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# Analysis of the Effect of Adding Insulators to Reservoirs Tank on Heat Losses as a Result of the Heat Exchanger System (Double Tube) for Water Heater

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***Abstract***

Air Conditioners release heat to the environment through a condenser and contribute to global warming. This can be minimized by utilizing exhaust heat as a source of water heating energy. This study aims to determine the effect of adding insulators to reservoir tanks on the temperature of the water that has been heated. This research was carried out by installing a *double tube heat exchanger* between the *compressor and the condenser to transfer heat from the refrigerant* of the air conditioner to the water. The volume of water used is 10 liters and 15 liters and the condition of the reservoir tank is insulated and the tank is uninsulated. The results showed that the water temperature in the reservoir tank fitted with an Armaflex insulator was 63.4ºC at a water volume of 10 L and 60.3ºC at a water volume of 15 L while the water temperature in a reservoir tank without an insulator was 57.7ºC at a water volume of 10 L and 52.3ºC at a water volume of 15 L. The heat loss of conduction in the insulated reservoir tank at the 50th minute was 3.94 kJ for a volume of water of 10 L and 3.70 kJ for a volume of water 15 liters, while the heat loss of conduction in a reservoir tank without an insulator is 2,404.46 kJ for a volume of 10 liters of water and 2,129.66 kJ for a volume of 15 liters of water. The use of Armaflex insulators in reservoir tanks results in thermal efficiency of more than 95% for 10 liter and 15 liter water volumes, but as the water temperature increases to the 50th minute, the efficiency decreases but is still above 95%. Meanwhile, the uninsulated reservoir tank provides a much lower thermal efficiency, which is 27.22% and 25.57% for the water volume of 10 liters and 15 liters respectively in the first 5 minutes of air conditioning operation, and continues to decrease to 1.88% and 2.30% in the 50th minute. This shows that the use of Armaflex insulators in reservoir tanks exhibits higher water temperatures, has a very significant effect in reducing heat loss to the environment, and higher thermal efficiency than non-insulated reservoir tanks.

***Keywords:*** *heat loss; insulator; thermal efficiency; temperature;waste heat.*

**Abstrak**

Air Conditioner melepas panas ke lingkungan melalui kondenser dan berkontribusi pada pemanasan global. Hal ini dapat diminimalisir dengan memanfaatkan panas buang sebagai sumber energi pemanas air. Penelitian ini bertujuan untuk mengetahui pengaruh penambahan isolator pada tangki reservoir terhadap temperatur air yang telah dipanaskan. Penelitian ini dilakukan dengan memasang sebuah *double tube heat exchanger* diantara *k*ompressor dan kondenser untuk memindahkan panas dari *refrigerant* AC ke air. Volume air yang digunakan adalah 10 liter dan 15 liter dan kondisi tangki reservoir berisolasi dan tangki tak berisolasi. Hasil penelitian menunjukkan bahwa temperatur air pada tangki reservoir yang dipasangi isolator Armaflex sebesar 63,4ºC pada volume air 10 L dan 60,3ºC pada volume air 15 L sedangkan temperatur air pada tangki reservoir yang tanpa isolator adalah 57,7ºC pada volume air 10 L dan 52,3ºC pada volume air 15 L. Kehilangan panas konduksi pada tangki reservoir berisolasi pada menit ke-50 adalah 3,94 kJ untuk volume air 10 L dan 3,70 kJ untuk volume air 15 liter, sedangkan kehilangan panas konduksi pada tangki reservoir tanpa isolator adalah 2.404,46 kJ untuk volume air 10 liter dan 2.129,66 kJ untuk volume air 15 liter. Penggunaan isolator Armaflex pada tangki reservoir menghasilkan efisiensi termal lebih dari 95% untuk volume air 10 liter dan 15 liter, tetapi seiring peningkatan suhu air hingga menit ke-50, efisiensinya menurun tetapi masih diatas 95%. Sementara itu, tangki reservoir tanpa insulasi memberikan efisiensi termal yang jauh lebih rendah, yaitu 27,22% & 25,57% untuk volume air 10 liter & 15 liter masing-masing pada 5 menit pertama pengoperasian AC, & terus menurun menjadi 1,88% & 2,30% pada menit ke-50. Hal ini menunjukkan bahwa penggunaan isolator Armaflex pada tangki reservoir menunjukkan suhu air yang lebih tinggi, memberikan efek yang sangat signifikan dalam mengurangi kehilangan panas ke lingkungan, dan efisiensi termal yang lebih tinggi dibandingkan tangki reservoir tanpa isolasi.

