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Development of hybrid Vapor compression Air Conditioning System Save Energy for Air Cool and Water Heater

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Abstract:

This paper describes an experimental study of using the waste heat from a Panasonic Under-Ceiling split room air - conditioner had a rated capacity of 3.51 kW (12,000 Btu/h). An under – ceiling split type air conditioning for heating domestic water in private homes. Energy recovery improved the performance, and the recovered energy could replace electricity completely for heating domestic water use. An extra charge of refrigerant in the air-conditioner could prevent its compressor from over heating during energy recovery. The experimental conducted on varies capacity of the range from 22.5 litres to 120 litres storage tank. Results show the water temperature increased lies in the range of 50 ^{O}C to 65 ^{O}C. It was found that, when the initial water temperature in the 22.5 litres storage tank 27 ^{O}C, the water temperature reached 65 ^{O}C in 105 minutes. For 120 litres water, temperature increased from 27 ^{O}C to 62 ^{O}C,5 in 240 minutes.

Keywords— **Air-Conditioning; Refrigerants R-22, Heat Recovery, Water Heating**

I. INTRODUCTION

In many countries of the world, domestic hot water can be produced by using the waste heat from an air conditioner. In the places with a year round air conditioning requirement, the heat rejected in the condenser is waste, unless the heat is recovered by using a heat exchanger. This can contributed to energy conservation, and be economically viable.

The use of a desuperheater for heating water deserves more attention in the ASEAN countries than in places where there is winter, because a desuperheater does not recover waste heat in winter, but rather uses the energy intend for heating. Normally, heating and cooling systems are widely used in comfort air conditioner and industrial applications. However, the share of the energy for heating and cooling purposes in total energy consumption increases. Due to the economical benefits resulting from high coefficient of performance (COP) values, mechanical heat pump systems become convenient devices for heating and cooling purposes [1], [2]. Heat pump is an apparatus or machine that moves heat from the heat source at a lower temperature to the heat sink at a higher temperature by means of mechanical work or a high temperature heat source [3]. The difference between a conventional a conditioner and a heat pump is that a heat pump can be used to provide heating or cooling.

However, heat pump is still uses the same basic refrigeration cycle for working. It can be easier to say that a heat pump can change which coil is the condenser and which the evaporator by using a reversing valve. So, in cooling conditions, it is common to require heat pumps that are designed only to provide heating. Now a day, the cost of energy continues to rise and it becomes an imperative to save energy and improve overall energy efficiency. A key idea for improving the energy efficiency of many industries is to recover every possible sources of waste heat and convert this energy to a useful output [4]. Moreover, many efforts tried to increase the heat pump performance. However, this study is aimed to investigate the hot water making potential by using the waste heat that released from condenser of the air conditioner.

The advantages of this system are as follows: 1) Save energy due to use of the waste heat to produce hot water 2) Without electric short circuit and 3) Fast to produce hot water and 4) Reduce green house gases [5]. So, some recent researches focused on this area are summarized as follows:

Roongutai et al. [6] studied the warm water making from air-conditioning system by using of the waste heat that released from the air-conditioner. A pressure switch was used to activate both of the condensers, which are automatically controlled. Their results indicated that the highest temperature of the water in the reservoir is 49 ^{o}C. Saisanit et al. [7] design and construct the prototype of the hot water making machine using waste heat released from a common air conditioner system.

Two types of the hot water system such as "submerged coil" and "flow through" are used in their study. Solenoid valves were used to control the flow direction of the refrigerant. Air conditioner with cooling capacity of 3,51 KW and working with R-22 was used in this study. The result indicated that the hot water making machine with submerged coil type is more appropriate to use than the flow through type.

As mentioned before, the purposes of this study are to investigate the potential of hot water making by using a conventional air conditioner as an air-water heat pump and then to compare the COP of the system between conventional air conditioner cycle and heat pump cycle. The energy saving potential for making of 120 L hot water is also presented.

