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Heat Transfer Comparison Between Continues and Intermittent Flow Controlled by Electrical System for Heat Recovery Unit in the Air Conditioning System

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***Abstract*—Application energy-efficient for air conditioning equipment are the main indicators of the energy conservation and sustainability in Heating, Ventilating, and Air Conditioning (HVAC) systems. The heat recovery is one of the methods of energy savings and optimization. The present work aims to compare the pump energy between two controlling methods (continuous mode and intermittent mode) for flowing the water from the heat recovery to the thermal storage tank. The continuous and intermittent flow was applied by on/off cycles controlled by the electrical system at 40-degree Celsius. This preliminary study focusses on total power consumed by the heat recovery pump, and total heat absorbed by the water in the heat recovery unit. For the two-flowing mode of heat recovery pump, the working parameters were charted and analysed by comparing pump energy data. The result shows that the energy consumption decreased by 58 percent and the total heat absorb was decrease by about 8 percent for intermittent flow condition.**

***Keywords*—heat recovery, energy consumption, flow condition**

I. Introduction

One refrigeration machine which is growing rapidly is the air conditioning (AC) system. Air conditioning is widely used for domestic and industrial applications for controlling the air temperature, humidity, and other function. In some applications, the air conditioning system was combined with a heat pump, heater, other equipment to optimize the energy used [1,2]. Energy conservation and sustainability play an important role in refrigeration heating ventilating and air conditioning (RHVAC) [3,4]. Special concern for domestic need, the quantity of energy consumed is enormous for air conditioning and hot water applications. In previous studies, many investigations have focused on the heating and cooling process and have ignored other characteristics such as waste energy, amount of water use, etc [5,6]. The heat energy provided to buildings is lost about 15% as waste energy through the drain system and more through the air conditioning system. These phenomena became challenging to optimize it for the recent researcher.

System design for efficient energy in refrigeration and air conditioning comprises the addition of grooves [7-9], application of indirect evaporative as a heat recovery which correlates overall energy input [10], optimization on subcooling of refrigeration cycles [11-13], heat recovery integration at outlet section of the compressor to collect the rejection waste heat from the system, floating condensing, and other methods to utilize the heat rejection [14-15]. There has a fast movement of use and optimization of the heat recovery unit linked with air conditioning [16]. Ji et al [17] propose the use of a thermal storage tank as energy storage to improved heat recovery room air-conditioner. Monerasinghe et al [18] conducted a study and feasibility of heat recovery room air-conditioning.

The gained waste heat can adequate the domestic hot water demand as free hot water from air conditioning. The air conditioning coupled with heat recovery gives influence on the system performance [19]. From the literature review above, no literature mentioned about heat recovery controlling system. To address the trends, a preliminary study through-out this research for predicting the flow cycles which is correlated to pump energy consumed by heat recovery for typical residential units in Bali.

II. Description and Methods

A. System Setup

The main component that forms a refrigeration system is the compressor, condenser, expansion device, and evaporator as shown in Figure 1. The key problem of this research is finding performance the air conditioning coupled with heat recovery. The heat recovery system is installed between the compressor and condenser line. Basically, heat recovery is the heat exchange device. The heat recovery is the equipment for heat exchange between refrigerant and water at different temperatures without direct contacting. For this study, the heat exchangers used is shell and coil heat exchanger type.

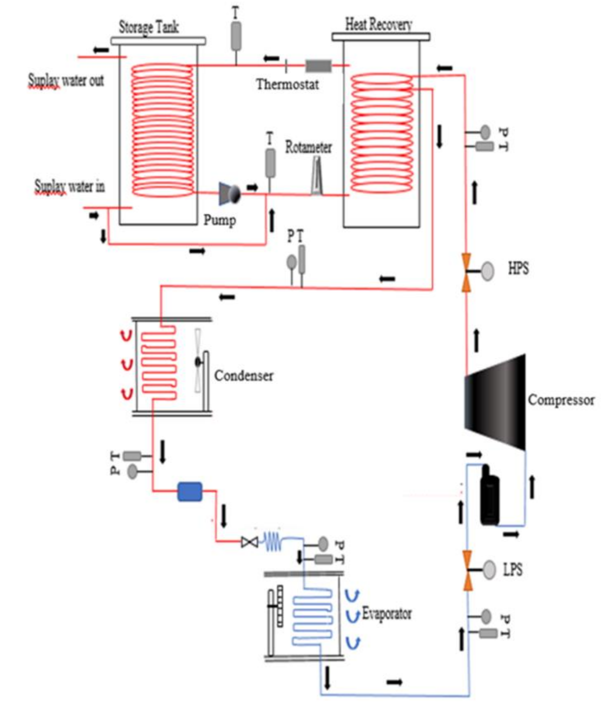

Fig. 1. Schematic installation setup.

