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Evaluation of Serpentine-Type Heat Exchanger Application on Water Heater with Passages Number Variation

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A B S T R A C T

For some people, using warm water for bathing needs is a tertiary need because getting warm water requires additional costs. Generally, people/industry use water heaters that are sold in the market. These water heaters generally use electricity, solar power, or natural gas. This study aimed to evaluate the use of heat recovery systems as water heaters with variations in the number of passages. This research is an experimental study on a serpentine-type heat exchanger. Tests were carried out on standard split air conditioners and split air conditioners integrated with heat exchangers. The independent variables in this study were variations of the heat exchanger type serpentine with a length of 4 m, with each heat exchanger having a height of 20, 25, and 30 cm, with variations of 10, 12, and 14 passages and variations of evaporator output air settings 16°C, 20°C and 24°C. The use of the evaporator outlet air temperature setting produces a different refrigeration effect value. The lower the evaporator output air temperature setting, the lower the resulting refrigeration effect value. The air temperature leaving the evaporator is 24°C which results in a higher refrigeration effect value. This study showed the best heater performance at the evaporator air setting of 16°C with a variation of 10 passages. In conclusion, the addition of a heat recovery system with serpentine-type heat exchanger variations 10 passages, 12 passages, 14 passages, and 24°C temperature loading variations, 20°C and 16°C on the evaporator burst will have an impact on decreasing the coefficient of performance on the split air conditioner system.

1. Introduction

At this time, the human need for energy is increasing along with the success of the development carried out. Energy has become a major need in modern life like today. On the other hand, the energy crisis is becoming a hot issue in various parts of the world. For some people, using warm water for bathing needs is a tertiary need because getting warm water requires additional costs. Generally, people/industry use water heaters that are sold in the market. These water heaters generally use electricity, solar power, or natural gas.[1-5]

The split air conditioner is an electronic piece of equipment that almost every home has. Split air conditioners produce heat energy that is wasted from the condenser. The potential of this heat energy can be optimized as a water heater for bathing and other household purposes. Utilization of a heat recovery system can be a solution as an energy source for converting heat energy from the condenser into a water heater. The working principle of this system uses a compression refrigeration cycle. Namely, the evaporator side is used to cool the room, and the side between the compressor and condenser is used to heat water. In this system, the added tool is a hot water storage tube equipped with a heat exchanger that is installed between the compressor and the condenser.[6-10] This study aimed to evaluate the use of heat recovery systems as water heaters with variations in the number of passages.

2. Methods

This study was an experimental study on a serpentine-type heat exchanger. Tests were carried out on standard split air conditioners and split air conditioners integrated with heat exchangers. The independent variables in this study were variations of the heat exchanger type serpentine with a length of 4 m, with each heat exchanger having a height of 20, 25, and 30 cm, with variations of 10, 12, and 14 passages and variations of evaporator output air settings 16°C, 20°C and 24°C. The dependent variable in this study is the coefficient of performance of standard split AC and split AC with the addition of a heat recovery system. The control variables in this study were the volume of 20 L of water, refrigerant R-22, and refrigerant filling up to a suction pressure of 80 psi. This study used a serpentine-type heat exchanger with 3 channel variations, namely 10, 12, and 14 lanes, ¼ inch in diameter, and 4 meters in length (Figure 1). Then, the heat exchanger is placed in a hot water storage tank that has a water capacity of 20 liters which will be used to heat water.

