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Analysis of Heat Recovery System Performance Using a Serpentine-Type Heat Exchanger on Water Heater with Fins Number Variation

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ABSTRACT

The water heater is a common facility found in hotels or homes. There are alternative ways to do this besides using water heaters on the market, namely by utilizing the heat generated by the compressor and which will be discharged through the condenser, by adding a heat recovery system to the air conditioning unit. These research tests were carried out on variations of the serpentine-type heat exchanger with variations in the number of fin plates on the performance of the heat recovery system and on the split air conditioner. This research is an experimental study on a serpentine-type heat exchanger. Tests were carried out on a variety of heat exchangers with variations in the number of fin plates combined with a heat recovery system on a split AC. The independent variables in this study were three variations of the placement of the fin plate on the serpentine-type coil and the setting of the output air of the AC evaporator. Enthalpy values, refrigeration effects, compressor work, condenser, and coefficient of performance (COP) are calculated and presented in tables and graphs. The results of the performance of the heat recovery system obtained variations in the setting of the air burst coming out of the evaporator 24°C has the highest COP value. The use of a heat recovery system can increase COP. With variations in the number of fin plates in a heat recovery system with a serpentine heat exchanger, the use of 5 fin plates has the hottest water temperature compared to the use of 3 fin plates and 1 fin plate.

1. Introduction

Water heating facilities generally use electricity, gas, and sunlight. There are alternative ways to do this besides using water heaters on the market, namely by utilizing the heat generated by the compressor and which will be discharged through the condenser, by adding a heat recovery system (HRS) on the air conditioner unit. HRS is a method of reducing overall energy use that can generate energy efficiency.[1-3]

The split air conditioner that is widely used in the community has a working system consisting of 4 components, namely the compressor, condenser, expansion valve, and evaporator. Utilization of condenser heat in a split air conditioner system that is added to a heat recovery system does not reduce the function of the air conditioner as a room cooler. Previous studies stated that the use of split air conditioners in homes with water heaters with coil variations was carried out to obtain an optimal coefficient of performance.[4-7] A series of experimental experiments conducted by investigating split air conditioners showed an increase in COP of about 10% in air conditioners with the addition of a water heating pump.[4,5]

One way to increase the rate of heat transfer is to use fins. The addition of plates to the fins is an important part of designing a serpentine heat exchanger.[8,9] Finned surfaces are generally used to enhance heat transfer and increase the rate of heat transfer from a plate surface.[10] This study was conducted with the aim of testing a finned plate serpentine heat exchanger integrated into a heat recovery system.

2. Methods

This research was an experimental study on a serpentine-type heat exchanger. Tests were carried out on a variety of heat exchangers with variations in the number of fin plates combined with a heat recovery system on a split AC. The independent variables in this study were three variations of the placement of the fin plate on the serpentine-type coil and the setting of the output air of the AC evaporator. The serpentine-type coil has dimensions of length 4 m, height 30 cm, 10 passes with fin plates (height 30 cm, width 6 cm), and installation of 1, 3, and 5 fin plates (Figure 1). Variation of output AC settings is 16°C, 20°C, and 24°C. The dependent variable in this study is the coefficient of performance HRS and AC. The control variable in this study was refrigerant filling up to a suction pressure of 80 psi and a volume of water in the tank of 20 L.