The point of comparison in this experiment is controlling the circulation of water through heat recovery. The water pumped by a centrifugal pump from the thermal storage tank to heat recovery. The main component for refrigeration was listed in Table 1.

TABLE I. MAIN COMPONENT

No	Component	Specification
1	Compressor unit	Hermetic, Rotary 750 W, R22
2	Condenser unit	Fin and tube with air cooled system.
3	Expansion device unit	Capillary tube
4	Evaporator unit	Fin and tube exchanger
5	Heat recovery unit	Shell and coil exchanger

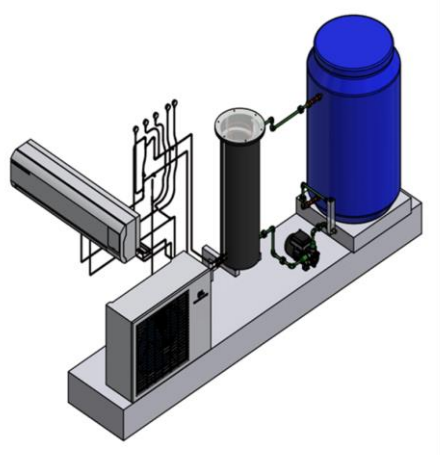

Fig. 2. Positioning of main component.

B. Operation Strategy

According to this investigation, as shown in Fig.1 and Fig.2, the circulation of recovery heat can be divided into two parts: capturing waste heat process and storing the heat in the thermal storage tank. The thermostat controlling the on/off pump cycles at 40^0C. It is important to have sufficient information and analysis of the amount of energy in waste heat. These parameters will affect the performance of the system.

The circulating water to heat recovery was maintained at 13 litres per minute. The water absorbed heat in heat recovery. The temperature circulating water increased and then entered the thermal storage tank through the heat exchanger. The circulating water sucked by the pump for flowing back to the heat recovery.

C. Instrumentation

The refrigerant temperatures R-22 and water circuit at inlet/outlet heat recovery and thermal storage tank were sensed by thermocouples k-type. The sensors are attached to the outside wall of the refrigerant copper tube or inside the thermal insulation. For hot water circuits in heat recovery, the k-type thermocouples are placed inside the water. Meanwhile for the electrical system for controlling the on/off cycles of flow using thermostat unit equipped by sensing bulb. It placed drawn in the heat recovery unit. All temperatures data were recorded using a data logger with sampling at 1 Hz and stored in computer memory.

D. Data Reduction

The important parameters are described below. The ΔT logarithmic mean temperature difference (LMTD).

$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)} = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln\left(\frac{T_{hi} - T_{co}}{T_{ho} - T_{ci}}\right)} \quad (1)$$

Heat absorbs by the water:

$$Q = \dot{m}.Cp.\Delta T \quad (2)$$

III. Results and Discussion

This section discusses about the performance of the heat recovery in the continues flow mode compared to the intermittent flow mode. The water volume flowrate is the same for the two circulating flow modes; their comparative performances are indicating to the performance of heat recovery and discussed as in figure 3.

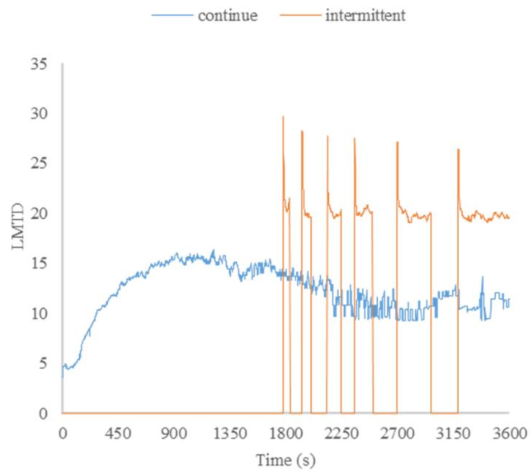

Fig. 3. Comparison of time series LMTD.

Figure 3 depicts the comparison of the time series of continuous mode and intermittent mode. It is obvious, the LMTD for continuous mode increase slowly until the 1800 s. It became more stable after the 1800s s. For intermittent flow mode, it started to increase after 1800 s and being fluctuated as on/off cycles.

