THE EXPERIMENTAL RESULT OF HEAT RECOVERY FROM HEAT PUMP SYSTEM FOR DOMESTIC WATER HEATING

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Abstract

This paper describes an experimental study of using the waste heat from a Carrier 42 AR Under-Ceiling split room air - conditioner had a rated capacity of 4.71Hp (12,000 Btu/h). An under – ceiling split type heat pump 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 180 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 was 27 ^{O}C, the water temperature reached 65 ^{O}C in 240 minutes. For the 180 litres of water, temperature increased from 27 ^{O}C to 62 ^{O}C in 240 minutes.

Keywords: Heat pump, conserve energy, water heating, cooling capacity.

1. FOREWORD

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 heat pump requirement, the heat rejected in the condenser is waste, unless the heat is recovered by using a plate 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.

Some work on the use of a heat exchanger for domestic water heating has been investigated by a number of authors C.T Healy et al (1965), however, are interested in water heating by recovery of rejected heat from heat pumps. T.Y. Bong et al , hot water from room air conditioners, three room air–conditioners equipped with a heat exchanger were tested. Lin et all (1988) studied experimentally the feasibility of recovering the waste condenser heat from heat pump an air-conditioning unit for water heating and the effect on the system performance. S.K Chan, studied transient simulation of direct heat recovery from an air-conditioning system for water heating. N.J Monarasinghe et al (1982) studied experimentally conserved energy from room air-conditioner for water heating.

A.O. Tay (1992) interested in a study of the use of heat pumps for recovering heat from central air-conditioner systems. Later Meyer et al (1997) studied domestic hot water consumption in South African houses for developed and developing communities

This paper describes a study experimental work done at the university on energy recovery from room air-conditioners. A room air- conditioners equipped with a plate heat exchanger were tested, with a different water heating arrangement.

2. EXPERIMENTAL APPARATUS

A Carrier 42 AR Under-Ceiling split room heat pump had a rated capacity of 4.71 Hp (12,000 Btu/h). Type 38AT Spartan (012-018). The heat pump 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 200 litres, and was located beside the air-conditioner. The system was tested in machine performance 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 240minutes.

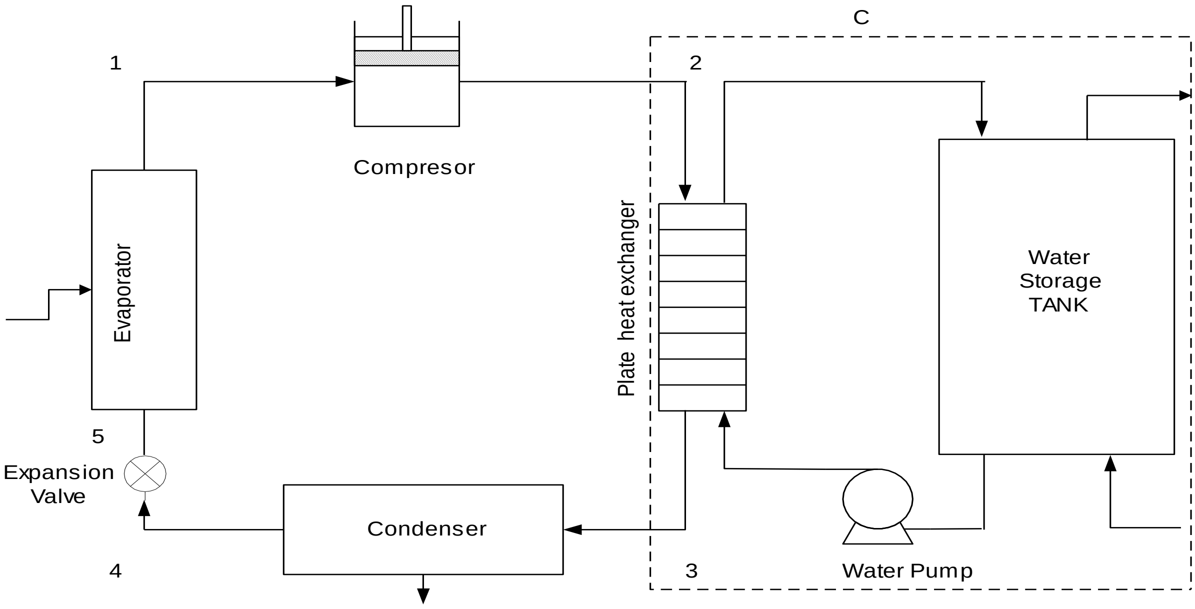

Figure 1 Schematic of air-conditioner with a plate heat exchanger

Consider the simple vapour-compression refrigeration cycle that forms part of heat pump 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 (a plate heat exchanger) between the outlet of the compressor and the inlet to the condenser.. The hot refrigerant vapours 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 vapour 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 is insulated. The tank has a surface area, A_s, and an overall heat transfer loss coefficient, U_s.

