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# Experimental study of split air conditioner with and without trombone coil condenser as air conditioning water heater

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## ABSTRACT

This paper reports an experimental investigation of the performance split air conditioner (AC) with and without combined coil (trombone coil condenser) as heat pump water heater. The coil is a heat exchanger that is placed between the compressor and the condenser (main condenser) by utilizing the heat rejection. The coil is placed in an insulated water storage tank with a capacity of 50L. Data are captured every 5 minutes during the 120 minutes of testing, where the room temperature is maintained at temperatures of 20ºC, 23ºC and 27ºC with variation of the cooling load at 1000W, 2000W and 3000W respectively.The results indicated that the use of coil increases the performance of air conditioner as an cooling air in room and water heater in reclamation tank simultaneously. The use of coil causes a slight increase in compressor power 0.014 kW (2%), where the COP increases around 12% higher than the increase in compressor power percentage, which is used as a water heater. Condenser temperature and room temperature with coil slightly rise compared to without coil at the cooling load increase. The finding indicates that the addition of the coil generates free hot water with temperature range around 61.54ºC-64.33ºC.The application of AC combined with water heater using coil does not affect the cooling performance but it can improve the energy performance considerably for cooling and energy saving for heating water.

***Keywords:*** Split air conditioner; water heater; trombone coil; COP; condenser.

## INTRODUCTION

The purpose of air conditioner (AC) is to create comfortable zone at temperature below its surroundings with absorbed heat in the room using evaporator and reject the heat using condenser at surroundings. The comfortable temperature in tropical zone is 24ºC- 27ºC [1]. The most common AC operates using vapor-compression refrigeration cycle. In this cycle, refrigerant as working fluid is vaporized with absorbed heat in low pressure and temperature at evaporator, compressed in compressor to a higher pressure and temperature, condensed with reject heat in condenser to surrounding, and throttling in an expansion valve at low pressure and temperature [2]. Vapor-compression refrigeration systems have four main components: compressor, condenser, expansion valve, and evaporator [3]. In vapor-compression refrigeration cycle, a part of reject heat in condenser can be used to heat water as heat pump water heater. Heat pump water heater is the refrigeration system that transfers heat from a low temperature side to a high temperature side for heating water in an isolated tank. In modified AC, a coil heat exchanger in a water tank was installed between the compressor and the condenser [4, 5]. The high-temperature refrigerant from the compressor transfers the heat to the water so that the water temperature in the tank increases (operated as water heater). The use of AC combined as a water heater (known as Air Conditioning Water Heater/ACWH) gives two benefits: air conditioning for comfortable room zone and hot water for various purposes, so that the use of electricity for heating water can be minimized or does not require the energy cost [6]. The use of air-conditioning combined as heating of water for residential use has been discovered since the 1960s. The energy savings compared to the cost of AC modification give promising results in economical value, associated with the payback period [7]. Several studies of ACWH can be found in many literatures, including applying in domestic AC [8-10], system consideration [4, 5], thermodynamiccs [11, 12] and heat transfer [13], performance characteristic [6], heat recovery technique [14] and economical analysis [15-17]. Yu Wang et al. [18] investigated a conventional air-conditioner working as air-water heat pump and showed AC improvement around 10% for COP. Chaiwongsa and Duangthongthongsuk [19] reported a conventional air-conditioner as an air-water heat pump for making hot water. 1 TR of AC with R-22 was used in their study and kept at room temperature between 21-25$^o$C and hot water temperature at 40, 45 and 50$^o$C. Guo et al. (a) [20] presented domestic heat pump waterheater based on grey system theory for a new approach to energy consumption prediction. Guo et al. (b) [21] also conducted experimental research and operation optimization of an air-source heat pump water heater and indicated the average COP for typical condition between 2.82 to 5.51.

Chen and Lee [22] studied combined space cooling and water heating system for Hong Kong residences. Questionnaire surveys distributed to 126 household residents. The combined system provided potential energy and fuel cost saving was estimated around 50%. Performance characteristics modeling for water-cooled air-conditioners (WACS) have been studied by Lee [23]. The result showed that the overall COP of the WACS was greater than 3 at 90% rated capacity. Gong et al. [24] proposed a new heat recovery technique for air-conditioning with heat pump system (ACHP). The results indicated that the new ACHP is able to perform stably and flexibly in various conditions. Jiang et al. [25] experimentally studied a modified air conditioner as domestic hot water supply (ACDHWS). They found that it could give 38.6% COP higher than the original unit and proved that ACDHWS can supply useful hot water continuously. The objective of this experimental study is to investigate the performance of residential split AC with and without the application of coil (trombone coil condenser) as heat pump water heater. Split AC with coil is modified of AC with two functions for cooling air and heating water simultaneously. Split AC without coil is original of AC for serving cooling air only. In this study, the compressor power, COP, condenser temperature, room temperature were reported in different cooling loads from low to high load and the comparison between ACWH (with coil) and the original of AC (without coil) was also reported.