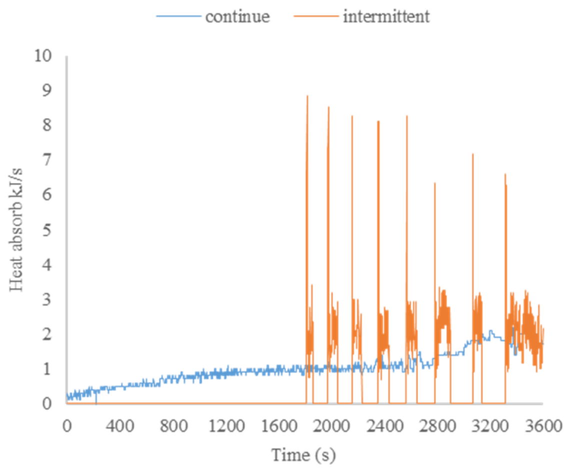

Fig. 4. Comparison of time series heat absorb by the water.

Figure 4 described the comparison of heat absorbed by the water from the refrigerant inside heat recovery. The same explanations agreed with Fig. 3 The total heat absorbed on continuous flow mode was higher than intermittent flow mode for about 8%. This condition is shown because the flow of intermittent cycle was started at 40^0C of heat recovery water temperature. The LMTD and heat absorbed of continuous flow mode is higher than the intermittent flow mode.

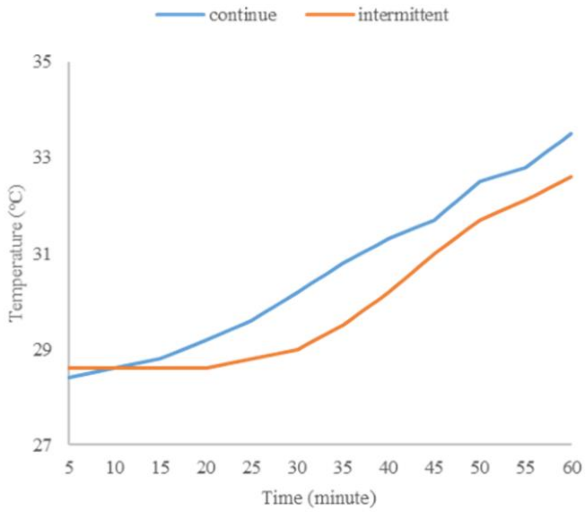

Fig. 5. Time series of temperature of thermal storage tank.

Figure 5 described the comparison of temperature of thermal storage tank. It is shown the temperature of continues flow increases gradually from starting time. Meanwhile for intermittent flow, the temperature of thermal storage tank starting increase after 30 minutes. The continues flow have better performance for thermal storage tank temperature compared to that of the intermittent flow.

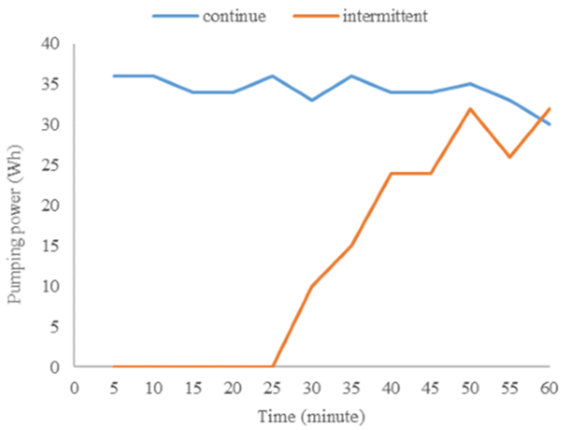

Fig. 6. Comparison of time series pumping power.

Heat recovery uses the waste condenser heat for heating the domestic water. Whether the heat recovered is sufficient, the optimization of pumping energy used still needs to be evaluated. Figure 6 shows the comparison of pumping power between continuous mode and intermittent mode in 60 minutes. Clearly seen that the pumping power for continuous mode was relatively stable. On the other hand, for the intermittent mode the pumping power was zero for 25 minutes, then increasing gradually and reached about the same value with continuous mode. The setting of the water temperature cycle for intermittent flow mode highly affect to total energy consumption. For continues flow mode, the energy consumption about 393 Wh and for intermittent flow mode about 165 Wh. We can calculate the saving energy by about 58%.

IV. CONCLUSION

In this paper, heat recovery has been optimized using a new useful method called the flow controlling. The conclusion of this experimental study as follows: The LMTD value for intermittent flow mode decreased about 56%, the total heat absorbed decreased about 8% and the energy consumed by the pump during flowing the water also decreased 58% compared to that of the continues flow mode.

LIST OF SYMBOLS

Cp heat capacity on constant pressure [kJ/kg^{0}C]

$\dot{m}$ mass flowrate [kg/s]

Q heat absorbed by water [kJ/s]

ΔT Temperature difference [^{0}C]

T_{hi} Inlet temperature of hot fluid [^{0}C]

T_{ho} Outlet temperature of hot fluid [^{0}C]

T_{ci} Inlet temperature of cold fluid [^{0}C]

T_{co} Outlet temperature of cold fluid [^{0}C]

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