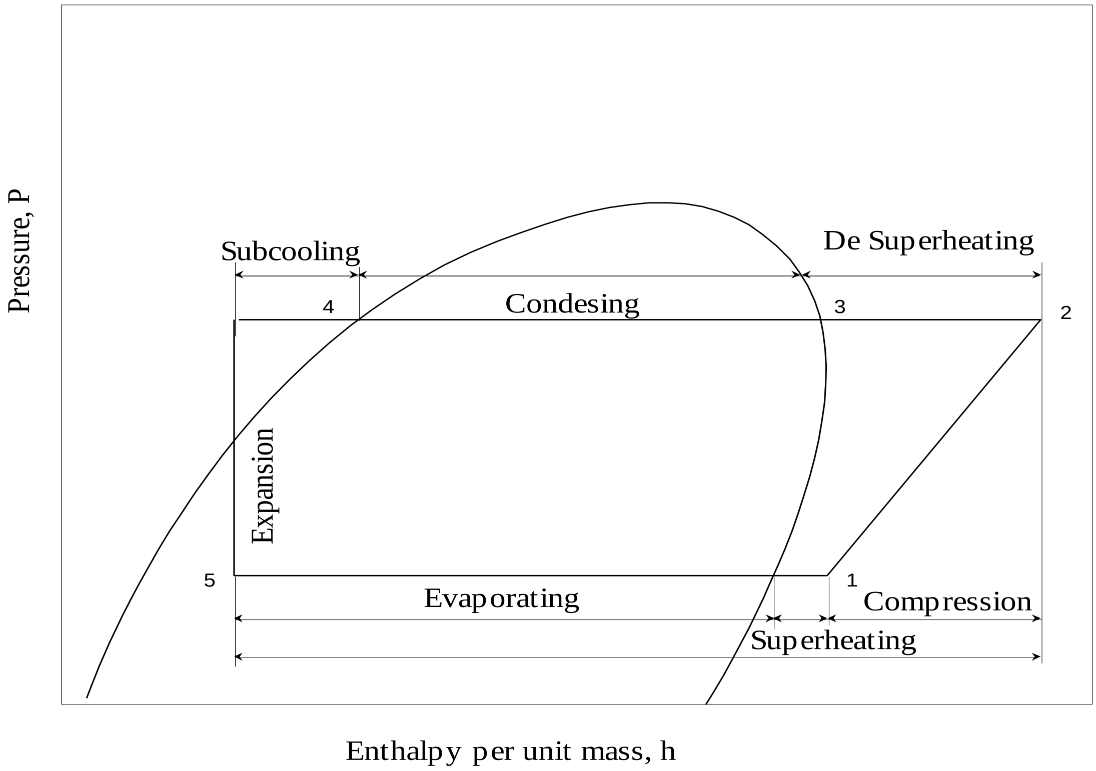

Figure 2 Pressure – enthalpy diagram

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.

Thereafter, the water temperature, T, the refrigerant outlet temperature of the plate 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.

3. ENERGY CONSIDERATION

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,

$$MC\frac{dT}{dt} = m_R(h_2 - h_3) - m_F c_{PF}(T - T_o) - Q_{LOSS}$$
(1)

Where

$$Q_{LOSS} = U_S A_S\,(T - T_o) \qquad (2)$$

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

$$\in = \frac{T_2 - T_3}{T_2 - T} \quad (3)$$

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

$$h_2 = h_1 + \frac{1}{\eta_c}(h_{2s} - h_1) \quad (4)$$

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

$$T_2 = f_1(P_{CO,} h_2) \quad (5)$$

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

$$h_3 = h_4 + Q_{CO} \quad (6)$$

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

$$T_3 = f_2(P_{CO}, h_3) \quad (7)$$

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.

4 RESULT AND DISCUSSION

The experimental results obtained in the heat recovery from heat pump system 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.

