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# Study on the LWT control schemes of a heat pump for hot water supply

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Heat pump systems have been widely used in buildings and industries due to their high performance. In this study, a leaving water temperature control scheme has been proposed for a water-to-water heat pump for hot water supply. The study was focused on the following four schemes: (1) using an auxiliary electric heater, (2) varying compressor speed, (3) adjusting water flow rate, and (4) adding heat to the secondary fluid flow of the heat source. With schemes (2) and (3), the system showed higher performance than other schemes. However, scheme (2) could not attain the appropriate LWT at low EWT heat source conditions. For all EWT conditions, using schemes (3) and (4) enabled the system to reach an appropriate LWT. Scheme (4) can be adopted as the best technology to control LWT, because it is not easy to vary flow rate of the secondary fluid as in scheme (3).

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## 1. Introduction

Heat pump has evolved to become a mature technology over the past two decades. However, it is not applied as widely as it should be [1]. The major benefits of the heat pump system over a conventional air-conditioning system are that it is an easier system to maintain along with a diversification of facility use, and high comfortability. In addition, a heat pump provides not only precise capacity modulation, but also energy conservation and possibility of application in an intelligent building system [2]. To a modern building in the residential, commercial, and industrial sectors, higher temperature hot water supply is necessary for daily life and is provided by a water heater making use of electricity or gas, which is known for great energy expenditure. The condensing temperature of a heat pump is about 50 °C, and the leaving water temperature (LWT hereafter) of heat pump is about 45 °C [3].

Many countries have introduced policies to reduce greenhouse gas emissions and encouraged a more rational use of energy. For these reasons, heat pumps have been selected throughout the world as heating and cooling systems to play a key role in national energy strategies to meet energy and environmental goals. Especially, heat pumps utilizing renewable energy (unused energy, geothermal energy, etc.) have been spotlighted as a key approach to improve energy efficiency, because of the great advantage with their system efficiency. Therefore, the development of heat pump systems with renewable energy sources to get higher temperature hot water supply has great potential to save energy and reduce thermal pollution [3–5].

Ma and Zhao [6] compared the performance of a heat pump having a flash tank with a system having a sub-cooler. Wang et al. [7] suggested the model to optimize a refrigeration system using gas injected scroll compressor with proposition of universal control and design methods. Dutta et al. [8] investigated the performance of a scroll compressor under liquid refrigerant injection. They observed performance improvement due to the decrease of the oil viscosity and cylinder temperature by liquid injection. Feng et al. [9] carried out an experimental analysis on liquid refrigerant injection into the suction line of a heat pump water heater. Heo et al. [10] compared the heating performances of an air-source heat pump systems using four types of refrigerant injection methods with various combinations of flash tanks and sub-coolers. In their study, injection methods affected average heating capacities.

Most previous studies were focused on air-to-air heat pumps. Investigations on heat pumps that utilize renewable energy to generate hot water are rarely reported in literature. The primary objective of this study is to provide the characteristics of hot water generation according to the LWT control methods simulating renewable energy sources such as unused waste heat and geothermal energy. In the present study, the performance of a water-to-water heat pump is analyzed according to four different schemes for increasing hot water temperature, and the best technology to control the LWT is suggested.

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**Nomenclature**

| | |
|---|---|
| COP | coefficient of performance |
| EWT | entering water temperature [°C] |
| ID HX | indoor heat exchanger |
| LWT | leaving water temperature [°C] |
| OD HX | outdoor heat exchanger |

## 2. Experimental setup and test procedure

### 2.1. Experimental setup

Fig. 1 shows the experimental setup designed to measure the performance of the heat pump for developing the schemes to control LWT. The test rig was composed of a water-to-water heat pump and the secondary fluid flow loops. The rated heating capacity of the tested heat pump unit was 5.8 kW, and R134a was adopted as the working fluid. The heat pump unit consisted of a compressor, two plate type heat exchangers (indoor and outdoor heat exchanger), and an expansion device. An auxiliary plate type heat exchanger was also installed to find a way to increase the LWT and system performance. The function of the auxiliary heat exchanger is described in detail in the result and discussion section. A vertical type variable speed compressor was adopted in the heat pump. All heat exchangers had counter flow pattern between refrigerant and the secondary fluid. EEV was used as the expansion device in the heat pump unit. Control system for driving EEV unit included an A/D card and a stepping motor driver.

The secondary fluid flow loops for the outdoor heat exchanger (OD HX hereafter) and the indoor heat exchanger (ID HX hereafter) included a magnetic pump and a constant temperature bath. A variable speed pump and a manual needle valve were used to control the water flow rate supplied to the OD HX (evaporator) and ID HX (condenser) to establish test conditions based on references [11–13]. Water was used as the secondary fluid for the ID HX and auxiliary HX, and water/glycol solution with the concentration by 15% was adopted for the OD HX.