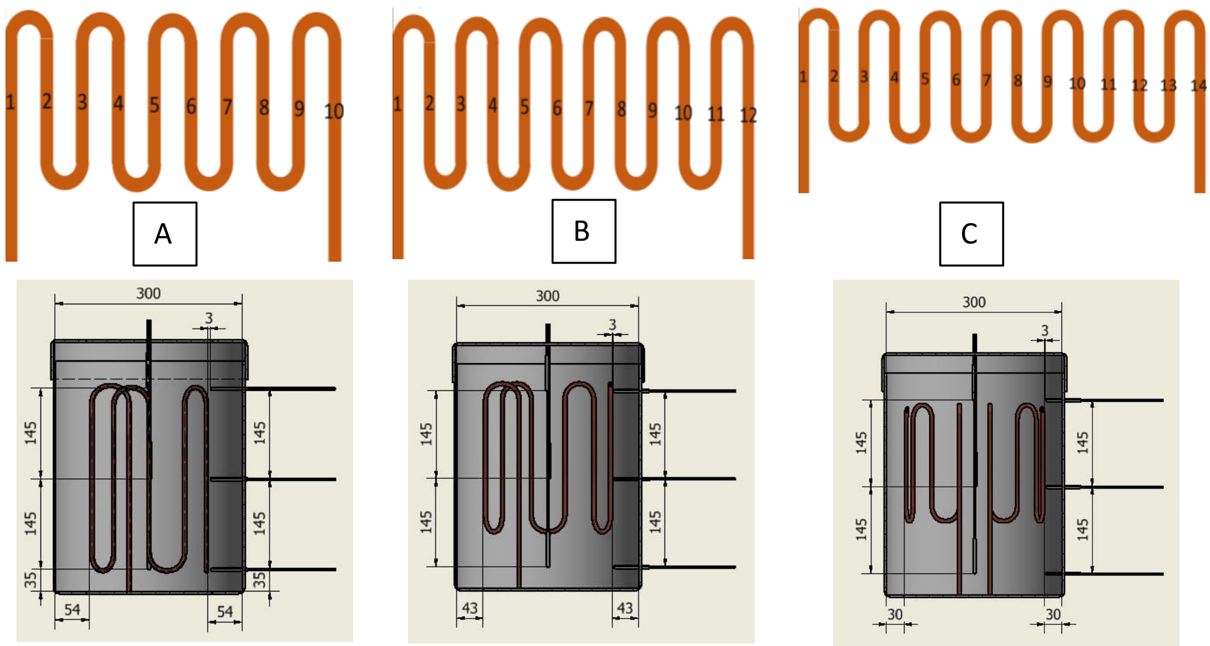

Figure 1. Serpentine-type heat exchanger with passages number variations; A) 10 passages; B) 12 passages; C) 14 passages.

The research procedure is carried out 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 steps for testing the heat recovery system (HRS) are as follows; The equipment prepared is a heat recovery system that has been installed with 10, 12, and 14-lane serpentine heat exchangers. 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 volume of 20 L. The split AC is then turned on at 24°C with a serpentine-type heat exchanger with a variation of 10 lanes. 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 AC split system and the water temperature in the tank is normal, and the same steps are done for the 12 and 14 passages variations as well as the evaporator output temperature variation, which is set at 20°C and 16°C. The enthalpy value, refrigeration effect, compressor work, condenser, coefficient of performance, and the highest temperature of heated water are calculated and presented in tabular and narrative form.

3. Results and Discussion

Split AC experiment standard and heat recovery system combined with a serpentine-type heat exchanger was carried out with various evaporator outlet temperature settings at 24°C, 20°C, and 16°C. In the early stages of the study, testing was carried out using a standard split air conditioner, then followed by using a heat recovery system with variations in the number of passes. Measurements were made at several points using a thermocouple. The enthalpy values for each experiment are presented in Table 1.

Table 1. Enthalpy values for standard and modified split AC.

Evaporator output air temperature (°C)	Enthalpy values (kJ/kg)				
	h1	h2	h2’	h3	h4
Standard split AC					
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
Serpentine-type heat exchanger with 10 passages					
24	411.75	438.57	416.85	240.42	240.42
20	410.96	447.35	417.03	240.34	240.32
16	408.40	449.61	417.21	240.09	240.09
Serpentine-type heat exchanger with 12 passages					
24	412.06	431.84	416.66	239.27	239.27
20	423.20	447.77	417.03	240.34	240.34
16	408.40	446.30	417.22	240.09	240.09
Serpentine-type heat exchanger with 14 passages					
24	412.50	430.01	416.33	239.33	239.33
20	411.75	445.40	417.13	240.34	240.34
16	410.12	448.83	417.65	240.57	240.57