Some work on the use of a heat exchanger for domestic water heating has been investigated by a number of authors Xingxing Zhang et al [8], however, are interested in characterization of a solar photovoltaic/loop-heat-pipe heat pump water heating system. Wonseok Kim et al [9], performance analysis of hybrid solar-geothermal CO2 heat pump system for residential heating were tested.

Pradeep Bansal et al [10] Status of not-in-kind refrigeration technologies for household space conditioning, water heating and food refrigeration. Boonrit Prasartkaew et al [11] interested in a study of the Experimental study on the performance of a solar-biomass hybrid air-conditioning system.

Anjali at al [12] studied the performance analysis of a solar hybrid air conditioner with waste heat recovery and re-use using evacuated tube collector. Aziz et al [13] studied the potential use of heat energy wasted in condenser ac central fo water heating to save energy.

In this study, the bourdon pressure gages were calibrated by the manufacturer. Similarly, all measuring temperature devices are well calibrated in a controlled temperature bath using standard precision glass thermometer. The uncertainty of all temperature measurement after considering the data acquisition system is r 0.1^{O}C.

During the test run, pressure and temperature at the inlet and exit of evaporator and condensers, power consumption at compressor were recorded under the steady state operating condition.

II. EXPERIMENTAL APPARATUS

A Carrier 42 AR Under-Ceiling split room air - conditioner had a rated capacity of 3.51 kW (12,000 Btu/h). Type 38AT Spartan (012-018). The air conditioner had a hermetic type compressor and a thermostatic expansion device. A plate heat exchanger is a model SWEP B15 x 26 plate compact brazed heat exchanger had a rate 4.5 kW was installed between its compressor discharge and condenser inlet. A schematic of the system is shown in Figure 1. The hot water storage tank had a capacity of 120 litres, and was located beside the air-conditioner. The system was tested in Machine Performance of room, which was at 27 ^{O}C. During the test, no hot water was consumed, and the water temperature in the storage tank increased from 27 ^{O}C to 62.1 ^{O}C in 240 minutes.

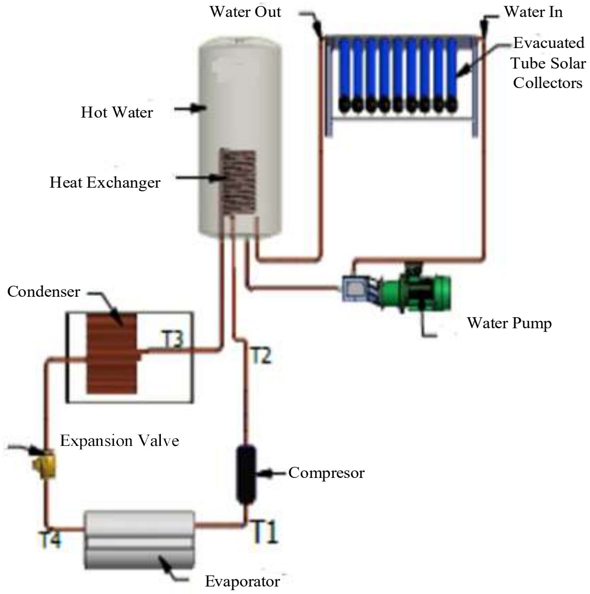

Fig.1 Schematic of air-conditioner with a heat exchanger

Consider the simple vapor-compression refrigeration cycle that forms part of an air-conditioning plants as shown schematically in Figure 1. The refrigerant property diagram on the pressure –enthalpy axes is shown in Figure 2. The refrigeration cycle is modified by the addition of a storage tank and a refrigerant-to-water heat exchanger between the outlet of the compressor and the inlet to the condenser. The hot refrigerant vapor from the compressor can be routed through the plate heat exchanger. The water- side of the plate heat exchanger is connected to allow water from the bottom of the storage tank to be circulated through the plate heat exchanger and back into the top of the storage tank by a circulating pump. The flow of the water and hot vapor in the plate heat exchanger is of the counter-current flow arrangement for more effective heat transfer. The storage tank contains water of mass M and specific heat capacity, C, and ais insulated. The tank has a surface area, A_s, and an overall heat transfer loss coefficient, U_s. The charging process of the storage tank commences when the circulating pump is turned on with no draw-off. Initially, the air – conditioning plant is expected to experience a slight increase in cooling capacity resulting in lowering of the condenser pressure and temperature.

