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A Study of Heat Exchanger Produces Hot Water from Air Conditioning Incorporated with Solar Energy System

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Abstract

This research is a study of Heat Exchanger Produces Hot Water from Air Conditioning Incorporated with Solar Energy System. Its objective is to compare the efficiency of heat exchanger produces hot water from the air conditioning incorporated with the solar energy. The experiment with hot water system is separated into two sections. The first section is the split operation of air conditioning and solar energy producing hot water and the second section is solar energy producing hot water incorporated with waste heat recovery from air conditioning. The study reveals that the temperature of solar energy producing hot water is 48.7 °C. While, the maximum temperature of hot water incorporated with waste heat recovery from air conditioning is 52.0°C with 0.025 kg/s of water flow rate. This flow rate through heat exchanger is the most efficient in the experiments on hot water production. In comparison with the first section, the temperature of hot water produced by the solar energy incorporated with waste heat recovery from air conditioning is increased by 3.3 °C and can save 21.7% of energy.

Keywords: Conditioning, Heat Exchanger, Hot water, Solar Energy, Waste heat recovery

Introduction

Hospitals are considered as large energy consumers for a variety of activities. In Thailand, 50% of electrical energy is consumed by air condition system, 30% of electrical energy is consumed by lighting system and the rest is used to produce hot water. Hover the electric energy is not a good energy source to produce the hot water. In the meantime, such a great deal of waste heat is rejected by the air-condition system. If the waste heat recovery from air conditioning is used with solar hot water system to produce hot water the energy consumption should be reduced. According to the study, it is found that the hot water production system using heat recovery from air condition incorporated with solar energy system can promote energy saving as well as reduce the global warming situation. However, in Thailand especially in hospital, and hotel, the operation of the two systems, air condition and solar energy, are separated function which causes much more waste heat energy. [1], [2] The objective of A Study of Heat Exchanger Produces Hot Water from Air Conditioning Incorporated with Solar Energy System is to study on the temperature of hot water in storage tank as well as to study on the ability to save energy of Air Conditioning Incorporated with Solar Energy System in compare with solar energy producing hot water. Therefore, the research aims at the development of Heat Exchanger Produces Hot Water from Air Conditioning Incorporated with Solar Energy System and the increase of air conditioning's efficiency.

THEORY

The actual heat transfer may be computes by calculating either the energy lost by hot fluid or the energy or the cold fluid, as show in equation (1). [3], [4]

$$q_H = \dot{m}C_p(T_{in} - T_{out}) \tag{1}$$

Equation (2) can be used to define an instantaneous efficiency. [5]

$$\eta_t = \frac{(q_H / A_c)}{I_t} \times 100 \tag{2}$$

The definition of instantaneous efficiency, provides the basis for simulation model as equation (3). [5]

$$\eta_{outdoor} = F_R(\tau\alpha)_n - F_R U_L \left[\frac{(T_o - T_a)}{I_T} \right] \tag{3}$$

$$\eta_{outdoor} = \frac{QU}{A_C I_T} = \frac{\dot{m}C_P(T_o - T_a)}{A_C I_T} \tag{4}$$

The ideal vapor-compression refrigeration cycle

Diagram frequently used in the analysis of vapor-compression refrigeration cycle is the P-h diagram, as shown in Fig.1. On this diagram, the heat transfer in the condenser and the evaporator is portion to the lengths of the corresponding process curves. The vapor-compression refrigeration cycle is the most widely used cycle for refrigerators, air-condition systems. [3], [6]

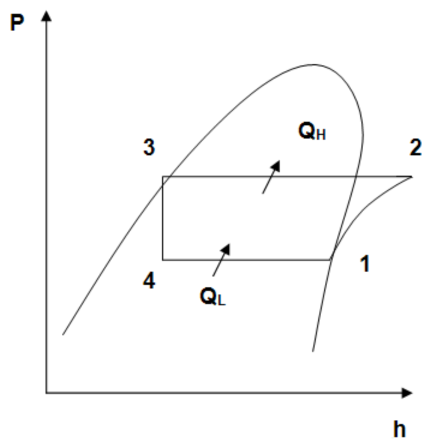

Figure 1 P-h diagram of the refrigeration cycle.

An air-conditioning system consists of processes: (for calculate COP.)