## METHODS AND MATERIALS

### Experimental Apparatus and Procedure

The experimental apparatus unit was built from split AC with coil as water heater in a tank. Figure 1 shows a schematic diagram of the experimental apparatus unit that has been used in previous research [26]. Figure 2 shows the experimental test facility picture that is used in this study [27]. The AC unit has a cooling capacity of 2.6 kW with R-22 as working fluid. The power of compressor was 0.67 kW. A coil (trombone coil condenser) was immersed in water tank and installed between compressor and condenser. The trombone coil condenser (coil) was made up of smooth copper tube with 3/8 inch in diameter, 5 windings and 5.5 m in length. The water tank has a capacity of 50 L. Control valves 2, 2a, and 2b were used to control the mode operation of experimental apparatus. The experimental apparatus has two operation modes: with coil mode (original AC combined Water Heater (ACWH)) and without coil mode (original AC). When the control valves 2a and 2b were closed and control valve 2 was opened, the operation mode of the system was without coil mode. Vice versa, when the control valves 2a and 2b were opened and control valve 2 was closed, the operation mode of the system was with coil mode.

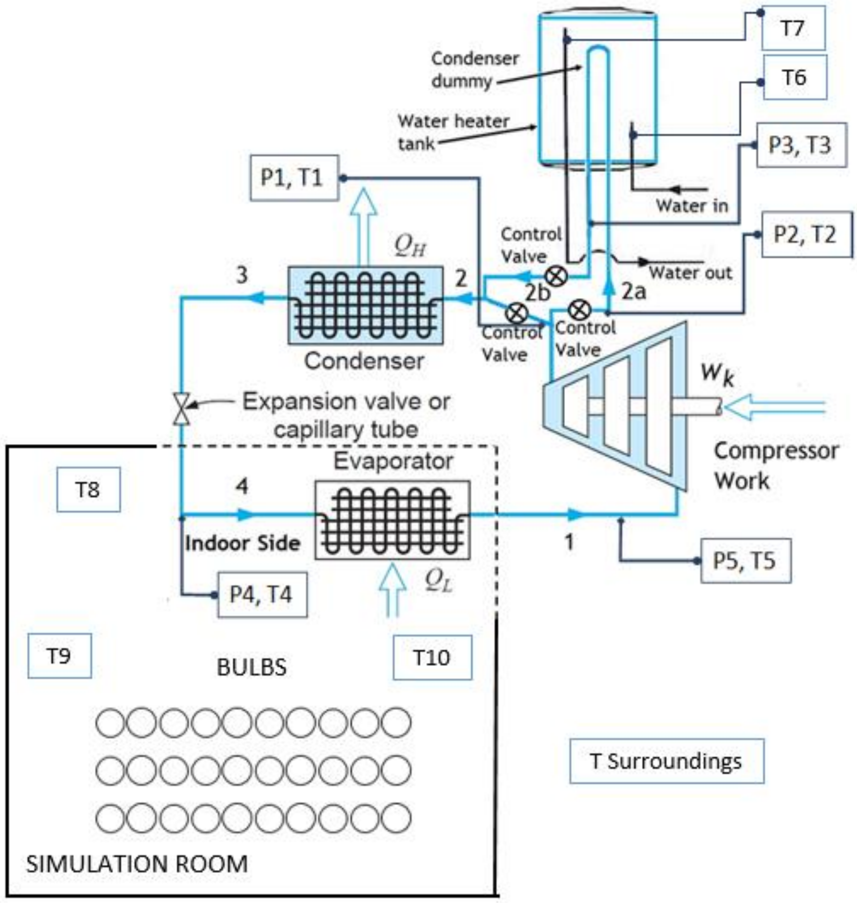


Figure 1. Schematic of the experimental apparatus [26].

Bourdon pressure gauges were used to measure high pressure refrigerant in condenser side and low pressure refrigerant in evaporator side. Refrigerant pressures were measured at five locations (P1, P1, P3, P4, P5) as depicted in Figure 1. These pressure gauges were new and factory calibrated with an accuracy of ±5 psi (high pressure gauge) and ±1 psi (low pressure gauge). As indicated in Figure 1, temperature measurements are made by K-type thermocouples at ten locations in the pipe surface of working fluid temperature using data acquisition module Omega TC-08. All the thermocouples were factory calibrated with an accuracy of 0.2 percent ± 0.5°C and have a resolution of better than 0.1°C. The digital thermometer is used at an accuracy of ±0,1°C to measure the surrounding temperature. The electric current and voltage of compressor were measured by ampere-meter (accuracy ± 2.0 percent and 3 digits) and voltmeter (accuracy ± 1.0 percent and 3 digits), respectively. The refrigerant mass charge was measured using a digital weighing scale (accuracy ±10 gram). In this study, all measurement devicex with provision and key features were placed as shown in Figure 1. The dynamic operation characteristics were tested under condition of the room temperature around 20$^o$C, 23$^o$C and 27$^o$C for cooling load 1000W, 2000W and 3000W, respectively. The captured of data were taken for 2 hours every 5 minutes to all measurements points of data set.

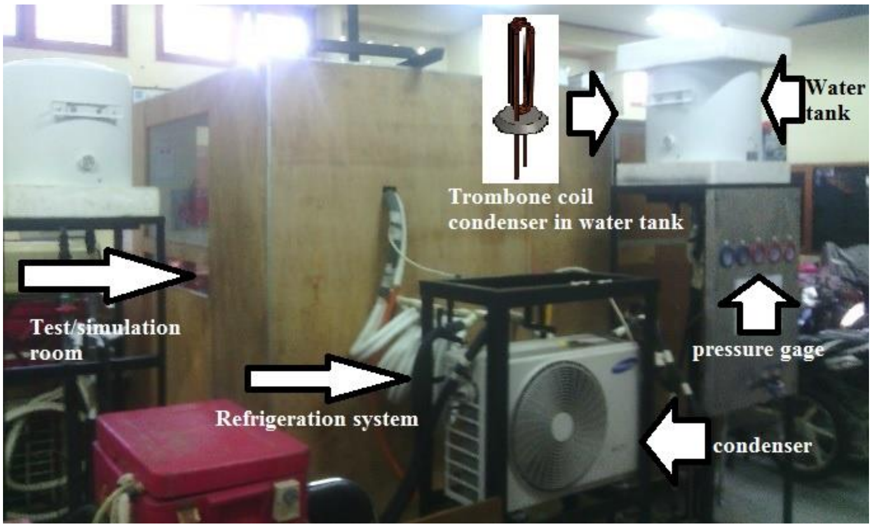


Figure 2. The test facility of experimental apparatus [27].