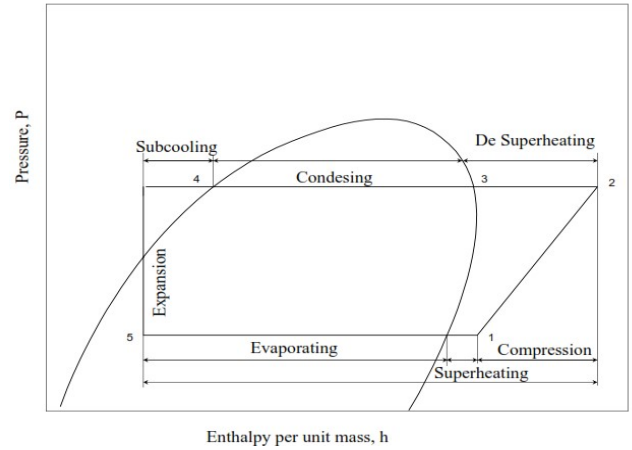

Fig. 2 Pressure – enthalpy diagram

Thereafter, the water temperature, T, the refrigerant outlet temperature of the heat exchanger, T and the condenser temperature, $T_{CO,}$ will all rise continuously throughout the charging process. This will also cause the condenser pressure to increase to its original level, hence causing the compressor outlet temperature, T_2, to rise. After a certain time, its, the discharge process will begin at a constant water draw-off flow rate of mf, and the tank water temperature will then slowly decrease until it reaches a steady value.

III. ENERGY CONSIDERATION

In order to study the hot water making potential of the heat pump system and then compare of the COP between common cycle and heat pump cycle, the important parameters can be calculated from following equation.

Cooling capacity at evaporator (Q_{Evap})

$$Q_{Evap} = h_1 - h_4 \quad (1)$$

Compressor work (W_{Comp})

$$Wcomp = h_2 - h_1 \quad (2)$$

Heating Capacity at Condensor, (Q_{Cond})

$$Q_{cond} = h_2 - h_3 \quad (3)$$

Coefficient of performance (COP)

$$COP = \frac{Q_{Evap}}{Q_{Comp}} \quad (4)$$

where h_1 and h_2 are the enthalpy at inlet and exit of compressor, respectively. h_3 is the enthalpy at exit condensor and h_4 is the enthalpy at inlet of evaporator.

Consider the control volume (CV), C, (Figure 1) which comprises the heat exchanger and the storage tank. The first law when applied to CV, C can be written as : Rate of increase internal energy of the tank water equals rate of decrease of the refrigerant enthalpy minus rate of increase of the discharged water enthalpy minus rate of heat loss of the storage tank to the ambient,

$$MC\frac{dT}{dt} = m_R(h_2 - h_3) - m_F c_{PF}(T - T_o) - Q_{LOSS} \quad (5)$$

Where

$$Q_{LOSS} = U_S A_S (T - T_o) \quad (6)$$

C_{pF} is the average specific heat capacity of the discharge fluid from the tank and T_O is the ambient temperature. It should be noted that the inlet and outlet temperatures, T_2 and T_3, respectively, of the heat exchanger are time-dependent functions.

By neglecting the storage capacity of the heat exchanger, the component may be assumed to function as a steady state device. Its effectiveness is therefore given by

$$\in = \frac{T_2 - T_3}{T_2 - T} \quad (7)$$

For a given compressor inlet condition and isentropic efficiency, the exit specific enthalpy, h2, of the compressor is given by

$$h_2 = h_1 + \frac{1}{\eta_c}(h_{2s} - h_1) \quad (8)$$

Where h_{2s} is the compressor exit specific enthalpy such that its specific entropy is the same as the compressor inlet specific entropy, s_1.

