# Design of an Intelligent Controller for Waste Water Heat Pump Recycled Energy Systems

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*Abstract*— **This study is intended to realize an intelligent controller using fuzzy control algorithms in order to recycle energy by recycling the waste water heat discharged by waste water heat collection boilers. Using waste water inflow temperature changes and waste water inflow amount changes as parameters, we present characteristic curves of the number of compressors being operated at fixed speeds and the temperature of hot water being discharged.**

**We propose an intelligent controller that determines the optimum number of compressors being operated at fixed speeds in real time by measuring changes in the temperature and amount of waste water inflows in order to minimize the number of compressors being operated at fixed speeds relative to the waste water load flowing into the waste water heat collection boiler.**

*Index Terms*— **waste water, heat pump, heat collection boiler, recycled energy**

## I. INTRODUCTION

**RECENTLY**, energy problem has been coming to the fore globally due to continuous increases in oil prices and raw material costs and energy use has been regulated in diverse ways. To effectively respond to those various regulations related to energy, more products with high energy efficiency should be supplied to industrial and general areas. In particular, not only attention to technologies using energy sources generated in nature such as the heat of the earth, solar heat and wind power is increasing but also technologies to maximize the energy efficiency performance of products are being introduced.

Certain spaces where high temperature water is needed at all times such as public baths acutely require energy saving. However, although large amounts of high temperature waste water are generated in these spaces through the process of energy consumption, most of it is being discharged without being recycled. If heat collecting devices are installed to collect high temperature waste water heat and recycle it in heating the water being supplied, not only energy consumption will be reduced but also effects can be expected in the aspect of environment protection such as reduction in carbon dioxide emission.

This study is intended to design controllers to maximize energy efficiency by determining the optimum number of compressors to be operated relative to waste water heat loads. Since actual waste water heat collection systems are complicated nonlinear systems involving uncertainty, designing the controller as general controllers used in linear systems is difficult, complicated and not effective.

In order to control the compressor output of such waste water heat collection systems, this study is intended to realize an intelligent controller using fuzzy control algorithms that can be easily designed and is reliable and flexible. Based on experimental curve of changes in waste water inflow temperatures and waste water inflow amounts relative to the temperatures of discharged hot water and the empirical knowledge of experts in adjusting the number of compressors being operated at fixed speeds in relation to those changes, we made fuzzy rules. We plan to improve energy efficiency by achieving optimum operation at fixed speeds and controlling inverter outputs in real time by estimating changes in waste water heat loads from experimental curves of changes in waste water inflow amounts and temperatures using the proposed fuzzy control algorithm.

## II. WASTE WATER HEAT COLLECTION BOILER

Unlike general river water or sewage water that show clear differences in temperatures by season along with the air, industrial exhaust heat or waste water heat sources discharged by industrial firms have smaller temperature changes compared to the air and thus they provide an advantage that they can be used throughout the year as they can be utilized as heat sources using the temperature differences between water temperatures and air temperatures or can be used as heat sources for producing refrigerants for room cooling.

For instance, if heat sources exist in the vicinity of heat demanders such as public baths, economic effects such as energy saving can be expected if waste water heat collection boilers are used to use the waste water heat. Figure 1 schematizes the principle of operation of waste water heat collection boilers.

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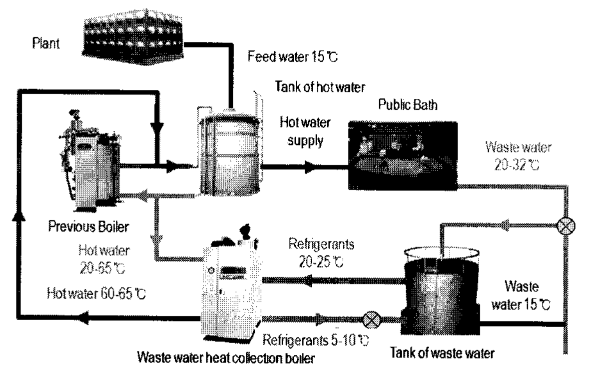


Fig. 1. Principle of waste water heat collection boiler operation.

Changes in the temperatures of the hot water discharged by the waste water heat collection boiler relative to changes in waste water inflow amounts at constant temperatures and waste water temperature changes can be estimated.[1]

## III. INTELLIGENT CONTROLLER DESIGN

The intelligent controller to achieve optimum operation at constant speeds and control inverter outputs in the waste water heat collection systems was realized using fuzzy control algorithms.[2][3] Figure 1 shows a block diagram of a waste water heat pump recycled energy control system using an intelligent controller.

In the fuzzy control rules, the changes in waste water heat temperatures and waste water heat inflow amounts used to estimate waste water heat loads were used as antecedent input variables and compensation current Uc was used as a consequent control variable.

