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NH_3-H_2O water source absorption heat pump (WSAHP) for low temperature heating: Experimental investigation on the off-design performance

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ABSTRACT

Heat supply systems based on absorption heat pump were assessed to have great potentials on energy savings and emissions reduction. A prototype of NH_3-H_2O water source absorption heat pump (WSAHP) designed for low temperature heating was experimentally investigated under different working conditions. The effects of driving source, hot water and source fluid temperature on the heating performance were studied. As driving source increases from 110 °C to 140 °C with 15 °C evaporator inlet and 45 °C hot water, COP increases from 1.429 to 1.552 and then decreases to 1.495, while the heating capacity increases from 32.23 kW to 88.35 kW. As hot water increases from 30 °C to 45 °C with 130 °C generator inlet and 15 °C evaporator inlet, COP decreases from 1.653 to 1.449, while the heating capacity drops from 94.55 kW to 60.37 kW. As the source fluid increases from −10 °C to 30 °C with 130 °C generator inlet and 45 °C hot water, COP increases from 1.203 to 1.609, while the heating capacity increases from 39.51 kW to 79.72 kW. Comparisons with former work indicate that the developed prototype can operate under evaporator inlet temperatures as low as −18 °C, which is significant to improve heating applicability in colder conditions.

1. Introduction

Energy consumption for heat supply, including space heating and domestic hot water, occupies a proportion of more than 40% in the total building energy consumption [1]. Most of the existing fuel-based heat supply systems directly utilize the high-grade energy, such as gas, high-pressure steam and high-temperature water, to meet the low-temperature demand, which is usually in the range of 30–60 °C [2]. The power capability of high-grade energy is completely wasted during simple direct utilization, unavoidably leading to low energy efficiency and high environmental impact.

Heat pump technologies are good alternatives to low temperature heating applications, among which air source heat pump (ASHP) [3,4] and ground source heat pump (GSHP) [5,6] are the most popular. Since these heat pumps are driven by electricity, the power generation efficiency from fossil fuel to electricity should be considered. In terms of the primary energy efficiency, the conventional heat pumps may not be advantageous all the time. It was found that they got worse than boiler when the ambient temperature or soil temperature is very low. Besides, both of the conventional ASHP and GSHP suffer serious performance decline under cold conditions, which has a great influence on heating reliability and energy efficiency [7–9].

To fully utilize the power capability of conventional fuel-based heat supply systems, the air source absorption heat pump (ASAHP) [10,11] and ground source absorption heat pump (GSAHP) were proposed previously [12,13], with the schematic diagram shown in Fig. 1. The conventional boiler or heat network drives the ASAHP or GSAHP instead of supplying heat through a heat exchanger directly. Since the ASAHP or GSAHP extracts additional heat from the air or the water through the evaporator, so an increased amount of heat can be produced in the condenser and absorber. The conventional heat exchanger is kept in parallel with the absorption heat pump to meet the peak load. The ASAHP and GSAHP were assessed to save primary energy by 20–40%, compared with conventional fuel-based systems [13]. In addition, the GSAHP can reduce the soil thermal imbalance and required

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Nomenclature

c_p	specific heat, kJ/(kg °C)
m	mass flow rate, kg/s
Q	heat exchange rate, kW
t	temperature, °C
V_f	volume flow rate, m^3/h
W	power rate, kW
ρ	density, kg/m^3
ξ	relative balance deviation
η	efficiency, %

Abbreviations

ASAHP	air source absorption heat pump
ASHP	air source heat pump
COP	coefficient of performance
GSAHP	ground source absorption heat pump
GSHP	ground source heat pump
WSAHP	water source absorption heat pump

Subscripts

a	absorber
c	condenser
e	evaporator
g	generator
h	heating
p	solution pump
w	water

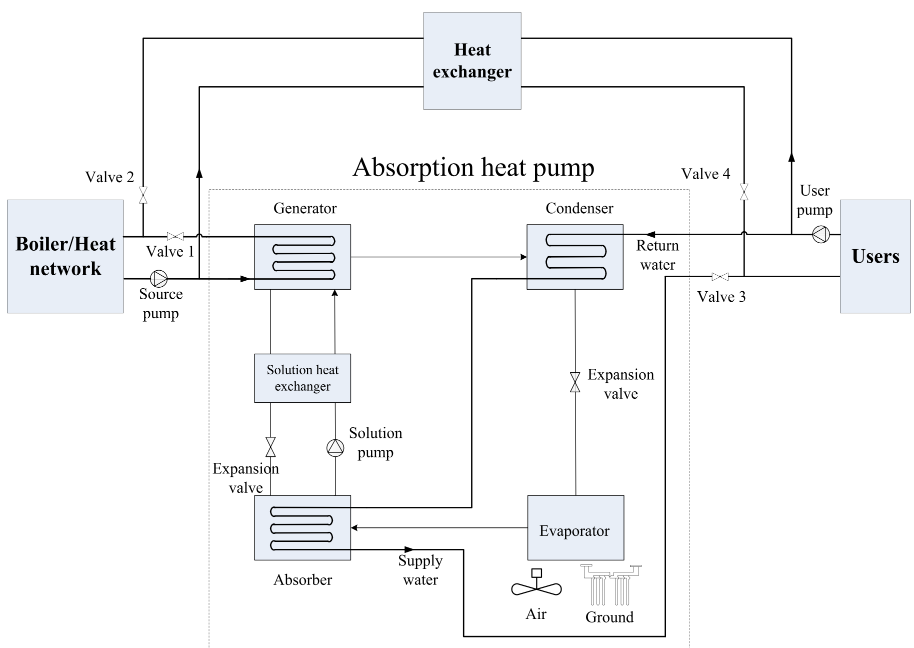

Fig. 1. Schematic diagram of the heating system based on the absorption heat pump.

boreholes of the conventional GSHP in cold regions, due to less heat extraction in winter [14].

Absorption systems were widely used for cooling and refrigeration in the past years, and attracted more and more attention in the area of heat supply recently. There have been a number of experimental and application studies on absorption heat pump used for heating purposes, with the H_2O-LiBr systems being the absolute majority. Zheng et al. [15] conducted flashing experiments on absorption heat and mass transfer of H_2O-LiBr solution with various types of flashing jets. Wang et al. [16] introduced a new type of multi-stage elementary unit for generating and condensing processes in absorption heat pumps. Experiments were carried out to study the flow characteristics of H_2O-LiBr solution through an orifice plate in generating processes. Mortazavi et al. [17] introduced a plate-and-frame absorber configuration in H_2O-LiBr absorption heat pump. The solution flow thickness was measured, and a significantly high absorption rate was achieved in comparison with the conventional absorption systems. Qu et al. [18] presented three configurations to improve boiler thermal efficiency by integrating absorption heat pumps with natural gas boilers for waste heat recovery. An H_2O-LiBr absorption heat pump was tested under 12 working conditions, with an average heating capacity of 72 kW and a coefficient of performance (COP) of 1.29. Li et al. [19] presented an application project of district heating system with Co-generation. With the aid of H_2O-LiBr absorption heat pumps, the heating capacity of the Co-generation system had increased by 50%. By experiment methods, the feasibility and reliability had been verified, and the optimum operation condition was determined. Alarcón-Padilla et al. [20] integrated a double-effect H_2O-LiBr absorption heat pump to a multi-effect distillation unit. In the experimental assessment, an overall performance ratio of 20 was measured, which doubled the performance ratio of the multi-effect distillation unit alone.

Despite of higher efficiency and better safety, the H_2O-LiBr is limited in a lot of heat supply applications due to solution crystallization problem and high refrigerant freezing point, which