1-2 Isentropic compression in compressor

$$\dot{W}_{12} = \dot{W}_C = \dot{m}_R \left(h_2 - h_1 \right) \tag{5}$$

4-1 Constant pressure heat absorption in an evaporator

$$\dot{Q}_{41} = \dot{Q}_{Evap} = \dot{m}_R \left(h_1 - h_4 \right) \tag{6}$$

The Coefficient of Performance of a refrigeration machine is the ratio of energy removed at the evaporator to energy supplied to the compressor. Thus using the notation of Figure 1, we have the formula [3], [5]

$$COP_R = \left(h_1 - h_4 \right) / \left(h_2 - h_1 \right) \tag{7}$$

Effectiveness – NTU Method

We define the heat-exchanger efficiency as [4]

$$\text{Efficiency } (\varepsilon) = \frac{\text{actual heat transfer}}{\text{maxmum possible heat transfer}}$$

The actual heat transfer may be heat transfer may be computed by calculating either the energy lost by the hot fluid or the energy gained by the cold fluid. Consider the counter-flow exchanger.

$$q = \dot{m}_h C_h (T_{h1} - T_{h2}) = \dot{m}_c C_c (T_{c1} - T_{c2}) \tag{8}$$

The fluid which might undergo this maximum temperature difference is the one having the minimum value of $\dot{m}C$ since the energy balance requires that the energy received by one fluid be equal to that given up by the other fluid; if we $\dot{m}C$ go through the maximum temperature difference, this would require that the other fluid undergo a temperature difference greater than the maximum, and this is impossible. So, maximum possible heat transfer is expresses as.

$$q_{\max} = \dot{m}C_{\min} (T_{hi} - T_{ci}) \tag{9}$$

The minimum fluid may be either the hot or cold fluid, depending on the mass-flow rates and specific heats. For the counter-flow heat exchanger, The subscripts on the effectiveness symbols designate the fluid which has the minimum value of $\dot{m}C$,

$$\varepsilon_c = \frac{\dot{m}_c C_c (T_{c1} - T_{c2})}{\dot{m}_c C_c (T_{h1} - T_{c2})}$$

$$\varepsilon_c = \frac{(T_{c1} - T_{c2})}{(T_{h1} - T_{c2})} \tag{10}$$

In a general way the effectiveness is expressed as

$$\text{Efficiency }(\varepsilon) = \frac{\Delta T(\text{minimumfluid})}{\text{maxmum temprature difference in heat exchanger}} \quad (11)$$

Equipment and Experiment

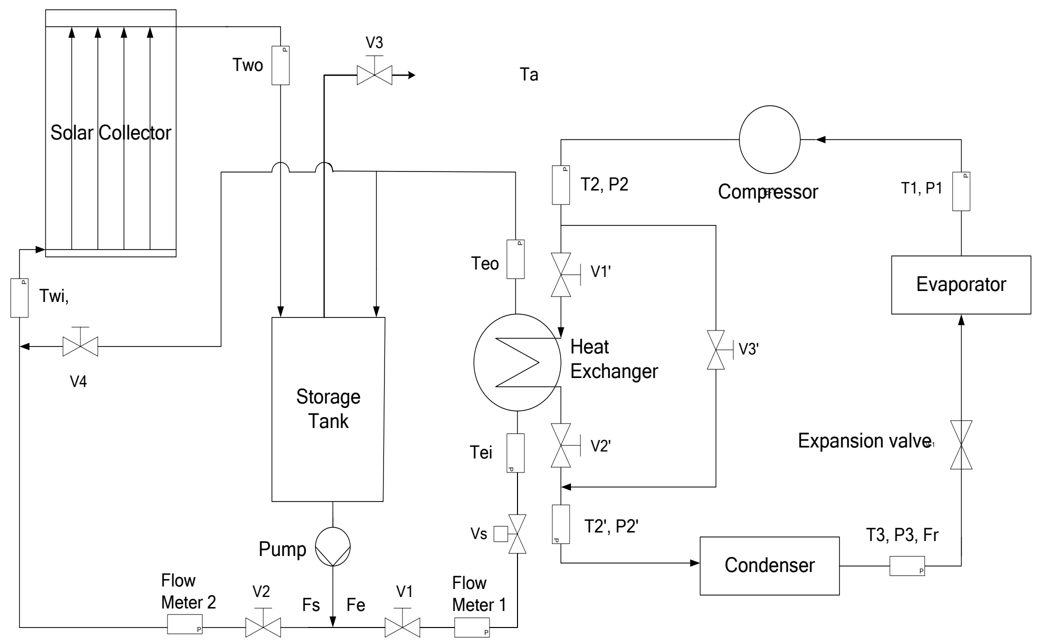

Figure 2 The diagram of Hot Water Production system and data collecting position.[7]

Experiment Methods

The experiment of the separate operation of air conditioning system and solar energy producing hot water:

1. Prepare the water in the tank at a top level of the system.
2. Open the valve for water to flow into solar collector at 0.024 kg/ s of the flowing rate. The heated water will be stored in the closed system tank. Data is collected at each position every 30 minutes between 11.00- 13.00 hours.
3. Turn on the air-conditioner at 25°C in order to collecting data on various temperatures of heat exchanger and solar energy producing hot water. Data is collected at each position every 30 minutes between 11.00- 13.00 hours.