**Data Reduction**

The coefficient of performance (COP) of experimental apparatus for without coil mode or original mode can be expressed as Eq. (1):

$$COP_C = \frac{CoolingEffect}{WorkInput} = \frac{Q_L}{W_k} \tag{1}$$

Where $Q_L$ is energy absorbed in experimental room ($Q_L = \dot{m}\, q_L = \dot{m}\,(h_1 - h_4)$) and $W_k$ is compressor power input.

The COP of experimental apparatus for with coil mode or ACWH mode (AC combined Water Heater) can be expressed as Eq. (2):

$$COP_{C+H} = \frac{CoolingEffect + HeatingEffectofCoil}{WorkInput} = \frac{Q_L + Q_{coil}}{W_k} \tag{2}$$

where $Q_{coil}$ is energy released in water tank.

The compressor power ($W_k$) can be calculated from the following equation:

$$W_k = \eta_m V.I.\cos\phi \tag{3}$$

where $\eta_m$ is electric motor efficiency, $V$, I and $cos\Phi$ are the electric voltage, electric current, and power factor, respectively.

Figure 3 shows a coil (the trombone coil condenser) used in the experimental apparatus. The superheat refrigerant at high temperature from discharge side of compressor that flows into the coil will reject the heat to heating water in the water tank. This hot water can be used for various purposes.

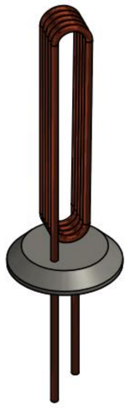

Figure 3. A coil (trombone coil condenser) [26].

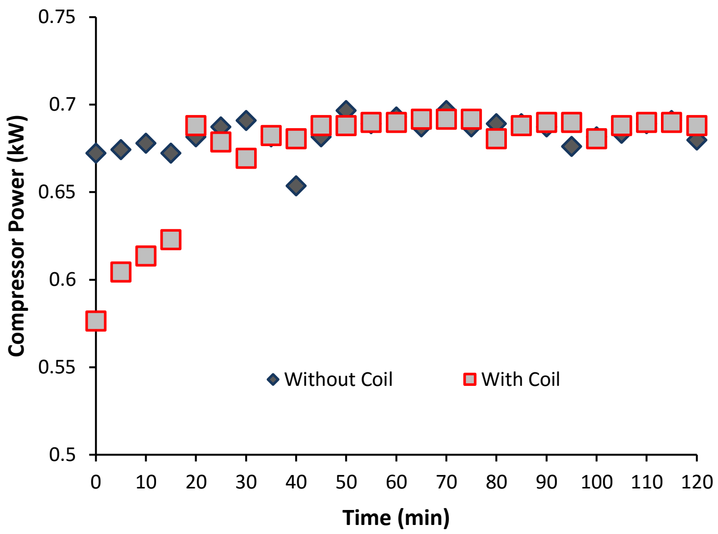


Figure 4. Compressor power without cooling load against time

## RESULTS AND DISCUSSION

### Compressor Power

Figure 4 shows the compressor power of the test unit without cooling load condition versus the time when it operated with coil mode and without coil mode. It can be seen that at the beginning after 30 minutes running, compressor power with coil mode (ACWH mode) consumes less power than without coil mode (original mode) because the rejected heat at superheated condition of hot refrigerant is used to heat water in the reclamation tank. This result is similar to that reported by Rahman et al. [4] for compressor power consumed at the beginning after the test unit was running. The average compression powers in 2 hours running with and without coil are 0.6836 kW and 0.6732 kW respectively. It can be stated that the average compressor power with coil and without coil tends to be similar, with only 1.5% difference. This is because at steady state condition, the rate at which energy is rejected to the surrounding region (outdoor unit) $Q_{out}$ by heat transfer is the sum of the energy supplied to the working fluid from the test room region (indoor unit), $Q_{in}$, and the net rate of work energy input to the compressor $W_k$ [28].

Figure 5 shows the compressor power average value of the test unit when operated with and without coil at different cooling loads (1000W, 2000W and 3000W). As shown in Figure 5, the average compressor power with coil was higher by just 4.4% and 2.9% compared to without coil for cooling load 2000W and 3000W respectively. The increase of average compressor power at different cooling loads with the addition of coil is very small, around an average of 2%. Thus, it can be stated that the effect of coil addition is not so significant. According to the energy conservation, the amount of energy absorbed in the evaporator and the compressor work should be equal to the amount of energy rejected in the condenser, so the addition of the coil does not affect the compressor work [29].