For a given condenser pressure, P_{CO}, the valued of h_{2s} is known; hence h_2 is given by Equation (4). Then from the State Principle, the compressor outlet temperature, T_2, is given by the equation of state

$$T_2 = f_1(P_{CO,} h_2) \quad (9)$$

From assumptions made in (f) and (g), the specific enthalpy, h_3, of the refrigerant at the entry to the condenser is given by

$$h_3 = h_4 + Q_{CO} \quad (10)$$

Where the condenser specific enthalpy, h_4, and the condenser specific cooling capacity, Q_{CO}, are functions of P_{CO} and (T_{CO}- T_{CW}), respectively. Hence the outlet heat exchanger temperature, T_3, can be written as

$$T_3 = f_2(P_{CO}, h_3) \quad (11)$$

For a given flow and ambient conditions, Equations (1) to (7) form a closed set of equations and together with the relevant refrigerant property routine, a numerical scheme can be established. The relevant properties, such as the storage liquid temperature, can be solved as functions of time.

VI. RESULT AND DISCUSSION

The results obtained in the heat recovery from air - conditioning for water heating test are presented here. Figure. 3 shows the temperature of the water in the tank and outlet air temperature versus time for various capacity of the tank. The water storage tank had a capacity of 22,5 litres, and was located next to the air-conditioner.

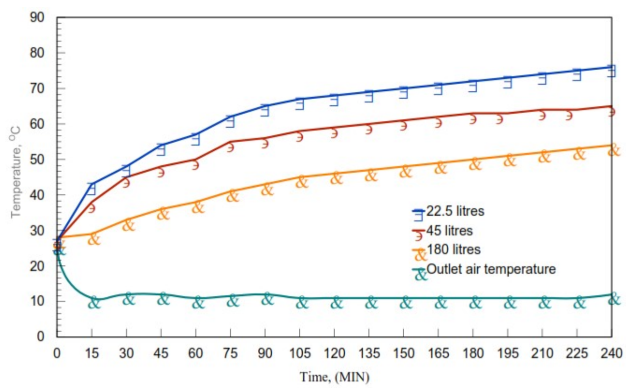

Fig. 3 Heating of different volumes of water vs Time

The System was tested in a room, which was at 27.5 ^{O}C. During the test, no hot water was consumed, and the water temperature in the storage tank increased from 27 ^{O}C to 70 ^{O}C in 240 minutes. For the capacity of storage 45 litres, the water temperature in the storage tank increased from 27 ^{O}C to 53 ^{O}C in 240 minutes. It was found that, when the water storage tank had a capacity of 180 litres, the water temperature reached 26 ^{O}C in 240 minutes. The energy recovered was equivalent to 43,7 % of the energy used by the room air-conditioner. Results also indicate that the temperature air outlet decreased when the water heating system is introduced than in the case when it functions normal

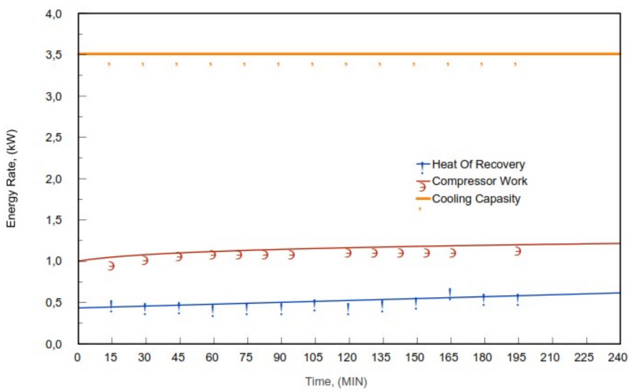

Fig. 4 Cooling Capacity, Power Consumption and Rate of Heat Recovery Versus Time

Figure 4 shows the cooling capacity, power consumption and energy recovery versus time. It can be seen in regard to the air-conditioner's performance, cooling capacity no changes. The initial energy consumption slightly increased, but afterwards the decrease in energy consumption by compressor. The energy recovery changes were found to be minimal.