**Kata kunci:** *efisiensi termal; isolator; panas buang kehilangan panas; temperature.*

## 1. Introduction

Over the past 10 years, there has been a surge in energy demand to meet human needs. This surge in energy demand has occurred in the residential sector. Energy is necessary for human comfort in daily activities. Two key components required for daily human comfort are air conditioning and water heating[1]. Conventionally, air conditioning is typically provided by an air conditioner (AC), which uses electricity. AC consumes approximately 39% of a home's total electricity needs[2]. Furthermore, AC significantly impacts heat release into the atmosphere, contributing to global warming[3]. Water heaters come in various types, including gas heaters, electric heaters, those that add hydrogen to natural gas, electric storage water heaters, solar water heaters, and heat pump water heaters. Electric water heaters are the most widely used because they are easy to install, require few components (a single package), and are relatively inexpensive[1].

Previous researchers have conducted extensive research on utilizing waste heat from AC condensers. Increasing the efficiency of heat extraction with heat exchangers in electric water heaters has also been widely carried out, namely by using double helical tube[4], shell and tube[5], and closed double shell[6] heat exchangers. Although efforts have been made to increase the efficiency of heat extraction, there are still shortcomings in the form of electricity costs that must be incurred. An alternative solution to this problem is to utilize waste heat as a free energy source and overall can reduce energy consumption. This waste heat comes from the AC condenser[7]. A water heating system that uses waste heat from the AC condenser that operates to maintain a room temperature between 16ºC-18ºC can raise the temperature of 25 liters of water to 90ºC. This system not only saves costs for water heating but also prevents waste heat from being wasted into the environment[8]. The AC waste heat recovery system designed by Anshul S, et. al can raise the temperature from 26.2 ºC to 51.6 ºC in 200 grams of water in 65 minutes[9]. Heri S, et. al. have modified the AC system by adding a condenser installed parallel to the pipe line before the old condenser. The new condenser functions as a water heater. The operation of this modified AC system is regulated by several valves. From the experimental results, it was found that a total of 40 liters of water can be heated from a temperature of 16 ºC to 69 ºC in 170 minutes [10]. Yudhi [11] has created a hybrid water heater with a heat source derived from AC exhaust heat and from solar thermal. The water heater whose heat source is only from AC exhaust heat can raise the water temperature above 40 ºC in 30 minutes, while the one using additional heat source from solar thermal in 15 minutes. Hasan Basri et. al. have designed a water heater with a modification in the form of a condenser added with a water cooler that simultaneously functions as a condenser and a water heater. This water heater can raise the water temperature to 43 ºC with a water flow rate of 1 liter per 9 minutes [12]. Another study conducted by Amit Choudhori on heat recovery from condensers showed that the overall system can increase the COP of an AC system from 2.80 to 3.32 and extract 9,300 kJ of energy, which can be used for sterilization in hospitals, hot baths, and other domestic needs.[13] Gunarto et al. have created a water heater using condenser waste heat using a helical heat exchanger. The water heater can raise the temperature to 44.4 °C in 70 minutes. The rate of heat transfer to heat water is 1.14785 kJ/s.[14]

Based on the literature review presented, research conducted on utilizing waste heat from AC has focused solely on the temperature of the hot water that can be reached within a certain time. However, how to maintain the heated water so that its heat is not lost to the environment or its temperature does not drop has not been studied. Therefore, this research focuses not only on utilizing AC exhaust heat to raise water temperature but also on how to maintain the temperature of heated water for long periods of time, even when the AC is not in operation. This study aims to determine the effect of adding an insulator to the reservoir tank on the water temperature, heat loss and thermal efficiency of reservoir tank in water heater. A heat exchanger is installed between the compressor and condenser to extract heat from the refrigerant, and the water is stored in the tank. The parameters investigated are the water temperature in the storage tank and the thermal efficiency of the system.

## 2. Material and Method

A combination of air conditioner (AC) and water heater is called Air Conditioner Water Heater (ACWH). It works by using a steam compression refrigeration cycle, which consists of a compressor, condenser, expansion valve, and evaporator[15]. During the compression steam refrigeration cycle, the refrigerant will experience an increase in temperature and pressure after passing through the compressor, before passing through the condenser[16]. This heat exchanger will heat water without the need for additional electrical power because it can work just by adding the heat exchanger which functions as a water heater on the system Air Conditioner [17]. The working principle of this water heater is to utilize the heat of the refrigerant that comes out of the compressor to heat the water in the water heater before it enters the condenser[18]. After that, the water will be stored in the tank reservoir to keep the water temperature hot. To be able to meet this, the addition of heat insulators such as glass wool, the powder of the tree trunk in order to be able to store hot water for a relatively long period of time. As research [19] using coconut tree trunk powder with a thermal conductivity of 0.08 W/m°C. Design and schematic of proposed Air Conditioning Water Heater are shown in Figure 1. and Figure 2.