Figures 3 and 4 shows the membership functions of the amounts of changes in waste water heat temperatures and changes in waste water heat inflow amounts respectively and Figure 4 shows the membership function of Uc. The actual range of inputs of the amounts of changes in waste water heat temperatures is from -12 to +12and the actual range of inputs of changes in waste water heat inflow amounts is from -90[l/min] to +90[l/min].

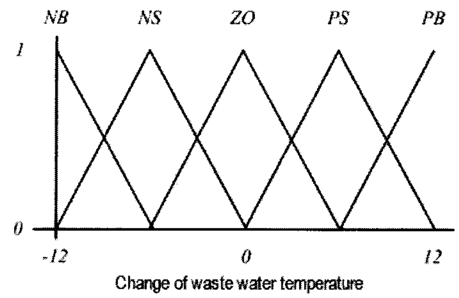


Fig. 3. Membership function of waste water temperature changes

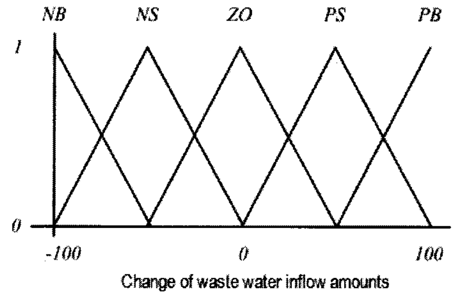


Fig. 4. Membership function of waste water inflow amounts

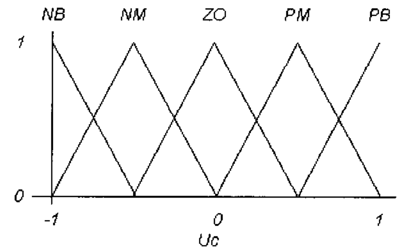


Fig. 5. Membership function of Uc

Based on experts' empirical knowledge, if waste water inflow amounts increase, the amount of heat discharged by the heat pump will increase and it will be judged that waste water heat loads have increased and the number of compressors operated at constant speeds will be increased. If waste water inflow amounts decrease, the amount of heat discharged by the heat pump will decrease and it will

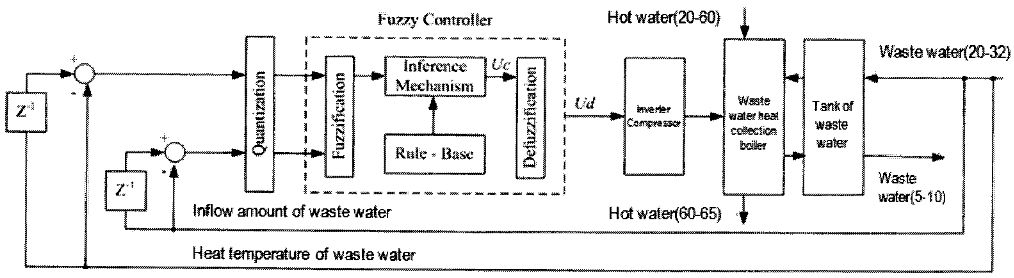


Fig. 2. A block diagram of a waste water heat pump recycled energy control system using an intelligent controller

be judged that waste water heat loads have decreased and the number of compressors operated at constant speeds will be increased. To obtain optimum energy efficiency, we made fuzzy rules.

The fuzzy rules used in this study are shown in Table 1.

TABLE I
FUZZY RULE

| ΔTemp \ L | NB | NS | ZO | PS | PB |
|---|---|---|---|---|---|
| NB | PB | PB | PB | PS | ZO |
| NS | PB | PS | PS | ZO | PS |
| ZO | PB | PS | ZO | NS | NB |
| PS | ZO | ZO | NS | NS | NB |
| PB | ZO | ZO | NS | NB | NB |

where, PB, PS, ZO, NS and NB represent Positive Big, Positive Small, Zero, Negative Small and Negative Big respectively. The MAX-MIN synthesis method was used as a fuzzy inference method and the center of gravity (COG) method was used for defuzzification.