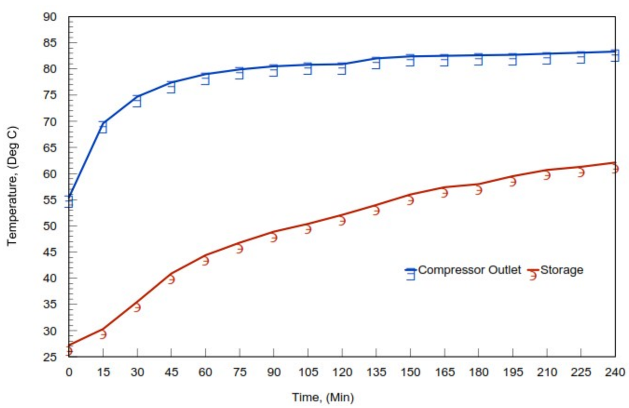

Fig. 5 Variation Temperature Vs Time

Figure 5 shows that the Temperature of Compresore outlet increase to 80^{O}C in 30 menit. While storage temperature 65 ^{O}C in 240 menit.

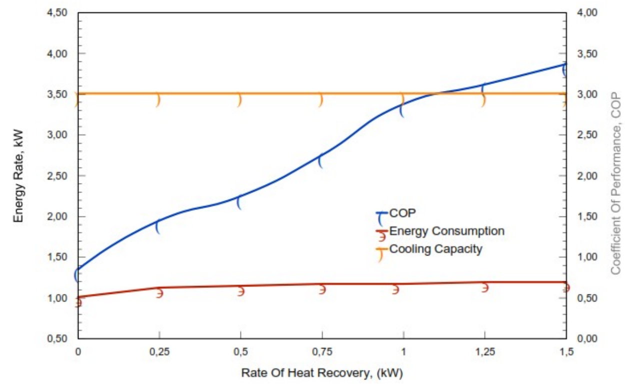

Fig. 6 Cooling Capacity, Power Consumption and Coeficient of Performance, COP

Figure 6 shows that the power consumption of the air- conditioner was slightly increased with increasing energy recovery, while the cooling capacity to be constant. The coefficient of performance increased with energy recovery.

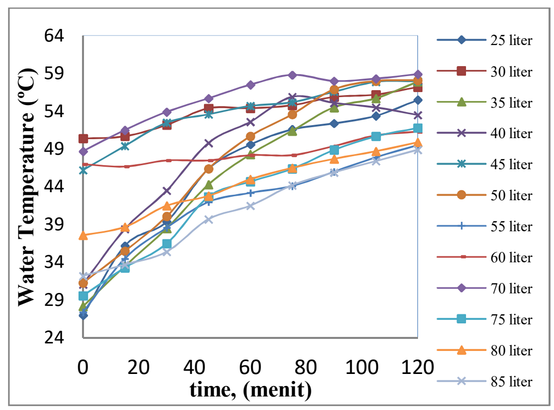

Figure 7. Heating Water Temperature and Time

Figure 7 shows that the water temperature varies on capacity of the storage in 120 menit.

V. CONCLUSIONS

The energy recovered from the traditional unnecessary waste of energy from air-conditioner system can be significant. The energy recovered from the rejected heat on cooling cycle is virtually free. On the other hand. Energy received from the air-conditioning. The heat recovery equipment appears to be in those installations where requirements for heating and cooling are paralleled by requirements for substantial amounts of hot water. Restaurants, hotels, motels, apartment houses, hospitals, nursing homes, dormitory and residences are examples of such cases.

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