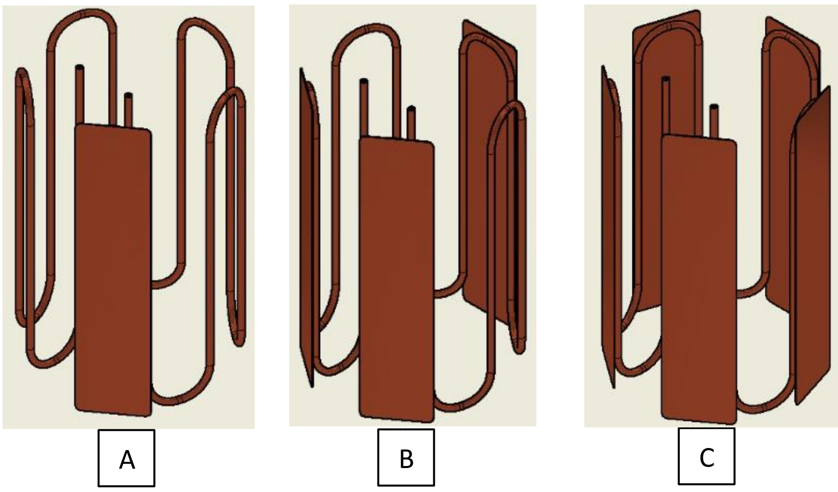

Figure 1. Serpentine-type heat exchanger. A) 1 fin plate, B) 3 fin plates, (c) 5 fin plates.

The experimental procedure is as follows; The split AC used is a standard AC with a compressor system capacity of 1 PK. The system is vacuumed with a vacuum pump for 30 minutes until the blue analyzer needle on the manifold is at -30 psi. Then, refrigerant R22 is filled with a pressure of 80 psi according to the capacity of the AC compressor. After the air conditioner is turned on, the initial pressure and temperature are measured. For every drop of 1°C on the thermistor, observe pressure (P1 and P2) and temperature (T1, T2, T3, and T4). The study was stopped if the evaporator outlet temperature reached 24°C. After the room temperature and split AC system is normal, the same steps are carried out for temperature testing at 16°C and 20°C.

Meanwhile, the testing steps for a split AC integrated with a heat recovery system (HRS) are as follows; The equipment prepared is a heat recovery system that has been installed with a serpentine-type heat exchanger with variations of 1, 3, and 5 fin plates. The system is vacuumed with a vacuum pump for 30 minutes until the blue analyzer needle on the manifold is at -30 psi. Then, refrigerant R22 is filled with a pressure of 80 psi according to the capacity of the AC compressor. Next, prepare the water to be put into the HRS tank with a capacity of 20 L. The split AC is then turned on at 24°C with 1 fin plate serpentine-type heat exchanger. For every drop of 1°C on the thermistor, observe pressure (P1 and P2), temperature (T1, T2, T3, and T4), and water temperature in the HRS tank. The study was stopped if the evaporator outlet temperature reached 24°C. After the room temperature, the split AC system and the water temperature in the tank are normal, and the same steps are carried out for testing the heat exchanger type serpentine 3 and 5 fin plates with the evaporator outlet temperature set at 20°C and 16°C. Enthalpy values, refrigeration effects, compressor work, condenser, and coefficient of performance are calculated and presented in tables and graphs.

3. Results and Discussion

Split AC experiment standards and a heat recovery system combined with a heat exchanger were carried out with various evaporator output temperature settings at 24°C, 20°C, and 16°C. Measurements were made at several points using a thermocouple. The enthalpy values for each experiment are presented in Tables 1 and 2.

Table 1. Enthalpy values for standard split AC.

Evaporator output air temperature (°C)	Enthalpy values (kJ/kg)			
	h1	h2	h3	h4
24	411.84	435.47	240.15	240.15
20	410.67	447.50	240.29	240.29
16	408.62	449.14	240.44	240.44

Table 2. Enthalpy values for heat recovery systems with serpentine-type heat exchangers.

Evaporator output temperature (°C)	Enthalpy values (kJ/kg)				
	h1	h2	h2’	h3	h4
1 fin plate					
24	411.92	434.86	416.69	239.93	239.93
20	411.29	444.92	417.4	240	240
16	408.94	448.6	417.7	240.05	240.05
3 fin plates					
24	412.33	434.25	416.59	239.75	239.75
20	411.36	444.26	417.36	239.81	239.81
16	409.07	448.41	417.61	240.02	240.02
5 fin plates					
24	412.52	434.22	416.57	239.72	239.72
20	411.42	443.81	417.12	239.75	239.75
16	409.13	448.18	417.58	239.85	239.85