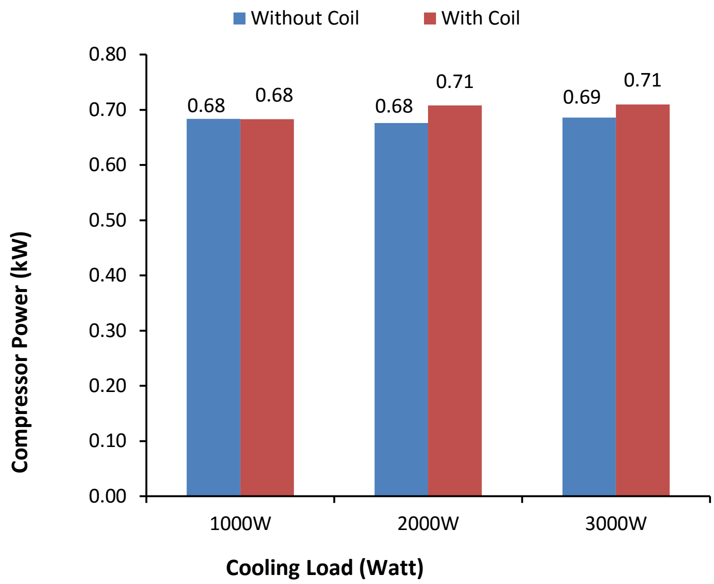


Figure 5. The average compressor power with and without coil at various cooling loads.

Figure 6 shows the highest compressor power of the test unit when operated with and without coil at different cooling loads (1000W, 2000W and 3000W). As shown in Figure 6, the highest compressor power value with coil was higher by just 4.1%, 10.1% and 7.1% compared to without coil for cooling load 1000W, 2000W and 3000W respectively. The increase of compressor power at the highest value with coil for different cooling loads is higher than the highest value. Thus, the addition of the coil (with coil mode or ACWH mode) does not give a significant effect on the increase of compressor power, if it is compared to energy saving for producing hot water. This is because the recovery of energy or energy saving that is used to heat the water in ranges around 0.462-0.483 kW is bigger than the value of the highest compressor power difference.

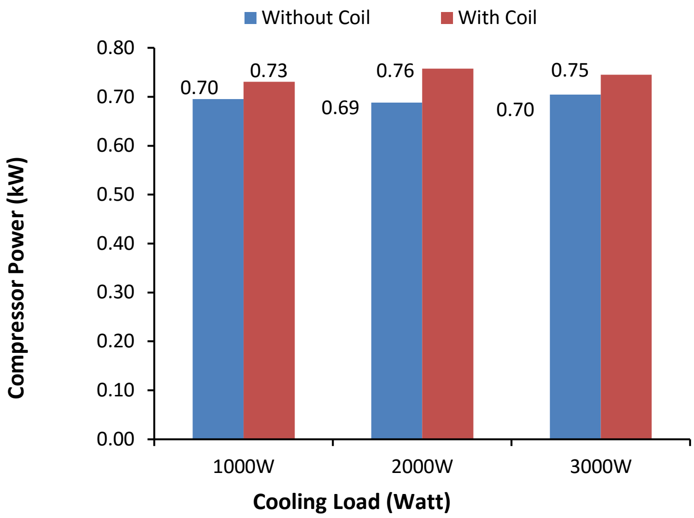


Figure 6. The highest compressor power with and without coil at various cooling loads.

**Coefficient of Performance**

The COP of the test unit when it operated with coil mode and without coil mode without cooling load condition is shown in Figure 7. The results show that the COP with coil mode (ACWH mode) is higher than the COP without coil mode (original mode). With coil mode, the required output is obtained as a combination of the cooling effect and the heating effect from the heat recovery system, so that the COP with coil is higher than COP without coil as described in equation 1 and equation 2 [3-28]. The average COP without coil mode ($COP_C$) and with coil mode ($COP_{C+H}$) without cooling load are 5.5 and 6.2 respectively. This is because, with coil mode, the test unit can be served as cooling air in test room and heating water in a water tank at the same time as combined heating and cooling simultaneously [30].

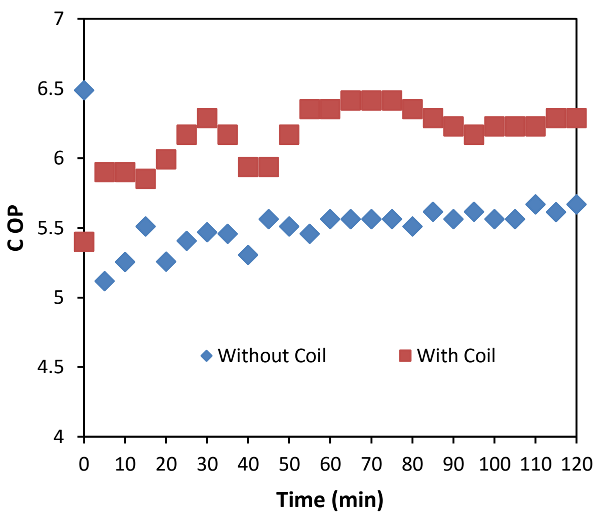


Figure 7. Coefficient of Performance (COP) without cooling load vs. time.

Experimental results of average COP at different cooling loads with and without coil is shown in Figure 8. It can be seen that the increase of cooling loads causes the COP to increase in very small values for each mode (with coil mode and without coil mode). The COP with coil increases with increase of cooling load around 10.5%, 11.9% and 13.2% for cooling compared to COP without coil. In other words, the increase of the COP value is proportional to the electric power for heating water around 0.4 kW, 0.455kW and 0.511 kW at different cooling loads of 1000W, 2000W and 3000W, respectively.