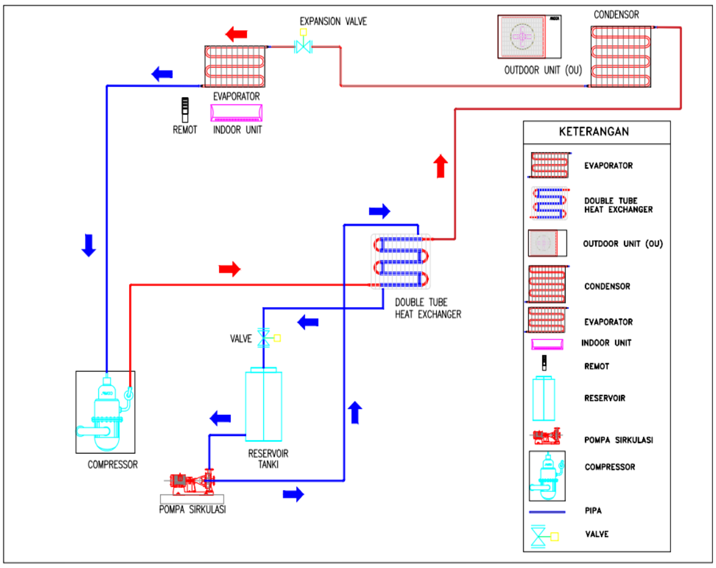


**Figure 1.** Schematic of Air Conditioner Water Heater

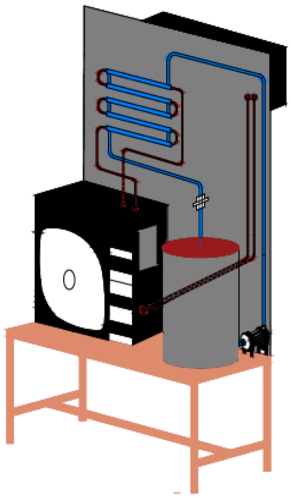

**Figure 2.** Desain of Air Conditioner Water Heater

Research Stage

In the first stage, preparation was carried out by preparing the tools and materials that would be used to create the air conditioner and water heater design. In addition, reservoir tanks were installed with and without Armaflex insulators. These reservoir tanks were then installed alternately to store the hot water from the water heater. The second stage was the testing phase. This testing phase consisted of four tests with water volumes of 10 liters and 15 liters. The third stage involved collecting data from each variation with and without insulators, with different water volumes. Data collection began by connecting the reservoir tank without an insulator to the water heater. Next, water was added to the reservoir tanks with volumes of 10 liters and 15 liters. The next data collection was carried out using the reservoir tank variation with Armaflex Class 1 insulators. Before replacing the reservoir tank, the water was drained to move the water pump to the reservoir tank that would be used. This was done to minimize the risk of hot water coming into contact with body parts. Afterward, water was poured into the reservoir tanks with volumes of 10 liters and 15 liters. The system was turned on and data was collected on the variations in the reservoir tanks with the Armaflex insulators. In the fourth stage, the previously collected data was analyzed. This was done by comparing the heating temperature, conduction heat transfer rate, and reservoir tank efficiency. The flowchart of research is presented in Figure 3.