The experiment of solar energy producing hot water incorporated with waste heat recovery from air conditioning:

1. Prepare the water in the tank at a top level of the system.
2. Open the valve for water to flow into solar collector at 0.024 kg/ s of the flowing rate.
3. The heated water is be stored in the closed system tank. Data is collected at each position every 30 minutes between 11.00-13.00 hours.

4. Open the solenoid valve which controls the water flowing into the heat exchanger. The valve operation depends on temperature at outlet temperature of the compressor.
5. Data is collected at each position every 30 minutes between 11.00- 13.00 hours.
6. Turn on the air-conditioner producing hot water from heat recovery. The heat exchanger is set up at outlet of the compressor that transfers heat from high temperature medium to a low temperature one. The water flow rate passes through the heat exchanger are 0.025, 0.050 and 0.075 kg/s respectively. Meanwhile, collecting data on various temperature of heat exchanger and solar energy producing hot water by setting the air-conditioner at 25°C. Data is collected at each position every 30 minutes between 11.00- 13.00 hours.

The accuracy of data collection should rely on repetition experiment, data comparison and ambient temperature.

Figure 3 Heat Exchanger.[7]

Results and Discussion

The experiment with hot water system is conducted in order to collect the data on various temperatures of heat exchanger and solar energy producing hot water. The experiment with hot water system is separated into two sections. The first section is the separate operation of air conditioning and solar energy producing hot water. The second section is solar energy producing hot water incorporated with waste heat recovery from air conditioner. The collected data of the two sections has been done between 11.00- 13.00 hours. Since this period boosts the system operation at its extreme capacity.

Result of Testing on Solar Collector

The collector efficiency of the experiment on solar energy producing hot water shows that value of FR($\tau\alpha$)n and FRUL are 0.612 and 8.085 W/m2°C respectively as presented in Figure 6

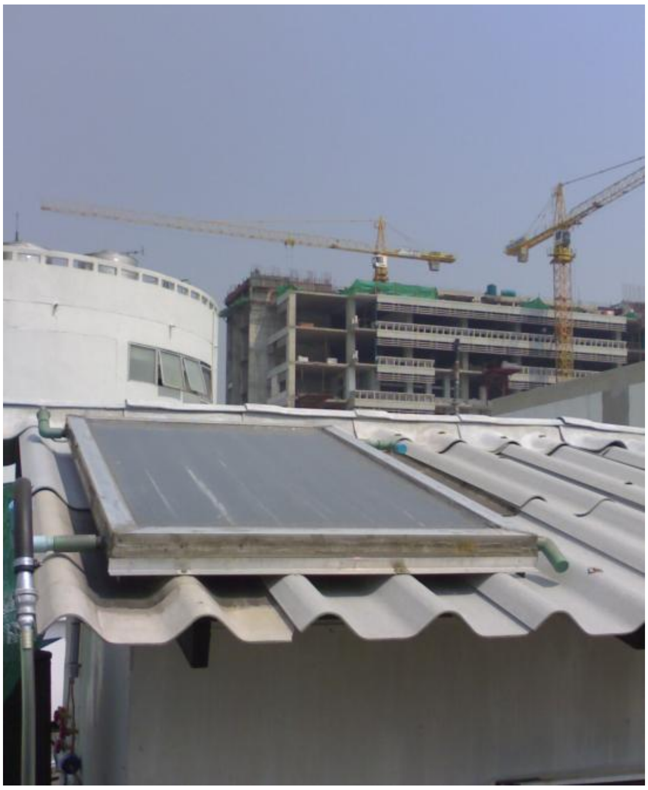

Figure 4 Solar Collector.[7]

Figure 5 Condensing Unit, Pressure gage, Control Valve and Hot Water Tank.[7]