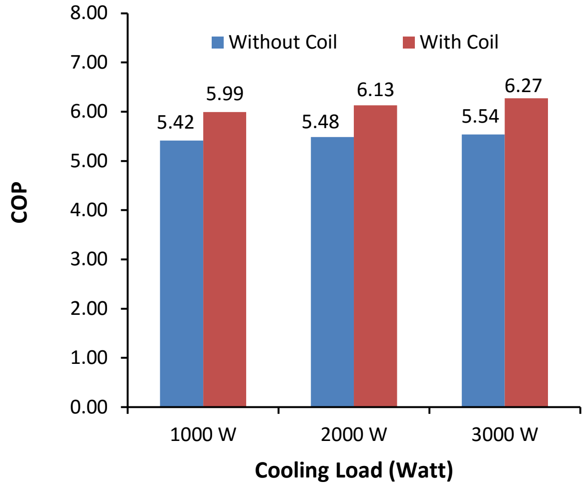


Figure 8. The average COP with and without coil at various cooling loads.

Experimental results of highest COP at different cooling loads with and without coil are shown in Figure 9. It can be seen that, the increase of cooling loads also causes the COP to increase in very small values for each mode (with coil mode and without coil mode) compared to Figure 8. This is because when the cooling load increases, the compressor power also increases; as shown in Figure 6, the COP value depends on the compressor power applied.

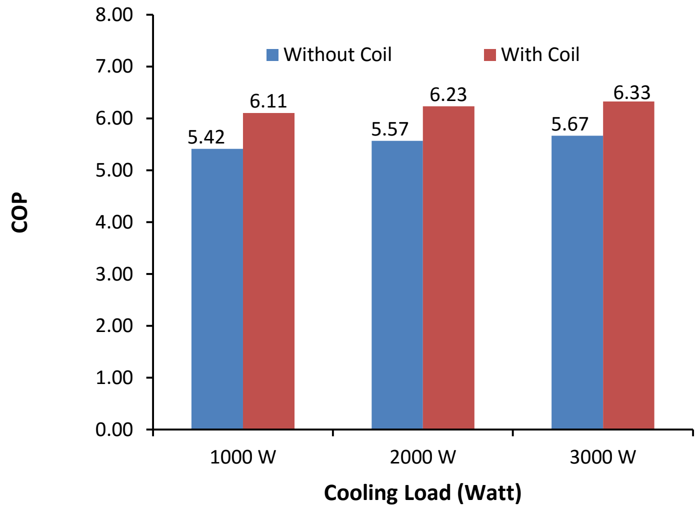


Figure 9. The highest COP with and without coil at various cooling loads.

Comparing the highest COP with coil to the COP without coil, the COP with coil increases with the increase of cooling load around 12.7%, 11.8% and 11.6% for cooling load 1000W, 2000W and 300W respectively. The increase of COP value is proportional to the heating power of water about 0.483 kW, 0.462kW and 0.462 kW for cooling load 1000W, 2000W and 3000W, respectively. In fact, the COP of the test unit when operated with coil mode (ACWH mode) will be given around 12% COP higher than COP without coil. This is equivalent to around 0.65kW of electric power saving for heating water in a tank. It is concluded that the test unit with coil mode can provide space cooling of test room and hot water simultaneously, which could save electricity for hot water supply.

**Condenser and Coil (Trombone Coil Condenser) Temperature**

Figure 10 shows the condenser and coil (trombone coil condenser) temperature of the test unit without cooling load when operated with and without coil for 120 minutes. It can be seen that the trombone coil temperature (with coil mode) is higher than condenser temperature (without coil mode). This is because the average trombone coil condenser superheats temperature (77,9$^{o}$C) higher than the average condenser superheat temperature (71,3$^{o}$C). The refrigerant then enters the trombone coil condenser at superheated vapor at state 2 in the highest temperature of refrigeration cycle as a result of heat rejection to the water in insulated tank, and then leaves as saturated liquid at state 3 as heat rejection to the surrounding [3].

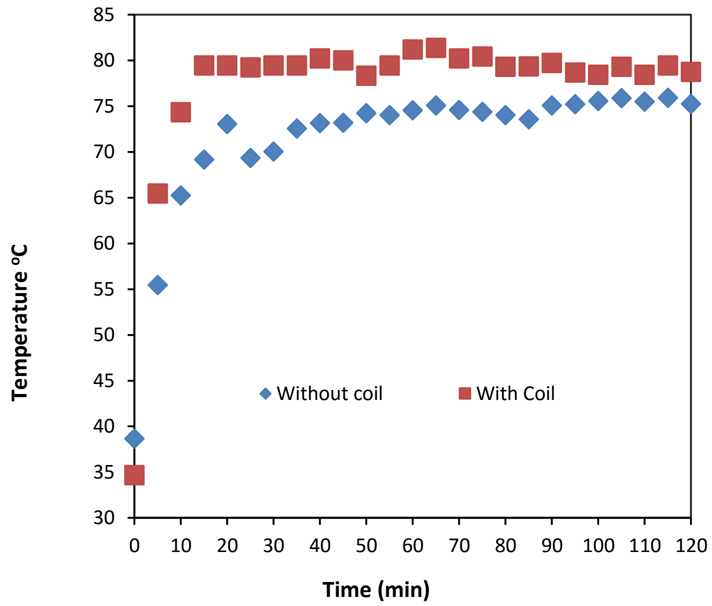


Figure 10. Condenser temperature (without coil) and trombone coil temperature (with coil) vs. time without cooling load