Variations in the evaporator air temperature settings have different refrigeration effect values (Figure 2). The smaller the outlet air temperature, the smaller the value of the refrigeration effect. The evaporator output air temperature setting of 24°C has the greatest refrigeration effect value because, at that temperature, the h1 value is the greatest compared to other evaporator outlet air temperature variations. In addition, the h3 value at this temperature is the smallest compared to other temperature variations. The use of fin plates has an impact on the refrigeration effect. At the same evaporator discharge temperature setting, the use of fin plates has an impact that makes the value of the refrigeration effect different. The use of plates makes the value of the refrigeration effect even greater. Figure 2 shows the use of 5-fin plates. The refrigeration effect is the greatest compared to the use of other plates. The more fin plates used, the better the heat absorption.[11-13]

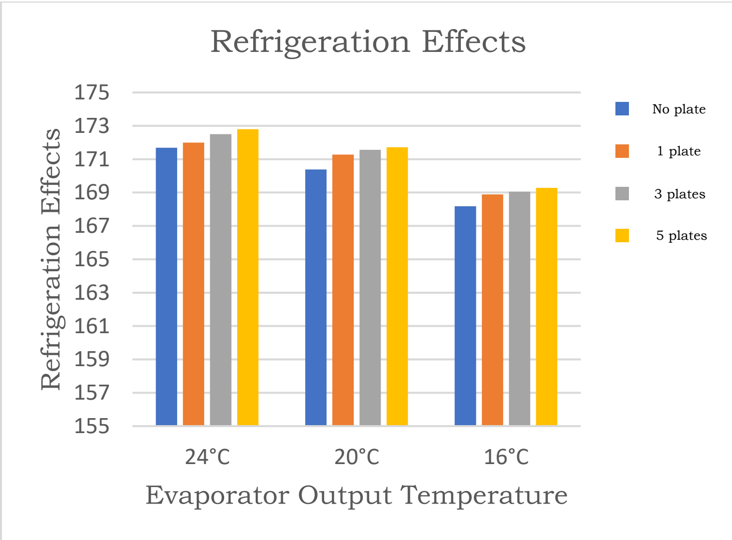

Figure 2. Refrigeration effect with various air burst settings.

Based on the work of the compressor, the smaller the temperature setting for the air leaving the evaporator, the greater the work value of the compressor. The evaporator outlet air temperature setting of 16°C has the greatest compressor work value. This is because, at 16°C, the enthalpy h2 value is the greatest compared to other evaporator outlet air temperatures. The use of fin plates has an effect on the compressor work. At the setting of the same evaporator outflow of air, the use of fin plates has an impact that makes the compressor work value different.[14,15] The use of plates makes the compressor work value smaller. This is evidenced by the use of 5 fin plates which have the smallest compressor work value compared to the use of other plates (Figure 3).

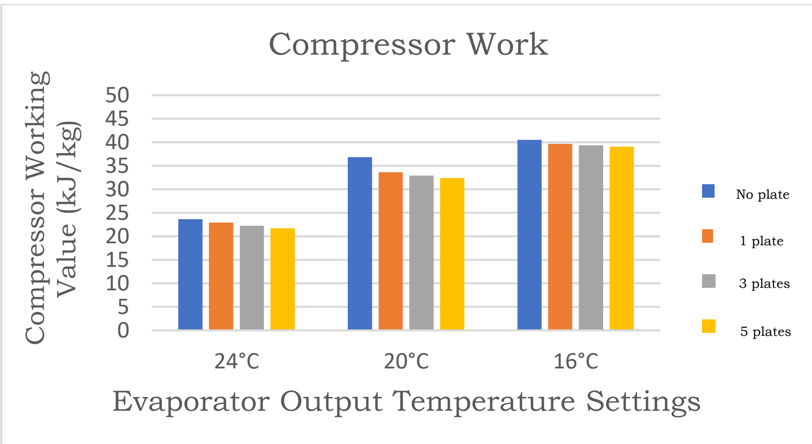

Figure 3. Compressor work on variations in air temperature settings outgoing the evaporator.