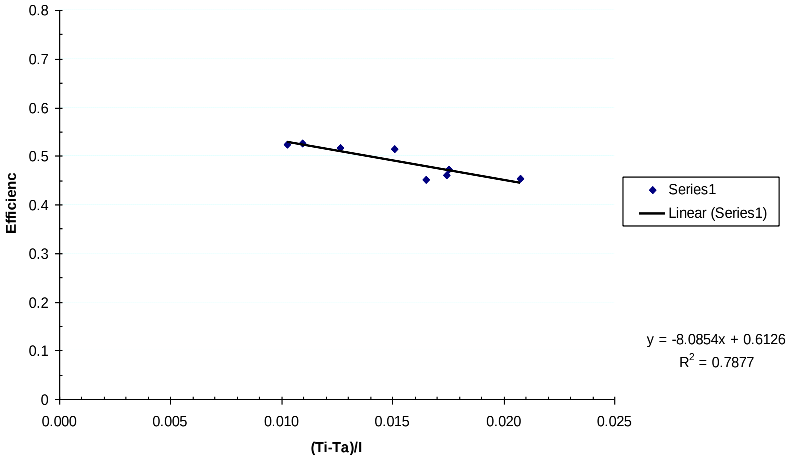

Figure 6 The efficiency of collector.[7]

The experiment with hot water system is separated into two sections. The first section is the split operation of air conditioning and solar energy producing hot water and the second section is solar energy producing hot water incorporated with waste heat recovery from air conditioning. The study reveals that the temperature of solar energy producing hot water is 48.7 °C. While, the maximum temperature of hot water incorporated with waste heat recovery from air conditioning with 0.025, 0.050 and 0.075 kg/s of water flow rate are 52.0, 54.0 and 52.5 oC respectively, the temperature of hot water produced by the solar energy incorporated with waste heat recovery from air conditioning is increased by 3.3, 5.3 and 3.8 oC respectively . Since this period boosts the system operation at its extreme capacity.

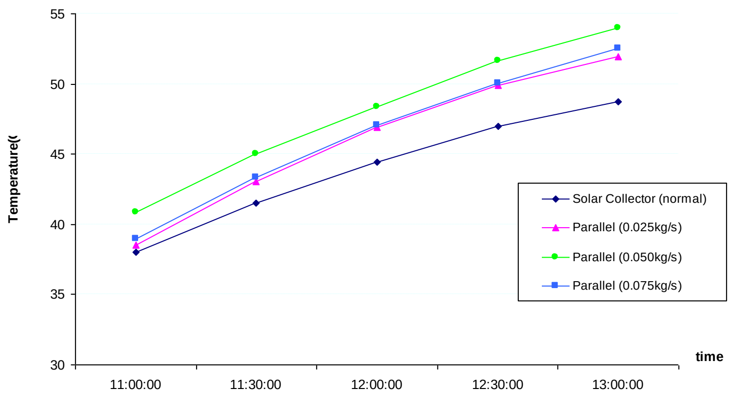

Figure 7 A comparison of water temperature in the tank between two experiments. [7]

The definition of instantaneous efficiency, provides the basis for simulation model as shown in Figure 8 and the collector efficiency is decreased since the temperature of hot water in storage tank is increased

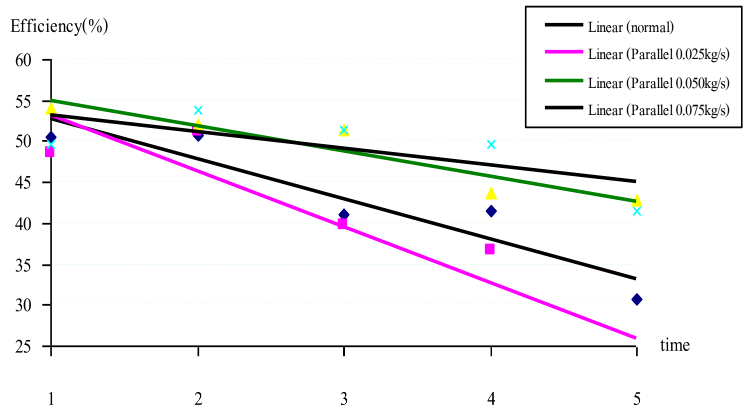

Figure 8 the efficiency of collector at each moment. [7]

The result of heat-exchanger efficiency is decreased when the water passes through heat exchanger has higher temperature. Figure 9 to Figure11 are shown various of water flow rates to heat exchanger.