Figure 11 shows the average temperature of condenser and coil (trombone coil condenser) load when operated at various cooling loads. According to the test results (Figure 11), the temperature difference with and without coil at cooling load 1000 W tends to be similar at without cooling load as shown in Figure 10, but the difference is very small at cooling loads 2000W and 3000W. At the coil condenser inlet refrigerant state is superheated with highest temperature refrigerant in the refrigeration cycle, so the average temperature of condenser with coil is slightly higher than compared to without coil [31]. Figure 12 shows the highest temperature of condenser and coil (trombone coil condenser) load when operated at various cooling loads. As seen in Figure 11 compared to Figure 12, the difference in temperature tends to be similar, with small difference on the cooling load of 1000W. It could be concluded that the coil temperature will increase with increasing cooling load with small temperature difference. In general, it can be stated that there is no significant impact with the addition of coil (condenser coil trombone) on the AC as ACWH with condenser temperature.

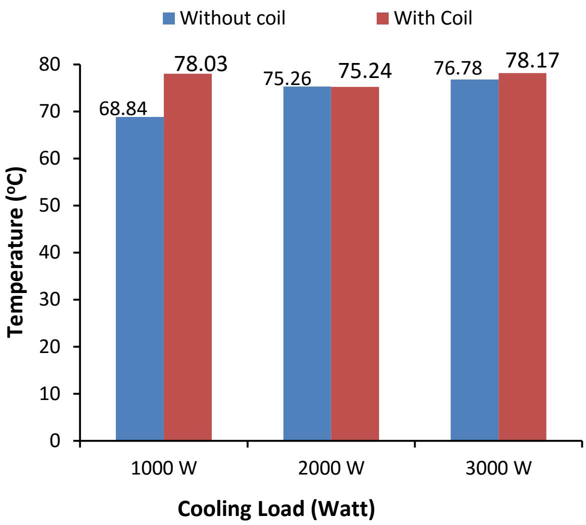


Figure 11. Average temperature of condenser (without coil) and trombone coil condenser (with coil) at various cooling loads.

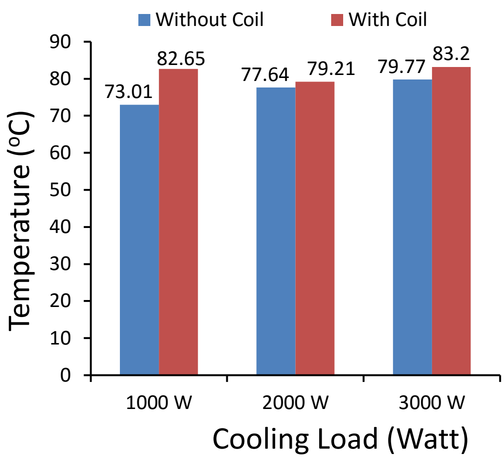


Figure 12. The highest temperature of condenser (without coil) and trombone coil condenser (with coil) at various cooling loads.

**Room Temperature and Water Temperature**

Figure 13 shows comparison of the room temperature of the test unit with coil (ACWH mode) and without coil (original mode) in 2 hours running without cooling load condition. The experimental results show that the room temperature with and without coil tends to be similar with little discrepancies. The experimental results show that the room temperature with and without coil tends to be similar with little discrepancies, hence it could be stated that there is no effect to the room temperature with coil addition as ACWH.

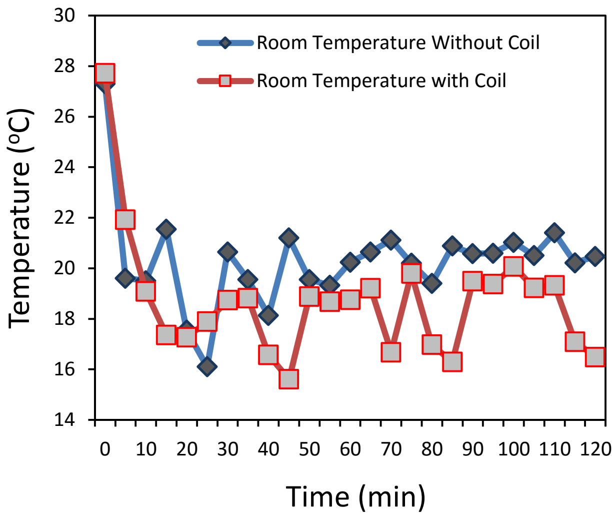


Figure 13. Room temperature with and without coil vs. time without cooling load.

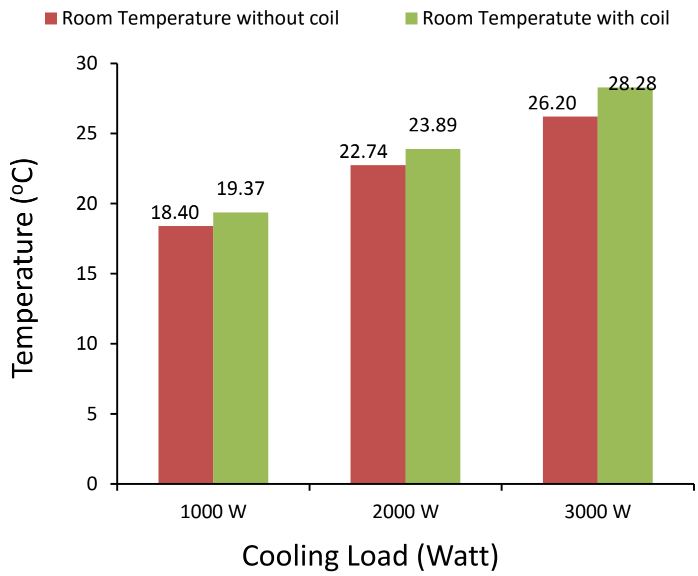


Figure 14.Average room temperature with and without coil at various cooling loads.

