorption refrigeration (VARS) system. The experimental tests were conducted at 20 °C, 25 °C and 30 °C three different ambient temperatures. The COP of water-cooled condenser was 2.14, 2.03 and 1.95 which is more than air-cooled condenser COP of 1.94, 1.85 and 1.75, respectively. Ebrahimi et al. [8] conduct the unique configuration absorption refrigeration system (ARS) for waste heat recovery and method from computer room air conditioning components in data center. They investigate and analyze the effect of waste heat quality and coolant type of the server, solution peak concentration and heat exchanger effectiveness, evaporator temperature, and operating pressures on the introduced system performance for obtaining highest COP. Based on exergy analysis, Anand et al. [9] elaborated a mathematical model to evaluate the performance of the steam powered single-stage ammonia/water vapor absorption refrigeration system. At different operating conditions, the results got the highest exergy loss of the generator and the lowest of the evaporator. Under actual case, they found which the exergy losses in absorber greater than the condenser to enhance the absorber and generator designing for improving the efficiency of the system.

A double effect lithium bromide absorption chiller is used to add a high pressure generator in the original heat exchange equipment for generating steam. The high pressure generator produces steam and the concentrated solution is delivered to the tube and the shell of the low pressure generator (Parallel flow circulated system of the solution). In order to raise COP of the unit, double effect lithium bromide absorption chiller is also installed with the heat exchanger for high temperature solution, heat exchanger of working steam condensate, and other supported facilities. This unit can adequately use heat and therefore its COP is higher. This study aims to show an experiment using temperature sensors for the performance of the actual performance of [Li-Br/ H_2O] waste heat driven parallel flow double-effect absorption chiller evaluation located on a specific point on the cycle components allows predicting the COP behavior for long time of operation. Theoretical analysis is developed to study the effect of high temperature generator, condenser, and absorber temperature, low and high temperature heat exchangers effectiveness on the COP at different loading condition.

Experimental methods

Description of the system

Waste-to-energy (WTE) plant generated the electrical energy on site for meeting the demands of the operated equipment. The rejected heat provide from power generation for space ventilation, cooling, heating, dehumidification, lighting, and domestic hot water of the building. Fig. 1 shows the absorption chiller in a waste-to-energy plant. Steam is generated in heat recovery boilers and distributed at different pressures to the final consumers. Steam turbines utilized to meet mechanical power demand or produce additional electricity. Absorption chillers are driven by heat to produce chilled water. The parallel flow absorption chiller system and the chiller specification are shown in Fig. 2 and Table 1, respectively. The system has four temperature zones (low temperature generator (LTG) temperature, high temperature generator (HTG) temperature, condenser temperature, and absorber temperature) and three pressure levels (low pressure of the evaporator and absorber, medium pressure of the condenser and LTG, the high pressure of the

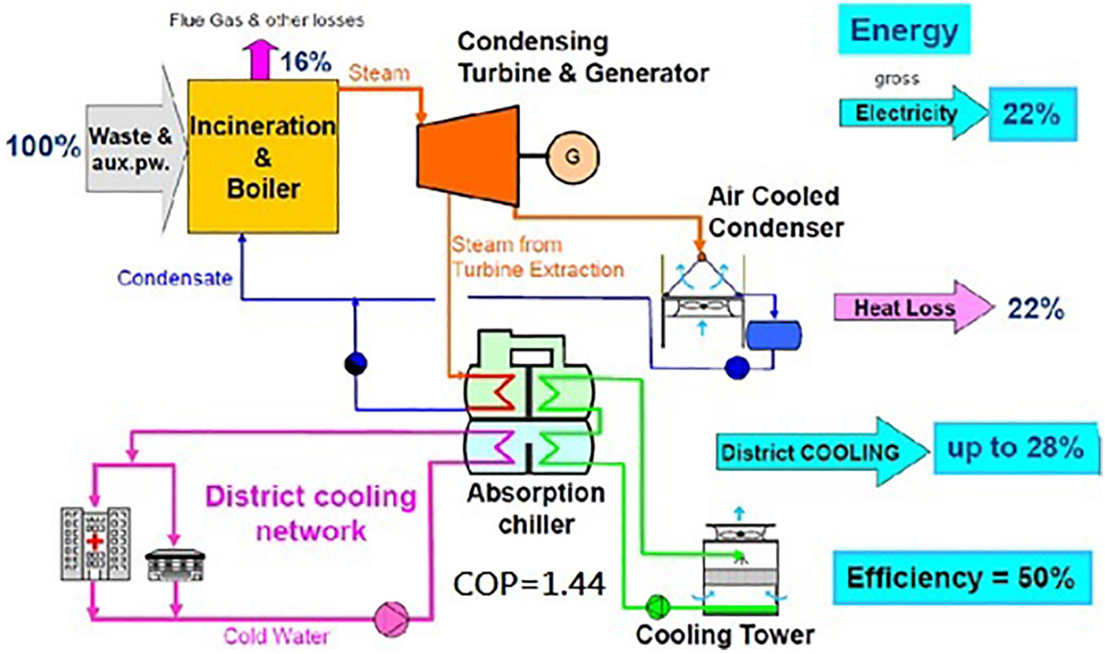

Fig. 1. Schematic diagram of waste-to-energy plant with absorption chiller system.