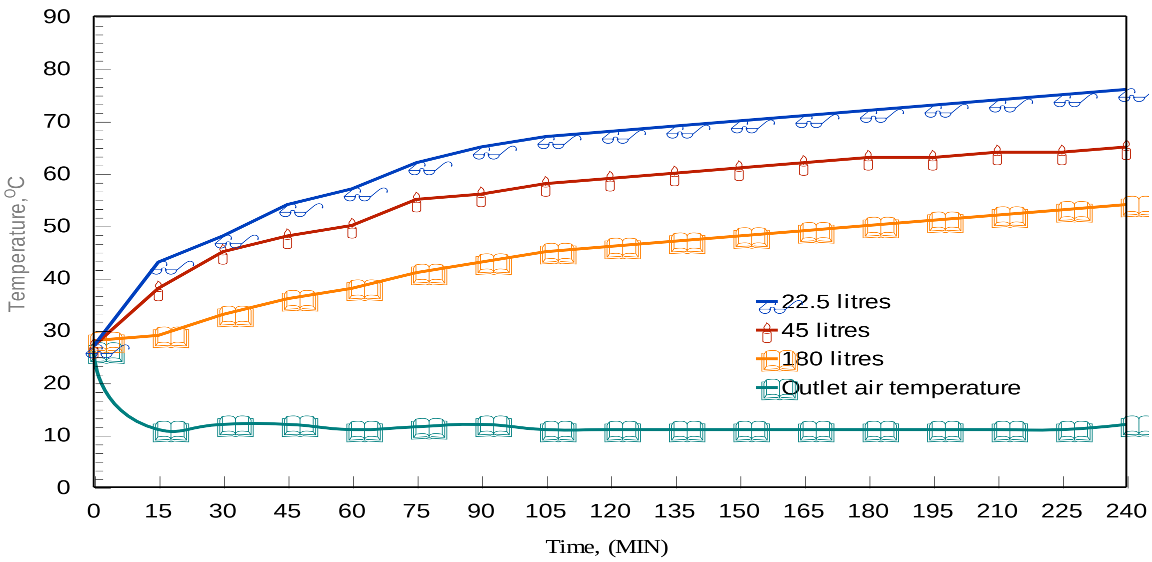

Figure 3. Graph showing heating of different volumes of water

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 normally.

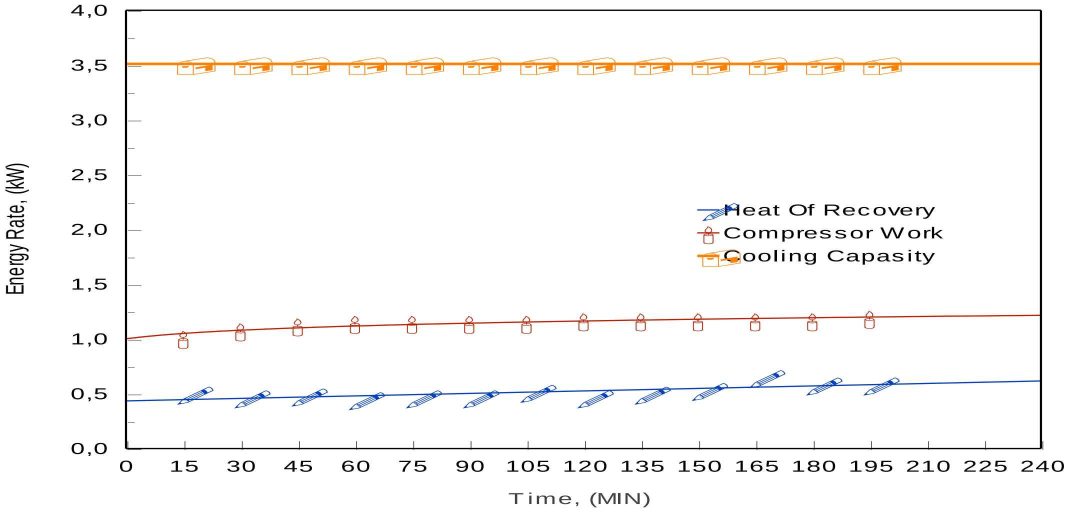

Figure 4. Cooling Capacity, Power Consumption and Rate of Heat Recovery Versus Time

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.