The average room temperature of the test unit when it operated with coil mode and without coil mode at various cooling load conditions is shown in Figure 14. The results show the temperature with coil mode (ACWH mode) is higher than without coil mode (original mode) around 1.5°C. This is because with coil mode, the temperature of coil (trombone coil condenser) is slightly higher than without coil mode; it is comparable with the room temperature is also higher with coil mode.

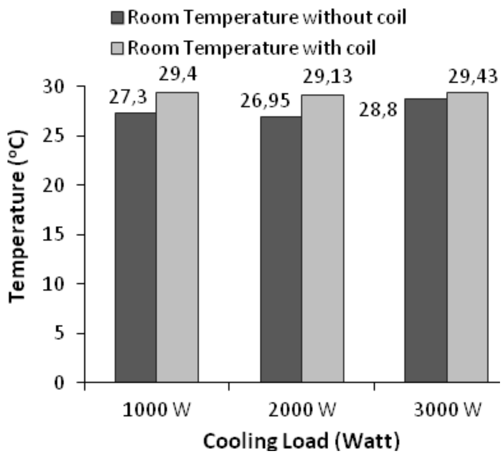


Figure 15. The Highest Room temperature with and without coil at various cooling loads.

Figure 15 shows the comparison of the highest room temperature of the test unit with coil (ACWH mode) and without coil (original mode) at various cooling load conditions. The results show the temperature with coil mode (ACWH mode) is higher than without coil mode (original mode) around 1.5°C. This result is similar when it is compared to Figure 14. This is because the room temperature increases with increasing cooling load from low to high, so it takes time to absorb the heat from the room in order to achieve the appropriate temperature. The room temperature depends on the cooling load applied, but the highest room temperature in various cooling loads is nearly the same as seen in Figure 15.

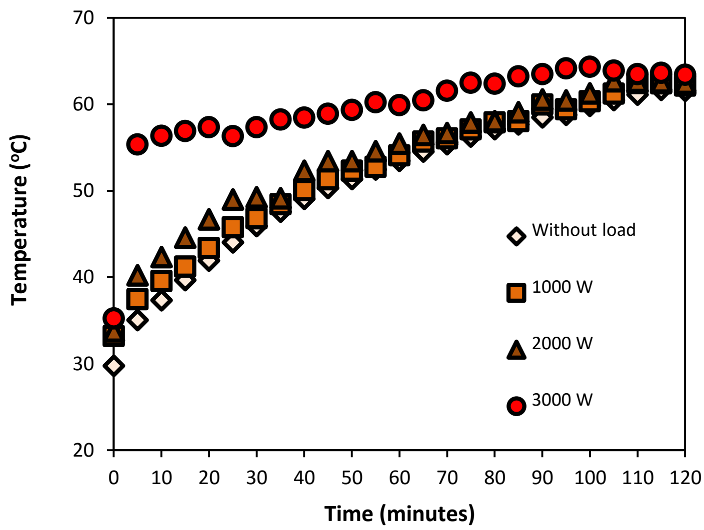


Figure 16.Water temperature in a tank vs. time at different cooling loads with coil (trombone coil condenser) [26].

Figure 16 describes the temperature at the water heat recovery tank using coil (ACWH mode) within two hours operation in various cooling loads from low to high (1000W, 2000W, 3000W) [23]. The highest temperature of water in heat recovery tank is 61.54°C, 62.43°C, 62,64°C, and 64,33°C for condition of without load, cooling load

1000W, 2000W, and 3000W, respectively. The experimental result shows that the water temperature increases with increasing cooling load from low to high, while the water temperature tends to rise higher in the cooling load of 3000W. This is because the more heat is absorbed by the water in reclamation tank, the more water temperature increases [32].

## CONCLUSIONS

The experimental study to investigate the performance of residential split AC with and without the application of coil (trombone coil condenser) as heat pump water heater was reported. According to the experimental results, the test unit can operate in two modes: original mode (without coil mode) and ACWH mode (with coil mode). The result of the comparison between without coil mode and coil mode indicates that the higher cooling load is given from low to high, the compressor power, condenser room temperature and room temperature will rise slightly with coil mode. The water temperature in reclamation tank also increases with the increase of cooling load while the increase is slightly higher at 3000 W load because more heat is absorbed in room and more heat is rejected in the reclamation tank. The use of coil causes a slight increase in compressor power (2% or 0.014kW), where the COP (coefficient of performance) increases around 0.66 (12% equal to 0.55 kW) higher than the increase of compressor power percentage, because the test unit gives capacity as cooling and heating simultaneously. Generally, the application of Air conditioner combined with water heater using coil (trombone coil condenser) does not affect the cooling performance but it can improve energy performance considerably for cooling and heating.

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## REFERENCES

[1] SNI 6390: 2001. Energy conservation and air distribution system on house and building (in Indonesian).

[2] Taib MY, Kadirgama K, Noor MM, Sani MSM. Performance analysis of a domestic refrigerator in malaysia using experimental method. International Conference on Recent and Emerging Advanced Technologies in Engineering Kuala Lumpur, 2009.

[3] Cengel Y, Boles M. Thermodynamics: an engineering approach, Ed. 5. Tata McGraw-Hill Publishing Company Limited, New Delhi; 2006.