An electric heater was installed in the secondary flow line after the ID HX for further heating of the hot water to increase the LWT. One more electric heater was installed in the secondary fluid flow line before the OD HX to investigate the effect of cycle enhancement on LWT.

Temperatures and refrigerant pressure in the test setup were monitored at the selected locations according to ASHRAE Standard 41.1 [14] and ASHRAE Standard 41.3 [15], respectively. A mass flow meter was installed between the ID HX and expansion device to measure refrigerant flow rate. The pressure drop across the mass flow meter was approximately 3.92 kPa, which was less than the value of 82.7 kPa allowed in ASHRAE Standard 116 [16] at standard condition. The T-type thermocouple, pressure transducer, and mass flow meter had accuracies of ±0.1 °C, ±6.9 kPa, and ±0.2% of reading, respectively. A volumetric flow meter with an accuracy of ±0.5% of reading was installed to measure the secondary fluid flow rate. The power consumption of the system was measured by using power meter with an accuracy of ±0.01% of reading.

### 2.2. Test procedure

The current study was mostly focused on the following four schemes to increase the LWT: (1) to use electric heater on the secondary fluid flow line, (2) to increase compressor speed, (3) to adjust water flow rate, and (4) to adopt an auxiliary heat exchanger. Table 1 shows the test conditions for controlling the LWT. Two sets of test for scheme (1) were executed by adjusting the electric heater in the secondary fluid flow line. One of the sets of scheme (1) called scheme (1-a), increased the LWT by supplying electric heat into the secondary fluid flow line after the ID HX. The other set which was called scheme (1-b) controlled the LWT by adjusting electric heat input into the secondary fluid flow line before the OD HX. In scheme (2), the compressor capacity was increased by increasing the compressor speed to get a higher LWT. In scheme (3), the secondary fluid flow rate through the ID HX was adjusted to control the LWT. In scheme (4), the LWT from the ID HX was adjusted using heat from hot water in the storage tank.

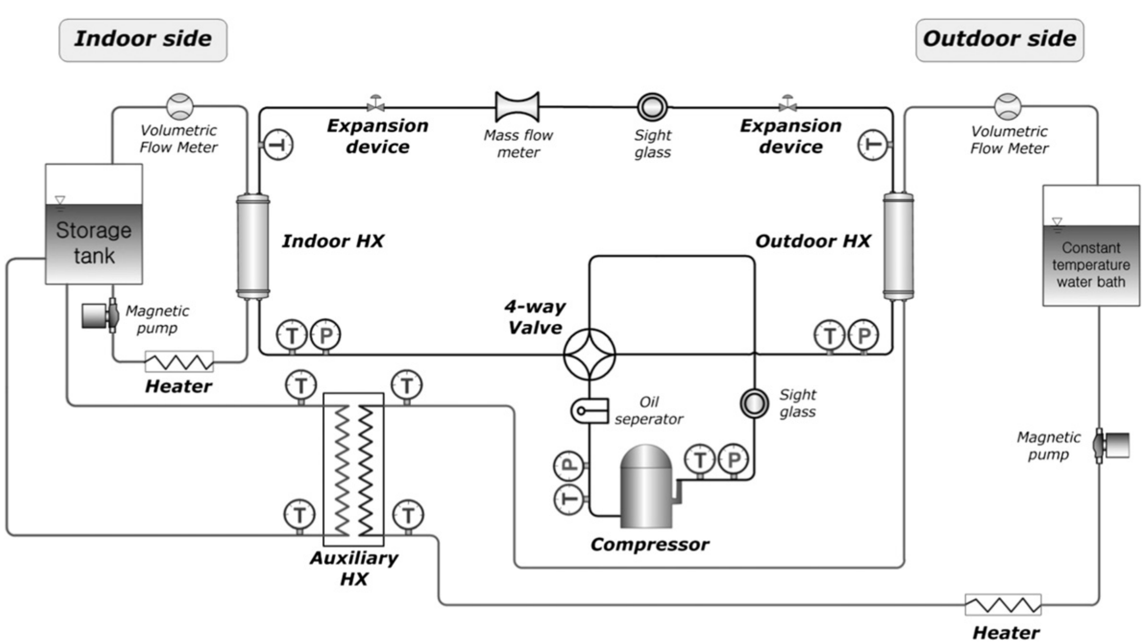


**Fig. 1.** Schematic diagram of a heat pump for adjusting LWT.

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