Table 2 shows that the use of the evaporator outlet air temperature setting produces different refrigeration effect values. The lower the evaporator outlet air temperature setting, the lower the resulting refrigeration effect value. The air temperature leaving the evaporator is 24°C which results in a higher refrigeration effect value. This is because the evaporator exit air setting is 24°C, resulting in a higher h1 value compared to the evaporator exit air temperature settings of 20°C and 16°C, resulting in the lowest h3 value compared to the evaporator exit air temperature settings of 20°C and 16°C.

The passages number variation of the serpentine-type heat exchanger produces an effect on compressor and condenser work. The use of variations in the number of passages of the serpentine-type heat exchanger results in a lower compressor work value. This can be seen in the use of the 14-pass variation, the lowest work value of the compressor and condenser compared to the 10 and 12-pass serpentine-type heat exchanger variations. A compressor is a mechanical device that works to suck steam refrigerant from the evaporator. From the results of this pressure, the temperature and vapor pressure become higher. In addition, the compressor also functions to drain refrigerant throughout the cooling system network. Meanwhile, the condenser functions as a heat exchanger or heat that changes the shape of the refrigerant from gas to liquid and serves to lower the temperature of the refrigerant. In this research, the more the number of passages, the less work the condenser and compressor will be lower.

Table 2. Performance evaluation of standard and modified split AC.

Setting the output temperature of the evaporator in the room (°C)	Refrigeration effect (kJ/kg)	Compressor work (kJ/kg)	Condenser work (kJ/kg)	Heat recovery system (kJ/kg)	Coefficient of performance	Compressor actual power (watt)
	Standard split AC					
24	171.69	23.63	195.32		7.27	675.07
20	170.38	36.83	207.21		4.63	691.9
16	168.18	40.52	208.70		4.15	744.26
10 passages						
24	171.83	26.81	198.15	21.72	7.20	641.41
20	170.62	36.39	207.01	30.32	5.50	667.59
16	168.31	41.51	208.41	32.44	4.80	729.30
12 passages						
24	172.79	19.05	192.57	15.18	9.40	645.15
20	171.18	36.17	207.41	36.74	5.70	667.59
16	168.31	37.90	206.21	29.08	5.20	731.17
14 passages						
24	173.17	17.50	190.68	13.68	10.60	650.76
20	171.41	33.70	205.06	28.27	5.90	669.46
16	169.55	38.71	208.26	31.18	5.10	738.65

Table 3. The highest water temperature is generated by the heat exchanger.

Variation of temperature at the output of the evaporator air jet (°C)	Variation in the number of passages of the serpentine-type heat exchanger	Water temperature (°C)	Time (s)
24	10	37.7	580
	12	35	280
	14	33.66	160
20	10	53.63	1930
	12	48.69	1610
	14	45.44	1340
16	10	78.56	12810
	12	77.91	12810
	14	66.5	4820

Heat recovery is a system that utilizes waste heat from the cooling system to heat water. Part of the refrigerant heat that has been compressed by the compressor is used to heat water with the help of a heat exchanger. This heat exchanger will determine the performance of the heat recovery system. A heat exchanger is needed that can transfer heat as much as possible from the refrigerant without causing excessive pressure drop, which can affect the performance of the cooling system. In this study, the best heater performance was shown at the evaporator air setting at 16°C with 10 passage variations (Table 3).[11-15]

4. Conclusion

The addition of a heat recovery system with serpentine-type heat exchanger variations 10 passages, 12 passages, 14 passages, and 24°C temperature loading variations, 20°C, and 16°C on the evaporator burst will have an impact on decreasing the coefficient of performance on the split air conditioner system. This is due to the addition of the length of the refrigerant channel, which results in an increase in compression work. The higher the compression work on the split air conditioner, the lower the COP results obtained.

5. References

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