[4] Rahman M, Chin WM, Ng A. Air conditioning and water heating-an environmental friendly and cost effective way of waste heat recovery. AEESEAP Journal of Engineering Education. 2007;31:38-46.

[5] Liu F, Huang H, Ma Y, Zhuang R. Research on the air conditioning water heater system. International Refrigeration and Air Conditioning Conference, Purdue University, Paper 893; 2008.

[6] Lokapure R, Joshi J. Waste heat recovery through air conditioning system. International Journal of Engineering Research and Development. 2012;5(3), 87-92.

[7] Jia J, Lee W. Applying storage-enhanced heat recovery room air-conditioner (SEHRAC) for domestic water heating in residential buildings in Hong Kong. Energy and Buildings. 2014;78:132-42.

[8] Ji J, Chow TT, Pei G, Dong J, He W. Domestic air-conditioner and integrated water heater for subtropical climate. Appl Therm Eng. 2003;23:581-92.

[9] Ji J, Pei G, Chow TT, He W, Zhang A, Dong J, et al. Performance of multi-functional domestic heat-pump system. Appl Energ. 2005;80:307-26.

[10] Lee W, Chen H. Applying a domestic water-cooled air-conditioner in subtropical cities. Proceedings of the Sixth International Conference for Enhanced Building Operations, . Shenzhen, China,November 6 - 9, 2006.

[11] Hepbasli A, Kalinci Y. A review of heat pump water heating systems. Renewable and Sustainable Energy Reviews. 2009;13:1211-29.

[12] Stalin MJ, Krishnan SM, Kumar GV. Efficient usage of waste heat from air conditioner. International Journal of Advances in Engineering and Technology. 2012;4:414-23.

[13] Ong KS. Heat reclaim from air conditioning system with internally submerged and externally wound condenser tubes. Engineering Management Research. 2012;1:101-9.

[14] Dr. U. V.Kongre , A. R. Chiddarwar , P. C. Dhumatkar , A.B.Aris. Testing and performance analysis on air conditioner cum water dispenser. International Journal of Engineering Trends and Technology (IJETT). Apr 2013;4:772-5.

[15] Sreejith K. Experimental investigation of a domestic refrigerator having water-cooled condenser using various compressor oils. International Journal of Engineering and Science. 2013;2:27-31.

[16] Jadhav PS, Sapkal ND, Kale MR, Bhandigare VV. Heat recovery from refrigerator using water heater and hot box. International Journal of Engineering Research and Technology: ESRSA Publications; 2014. p. 349-58.

[17] Çomaklı K, UğurÇakır EŞ, Kuş AÇ. Energetic and exergetic comparison of air to air and air to water heat pumps according to evaporator conditions. and Authors Page. 2013; 8:1108-20.

[18] Wang Y, You Y, Zhang Z. Experimental investigations on a conventional air-conditioner working as air-water heat pump. International Conference on Power Electronics and Engineering Application. 2011;23:493-7.

[19] Chaiwongsa P, Duangthongsuk W. Hot water making potential using of a conventional air-conditioner as an air-water heat pump. Procedia Engineering. 2011;8:165-70.

[20] Guo J, Wu J, Wang R. A new approach to energy consumption prediction of domestic heat pump water heater based on grey system theory. Energy and Buildings. 2011;43:1273-9.

[21] Guo J, Wu J, Wang RZ, Li S. Experimental research and operation optimization of an air-source heat pump water heater. Applied Energy. 2011;88:4128-38.

[22] Chen H, Lee W. Combined space cooling and water heating system for Hong Kong residences. Energy and Buildings. 2010;42:243-50.

[23] Lee W, Chen H, Yik F. Modeling the performance characteristics of water-cooled air-conditioners. Energy and Buildings. 2008;40:1456-65.

[24] Gong G, Zeng W, Wang L, Wu C. A new heat recovery technique for air-conditioning/heat-pump system. Applied Thermal Engergy 2008;28:2360-70.

[25] Jiang H, Jiang Y, Wang Y, Ma Z, Yao Y. An experimental study on a modified air conditioner with a domestic hot water supply (ACDHWS). Energy. 2006;31:1789-803.
[26] Aziz A, Satria AB. Performance of air conditioning water heater with trombone coil type as dummy condenser at different cooling loads. Proceeding of The 1st International Conference on Ocean, Mechanical and Aerospace -Science and Engineering, 2014. p. 150-4.
[27] Satria AB. Performance of hybrid air conditioner using dummy condenser with trombone coil type as water heater: University of Riau. (in Indonesian); 2014.
[28] Moran MJ, Shapiro HN, Boettner DD, Bailey MB. Fundamentals of engineering thermodynamics 7th Ed. New York: John Wiley & Sons; 2011.
[29] Jiang ML, Wu JY, Xu YX, Wang RZ. Transient characteristics and performance analysis of a vapor compression air conditioning system with condensing heat recovery. Energy and Buildings. 2010;42:2251-7.
[30] Heat Recovery from Chilled Water Systems. Applications For Heat Reclaim Chillers. Carrier Company; 2008.
[31] Techarungpaisan P, Theerakulpisut S, Priprem S. Modeling of a split type air conditioner with integrated water heater. Energy Conversion Management. 2007;48:1222-37.
[32] EE IIT K. 40 lessons on refrigeration and air conditioning from IIT Kharagpur. useful training material for mechanical engineering students college,or as reference for engineer EE IIT. Kharagpur, India, 2008.