The use of evaporator exit temperature settings has different condenser work values. The smaller the evaporator outlet air temperature setting, the greater the condenser work value.[16,17] The evaporator outlet air temperature setting of 16°C has the greatest condenser work value. This is because the evaporator exit air temperature setting is 16°C, has the largest h2 value than other evaporator outlet air temperature settings, and also has the largest h3 value than other evaporator outlet temperature settings. The use of 5 fin plates has the effect that the working value of the condenser is getting smaller.

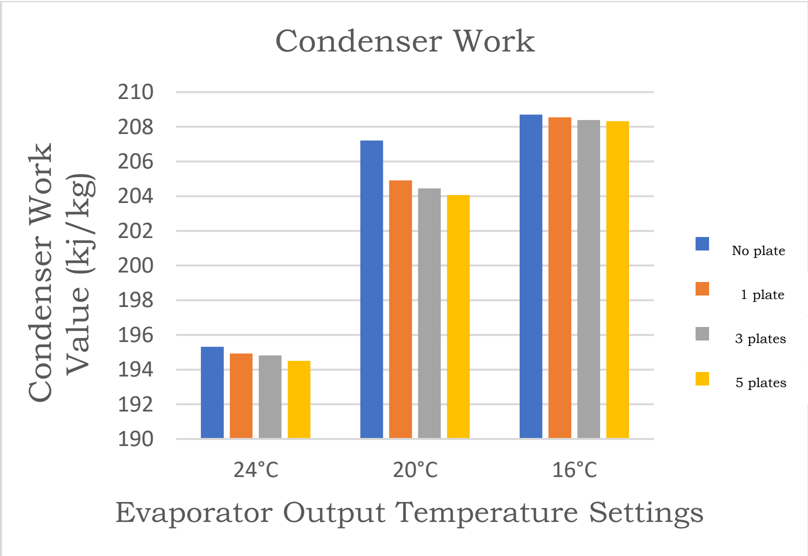

Figure 4. The work of the condenser with various settings for air bursts coming out of the evaporator.

The use of evaporator outlet air temperature settings has a different coefficient of performance (COP) value. The smaller the evaporator outlet air burst setting, the smaller the COP value. The evaporator outlet air temperature setting of 24°C has the largest COP value. This is because the evaporator exit air temperature setting is 24°C, has the highest h1 value than other evaporator outlet air temperature settings, and also has the smallest h2 value at other evaporator exhaust air temperature settings. The use of fin plates has an effect on COP [18,19] at the same evaporator exhaust airflow setting. The use of fin plates has an impact that makes the COP value different (Figure 5).

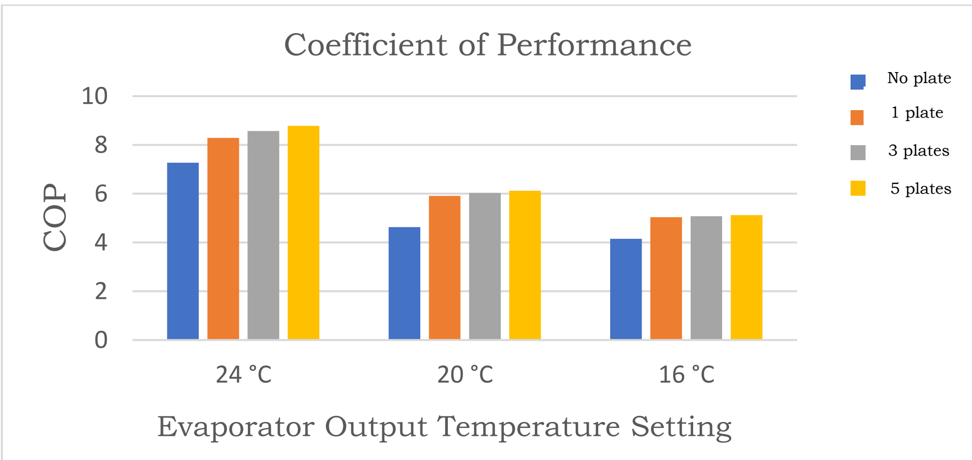

Figure 5. COP in setting the air burst out of the evaporator.

