A brief comparative thermodynamics review of domestic air conditioning system with or without installed heat recovery

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Abstract. With the increase of mean all season temperature in many cities and demand of hot water for domestic used, high energy consumption of cooling system and electricity are rising continually and rapidly. Thus, the conservation of energy in domestic application more and more important to minimize resources consuming. Following that, room thermal stratification, amount of heat rejected by condenser and recovered by heat recovery is an effective means of saving energy. In this paper, a model of domestic air conditioning system equipped by heat recovery unit was conducted to get the thermodynamics performance, cooling capacity, work of compressor, amount of heat recovered are taken as a case study to evaluate the energy saving and conservation effect. The result from time series data indicate installed the heat recovery unit in domestic air conditioning give benefit to thermodynamics aspect of refrigeration system about 46.1-53.8 percent so it has great potential for energy conservation. Then system that made use of waste heat to produce hot water to serve the building needed was proposed and the heat recovery also has economic viability. Therefore, using the heat recovery system in domestic air conditioning can improve the energy efficiency and realize the energy saving.

1. Introduction

In the last few years, optimization of heat exchanger through surface engineering [1, 2], energy consumption and conservation in building [3-6], thermal power plant, air conditioning system (HVAC) for domestic and commercial using [7, 8] and many others application are always becamethe main concern of recent researcher. It is challenging to optimize the energy used of all the equipment facilities. Special concern for domestic needed, the air conditioning and hot-water system consume energy intensivly [9]. Both systems consume nearly 40% energy from the household total energy. Thus saving energy consumption or increasing the efficiency of energy as small as any will contribute significantly to total energy, cost effective and reductions of greenhouse emission

Efficient energy system design in refrigeration and air conditioning includes integration grooves [2], [10-12], utilization of evaporative condensing unit to minimizepower input to the system [13], optimization on mechanicalsubcooling system [14-16], application of heat recovery unit, floating condensing and other equipment to recover waste heat [17-18].

There has rapid development of utilization heat recovery equipment associated with air conditioning [19]. To resolve this problem, recent researchpropose the use of storage tank as a thermal energy reservoir for recovering condenser heat to enhanced heat recovery room air-conditioner [20]. Monerasinghe *et al.* conducted a pilot study on strorage–enhanced heat recovery room air-conditioner

and confirmed its feasible use in Malaysia [21]. Whether or not the recoverable heat can sufficient the household water heating demand to achieve the freehot water for domestic from air conditioning. From refrigeration system point of view, the application of heat recovery device give impact to the system performance. To address the concerns, an preliminary investigation throught out this research predicting of the refrigeration system performance for typical residential units in Bali.

2. Physical description
The refrigeration system component specification are listed on Table 1.

Table 1. Refrigeration system component specification.

No	Equipment	Description
1	Compressor	Hermetically sealed, Rotary 1 pk, R22 refrigerant
2	Condenser	Air cooled, finned coil.
3	Expansion device	Cappilary tube
4	Evaporator	Fin and tube heat exchanger
5	Heat recovery	Shell and coil heat exchanger

The experimental study was conducted in a test facilityshows in Figure 1. The refrigerant fluid (R22) is compress to superheated vapor state at high pressure and high temperature insidecompressor. Then, flows to the heat recovery exchanger to decrease the temperature at constant pressure condition. The refrigerant then enters the air-cooling condenser, condenses into the fully liquid state inside the condenser coils. For next step, flows into the capilarry tube with a decrease in temperature and pressure became liquisand gas state and flow into evaporator. The evaporator heated by thecirculated air from the fan coils unit (FCU), and turns back into a superheated vapor state. In this experiment heat recovery as function only storage heat as hot water. The hot water not flowing to other equipment or using by the occupant. The basic important parameters of interest are describe below.