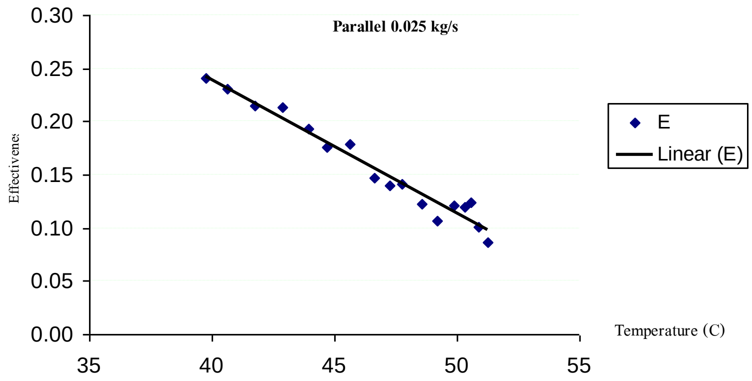

Figure 9 A comparison of heat-exchanger efficiency with water temperature inlet, 0.025 kg/s of water flow rate. [7]

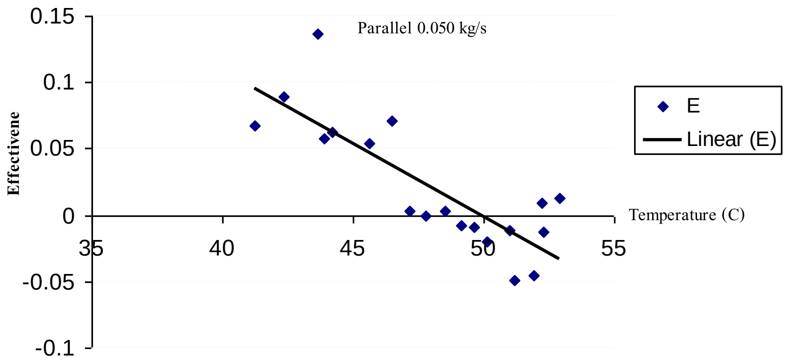

Figure 10 A comparison of heat-exchanger efficiency with water temperature inlet at 0.050 kg/s of water flow rate. [7]

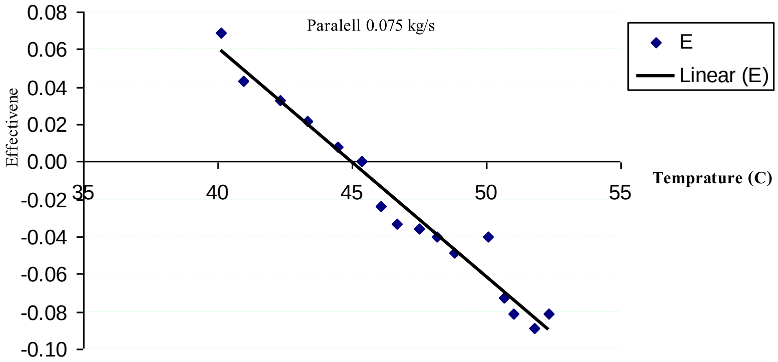

Figure 11 A comparison of heat-exchanger efficiency with water temperature inlet 0.075 kg/s of water flow rate. [7]

In comparison, the Coefficient of Performance (COP) of the air conditioner of the first experiment has constant value when it operates normally. The COP of the second experiment is higher than that of the first one since the water in the tank has lower temperature. It causes the refrigerant transfer heat from higher temperature medium to a lower temperature one before flowing into condenser and also takes much heat from the experiment room. The water flow rate in the second experiment is 0.025 kg/s, 0.050 kg/s and 0.075 kg/s. When comparing with normal system air-conditioner, it can save 21.7%, 13.3% and 7.5% respectively.

Conclusion

The study reveals that the temperature of solar energy producing hot water is 48.7 ^{O}C. For the second experiment on solar energy producing hot water incorporated with waste heat recovery from air conditioning by using the parallel connection of heat exchanger and solar collector with water inlet at 0.025, 0.050 and 0.075 kg/s of flow rate and the temperature of hot water production are 52.0 ,54.0 and 52.5 ^{O}C respectively. These temperature values in orderly are 3.3, 5.3 and 3.8 ^{O}C higher than solar energy producing hot water. Moreover, Solar energy producing hot water incorporated with waste heat recovery from air conditioning can save 21.7, 13.3 and 14.4% of energy when comparing with normal operation system air-conditioner. In summary, hot water incorporated with waste heat recovery from air conditioning is the most efficiency system among the two experiments since the maximum temperature of hot water is 52.0^{O}C with 0.025 kg/s of water flow rate. The temperature of hot water produced by the solar energy incorporated with waste heat recovery from air conditioning is increased by 3.3 ^{O}C which affected on increasing COP efficiency of normal system air-conditioner and can save 21.7% of energy.

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