## IV. SYSTEM CONFIGURATION

Based on the controller designed as set forth under chapter 3, we configured a heat pump recycled energy system. The intelligent home network based waste water heat pump recycled energy system uses a compressor to exchange the heat of the refrigerant with waste water heat sources in the hot waste water tank. The waste water will be discharged as low temperature waste water at around 5~10°C and the refrigerant that obtained heat will become hot at around 100°C when it has been compressed by the compressor. Heat exchanges will occur between the refrigerant and supply water in the condenser heat exchanger through which supply water flows to eventually produce hot water at around 60 ~ 65°C.[4]

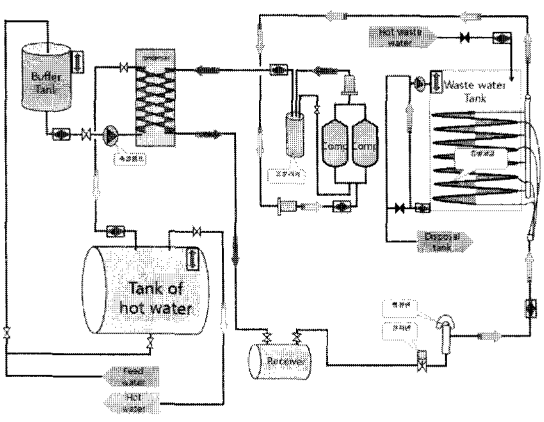


Fig. 6. Heat pump cycle system diagram

This principle is an operation principle to efficiently recycle energy by drawing the heat source in discharge waste water with heat pumps using compressors and transmitting the heat to the water heated by existing boilers to assist the boilers. We configured a heat pump cycle system diagram shown as figure 6.

In the fabricated heat pump system, a heat exchanger is installed in the waste water tank and the refrigerant is evaporated in the heat exchanger to absorb latent heat in waste water. The absorbed heat generates high temperature(100℃) heat when it is compressed by the compressor. We fabricated a heat pump system that brings about energy saving effects by producing hot water at 60°C or higher temperatures using this high temperature heat.

The Controller of the intelligent home network based waste water heat pump recycled energy system was composed of a Microcontroller control part, a constant speed compressor control part, a general valve control part, a temperature sensing/ entry part, compressor over-current sensor entry part, a high/low pressure sensor entry part and an RS485 communication part and the composition of the hardware of the dedicated Controller includes Microcontrollers equipped with variably controllable control algorithm of the waste water heat pump recycled energy system designed as set forth under chapter 3. For existing waste water heat collection systems, in spite of their stability and convenience, diverse mechanical systems with improved individual parts and related parts are available. However, dedicated controllers that can organically and efficiently control these mechanical parts have not been developed. In this respect, we developed a controller dedicated to waste water heat pump recycled energy systems in this study and also fabricated a heat pump system in order to implement the optimum algorithm suitable for the present system.

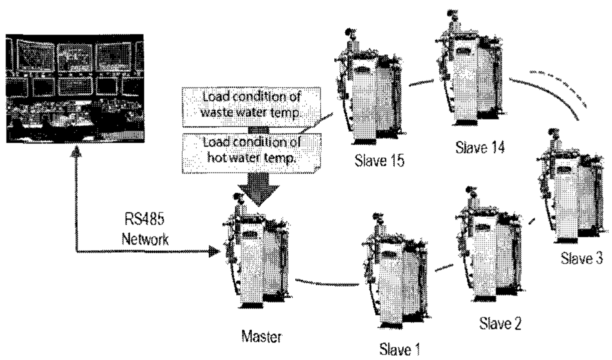


Fig. 7. A configuration diagram of automatically determining the number of compressors based on network based waste water heat load conditions

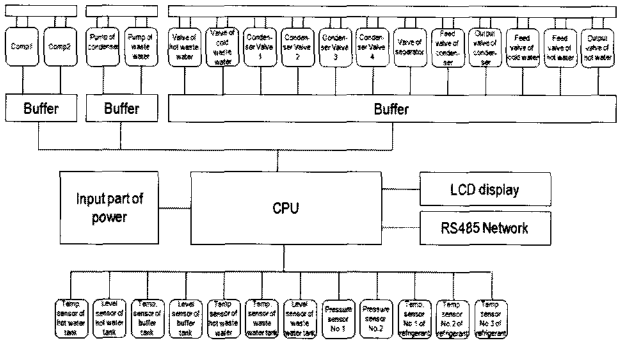


Fig. 8. Heat pump system circuit block diagram

Fig. 9. Compressor mechanical part fabrication diagram

## V. CONCLUSIONS

In this study, in order to achieve compressor operation at constant speeds and optimize inverter outputs in waste water heat collection boiler systems, we designed an intelligent controller using fuzzy control algorithms.

We presented experimental curves of changes in discharged temperatures, waste water heat temperatures and inflow amounts for estimating changes in waste water heat loads and presented fuzzy rules based on these curves and experts' empirical knowledge. The intelligent controller that takes changes in waste water inflow amounts and temperatures can maximize energy efficiency and economic efficiency by estimating changes in waste water heat loads in real time to control the minimum number of compressors to be operated and the amount of operation.

## ACKNOWLEDGMENT

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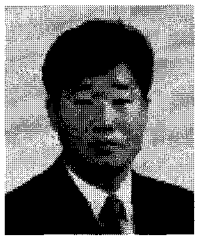

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