The difference in setting the temperature of the air leaving the evaporator has a different actual compressor power value. The smaller the setting for the air bursts coming out of the evaporator, the smaller the actual power value of the compressor (Figure 6). The evaporator outlet air temperature setting of 24°C has the smallest actual compressor power value. This is because the evaporator outlet air temperature setting of 24°C has the smallest Amperage value compared to other evaporator outlet air temperature settings. The use of 5 fin plates has the smallest actual compressor power because the heat absorption is better, so the compressor work is lighter.

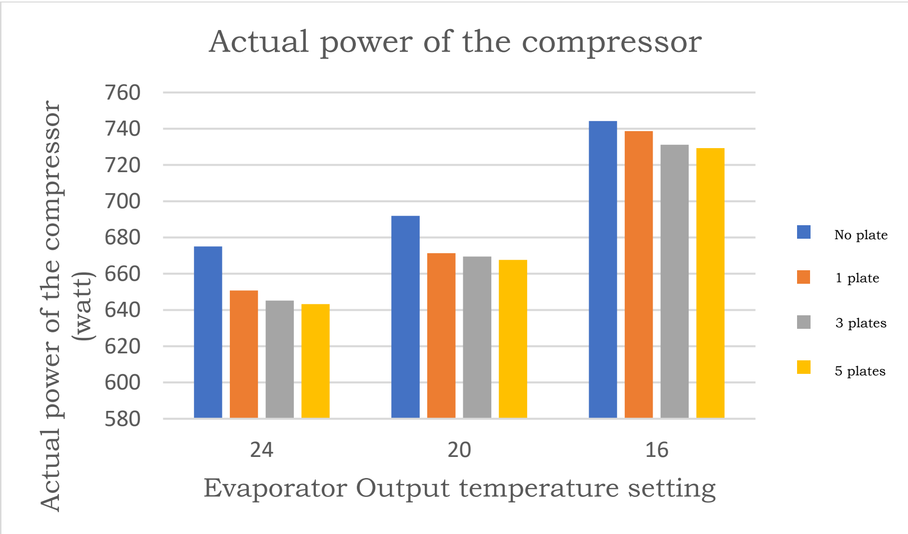

Figure 6. Actual compressor power setting evaporator output temperature.

Using the setting for the air jet coming out of the evaporator at 16°C produces the hottest water temperature because it takes the longest time to reach the temperature setting for the air jet coming out of the evaporator at 16°C compared to the setting for the air jet coming out of the evaporator at 24°C and 20°C, so The hot water produced at the temperature setting of the evaporator exhaust air is 16°C, the hottest compared to the evaporator discharge airflow settings of 24°C and 20°C. By using variations in the number of fin plates in a heat recovery system with a serpentine-type heat exchanger,[19,20] the use of 5 fin plates has the hottest water temperature. Possibly this is because the use of 5-fin plates has more surface area and is optimal for transferring heat by convection with water compared to using 3 and 1-fin plates.

Table 3. The highest water temperature produced.

Evaporator air output temperature variation	Variation in the number of fin plates	Water temperature(°C)	Time(s)
24	1	34.58	310
	3	34.75	300
	5	34.87	300
20	1	46.52	1170
	3	47.85	1180
	5	48.05	1140
16	1	78.44	13690
	3	79.25	13570
	5	80.38	13380

4. Conclusion

The largest and fastest coefficient of performance is obtained at the evaporator air burst temperature setting of 24°C. The use of 5 fin plates produces the hottest water temperature compared to other variations of fin plates.

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