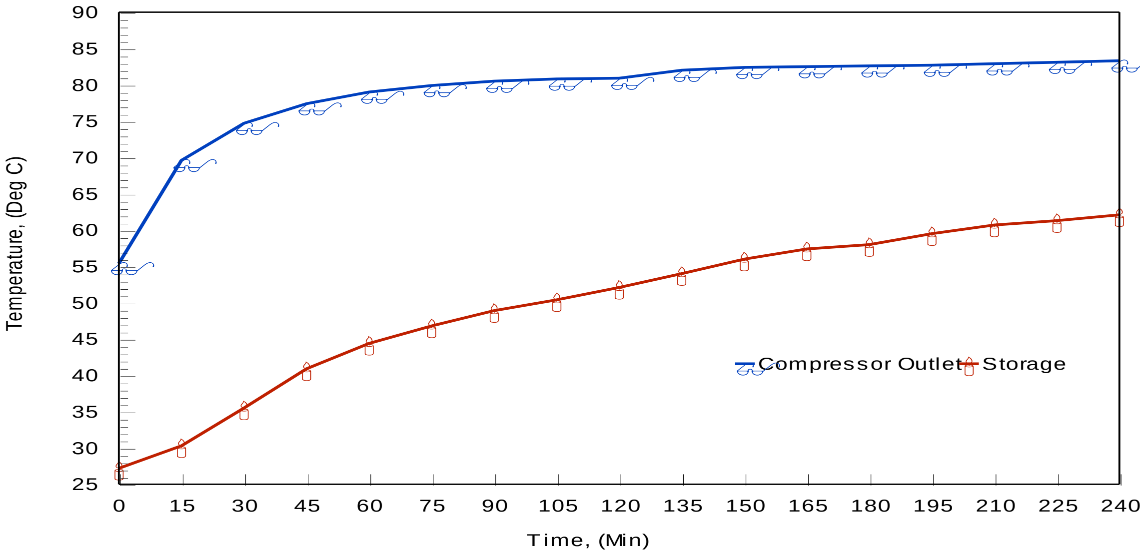

Figure 5 Time Versus Variation Temperature

Figure 5 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.

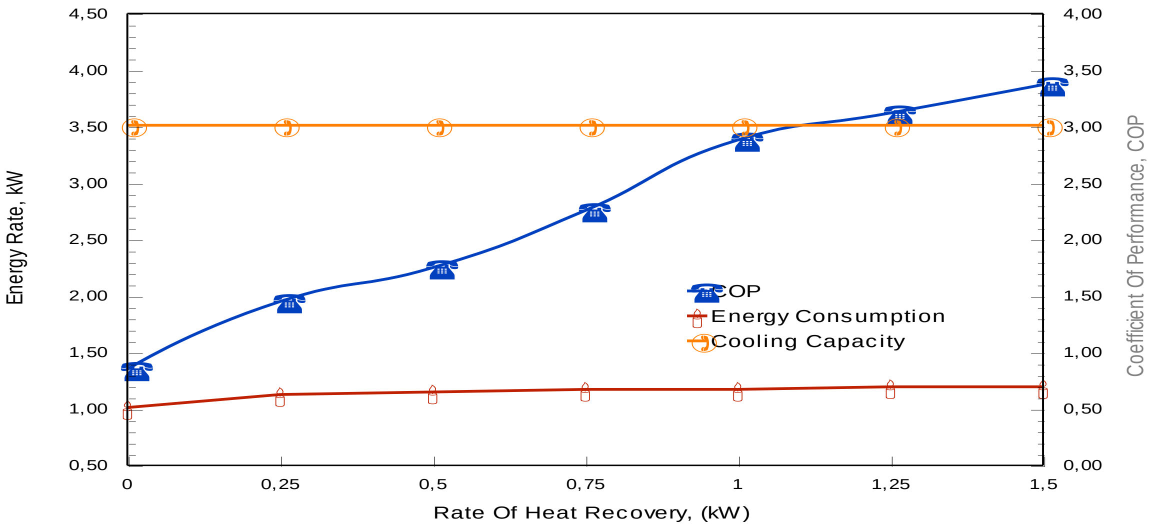

Figure 6 Cooling Capacity, Power Consumption and COP

5. CONCLUSIONS

The energy recovered from the traditional unnecessary waste of energy from heat pump 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 heat pump system. 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. Generally the energy recovery increased the cooling capacity, and decreased the energy consumption, and therefore increased the coefficient of performance.

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