Heat absorbed in the evaporator,

$$Qe = h_1 - h_4 \qquad (1)$$

Heat rejected in the condenser,

$$Qc = h_3 - h_5 \qquad (2)$$

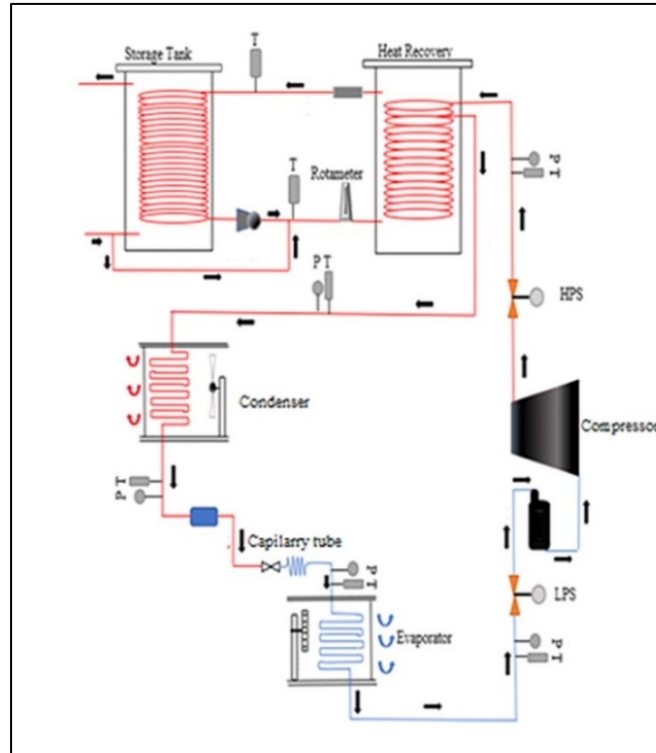Heat absorp in heat recovery unit,

$$Q_{HR} = h_5 - h_2 \qquad (3)$$

Coefficient of performance (COP),

$$COP = \frac{Q_c + Q_{HR}}{W} \qquad (4)$$

Where Qe is heat absorbed by evaporator [kJ/kg]; Qc is heat rejected by condenser [kJ/kg]; h_1 is enthalpy of R22 at outlet evaporator [kJ/kg]; h_2 is enthalpy of R22 at outlet compressor [kJ/kg]; h_3 is enthalpy of R22 at outlet condenser [kJ/kg]; h_4 is enthalpy of R22 at outlet TXV [kJ/kg]; h_5 is enthalpy of R22 at outlet heat recovery [kJ/kg]; W is work of compressor [kJ/kg]; and COP is performance coefficient.

3. Experimental apparatus and method

The sketch of experimental apparatus shown in Figure 1.

Figure 1. Schematic diagram of experimental apparatus.
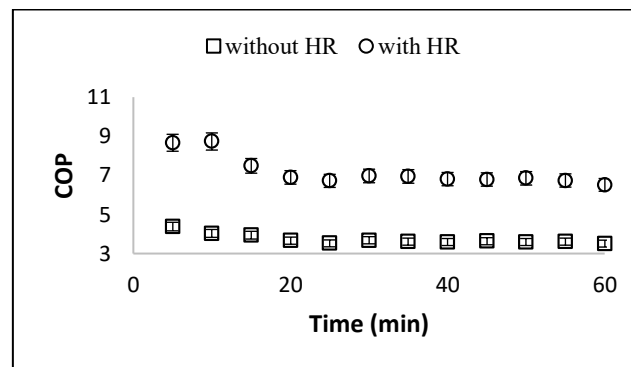
3.1. Instrumentation

The temperatures of refrigerant R-22 and water in heat recovery were measured by thermocouples k-type, attached to the copper tube wall and inside the water. The all temperatures data were digitalized using data logger with frequency 1 Hz and recorded in computer memory. The current of compressor was measured by digital amperemeter with the accuracy data acquisition 0.1 A. The refrigerant pressure in each refrigeration system state point of cycle were measured by 4 (four) analog pressure gauge.

This investigation aims is to determine the theoretical valueof coefficient of performance (COP) of domestic air conditioningsystem. The temperature and pressure data observed from the experiment model calculate using coolpack 1.5 software to calculate the enthalphy of each point.

4. Results and discussion

The data from all of experiment variable taken every 5 minutes. The first step, data temperature collected from air conditioning without heat recovery system. Then, calculated using Equation (1)-(4) to find the theoretical parameter of system performance.

The result indicates that the average COP for air conditioning equipped with heat recovery increase about 46.1% - 53.8% compare to that of air conditioning without heat recovery. The graphic in Figure 2 equiped by the error bar 5%. It shows, the more usefull heat of AC with heat recovery. The usefull come from the heat absorbed by the water becoming hot water and heat absorb from room to be conditioned. Meanwhile the AC without heat recovery, the usefull heat only came from room to be conditioned. There is a lot of heat could use for heating water in the other hand the work of compressor relatively same between the two conditions.

Figure 2. Comparison of COP system.

5. Conclusions

An experimental investigation of domestic air conditioning system with/without heat recovery throught out under tropical climate in Bali. The result can be summarized that the use of heat recovery give many benefit to the system performance. The COP value has increases about twice compare to that of without heat recovery. Another added value is the free hot water for the household.

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