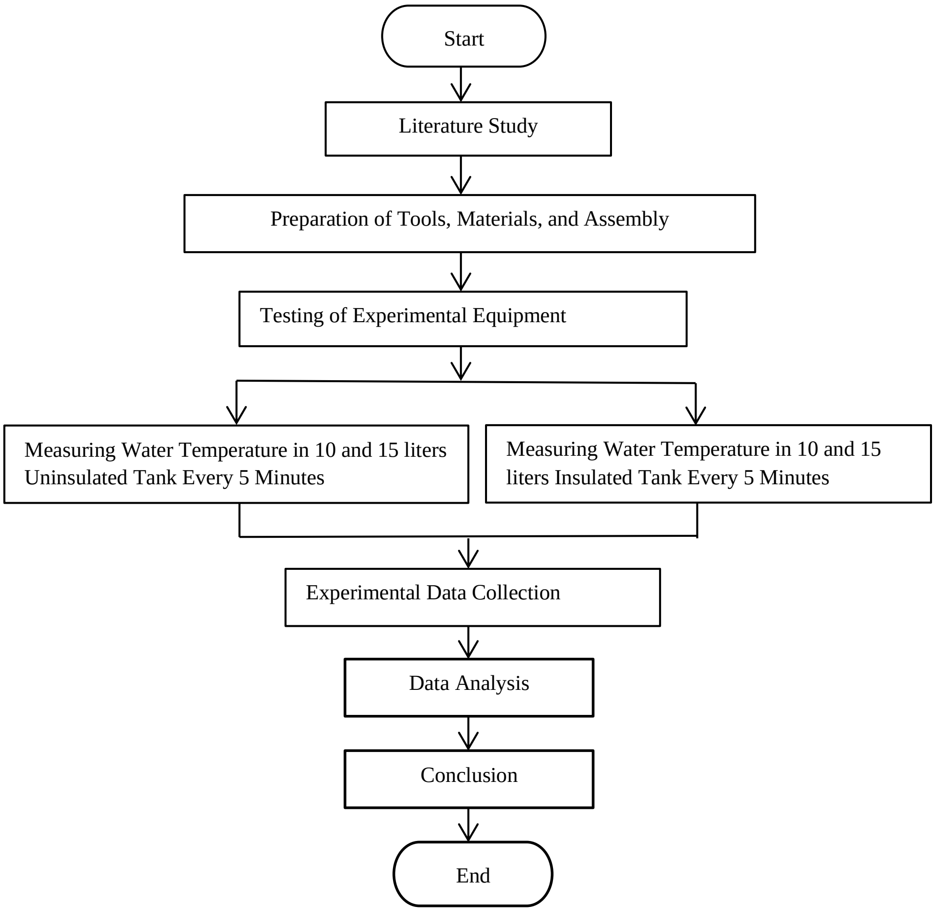


**Figure 3.** Research Flowchart

The reservoir tank is one of the main components of an air conditioning water heater which functions as a container for collecting and storing heated water. With this tank reservoir, hot water can be obtained at any time when needed, so the tank reservoir must be able to store system heat so that it does not escape[20].

To reduce the rate of heat transfer, thermal insulation is used. Conduction, convection, and radiation are some of the ways in which heat energy can be transferred, or when a change in form occurs. Heat energy can flow from high temperatures to low temperatures. The amount of heat energy flowing through a material varies depending on the properties of the material. The material used to reduce the rate of heat transfer is called an insulator[21]. The experiment used Armaflex class 1 insulators with a thermal conductivity of 0.034 W/m°C. Armaflex has low thermal conductivity so that it is effective in reducing heat loss.

The heat contained in the water will flow away from the heat system in the water through the stainless steel wall. R1 is thermal resisant of stainless steel. R2 is thermal resistant of Armaflex insulator. The inner radius of stainless steel is denoted by $r_1$ while outer radius is denoted by $r_2$. The outer radius of Armaflex insulator is denoted by $r_3$. The heat coming out through the R2 will be inhibited using an *Armaflex* insulator and then flows out. Heat transfer mechanism on reservoir tank hot water storage can be seen in Figure 4 below[22]:

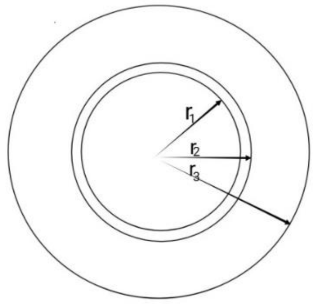


**Figure 4.** Heat Transfer Mechanism on Reservoir Tank [22]

The thermal resistance arrangement of the insulated reservoir tank is shown in the Figure 5.

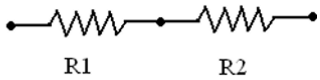


**Figure 5.** Heat Transfer Scheme through stainless steel and armaflex [23]

The heat transferred to water ($Q_{water}$)

The heat transferred from refrigerant to water[24]:

$$Q_{water} = m.cp.\Delta T \quad (1)$$

Where $Q_{water}$ is the rate of heat transfer in the water in the reservoir tank (J), m is the mass of water in the reservoir tank (kg), cp is the specific heat of water (J/kg°C), ΔT is the temperature change where the temperature change is obtained every 5 minutes with the equation ΔT = T2-T1, where T2 is the temperature after 5 minutes and T1 before 5 minutes.

The heat loss to environment ($Q_{loss}$)

The heat transferred from reservoir tank walls to environment[25]:

$$Q_{loss} = \frac{Ti - To}{R_{th}} \quad (2)$$

Where $Q_{loss}$ is the rate of heat transfer loss in the reservoir tank (J), $T_i$ is the temperature inside the reservoir tank (°C), $T_o$ is the temperature outside the reservoir tank (°C), $R_{th}$ is the thermal resistance (W/m2.°C).

To find the thermal resistance (R) can be calculated with the following equation[26]:

$$R = \frac{\ln\left(\frac{ro}{ri}\right)}{2\pi.k.L} \quad (3)$$

$R_{th} = R_1 + R_2$

Where $R_1$ is the thermal resistance of the fluid to the stainless steel plate (W/m2.°C), $r_i$ is the radius of the inner tank reservoir (m), L is the height of the tube (m), $R_2$ is the thermal resistance between the stainless steel plate to the armaflex (W/m2.°C), $r_o$ is the radius of the outer tank reservoir and k is the thermal conductivity of the armaflex.

Tank reservoir *efficiency* (η)

The efficiency of reservoir the tank can be calculated by the following equation[19]:

$$\eta = \frac{Q_{water}}{Q_{Total}} x100\% \quad (4)$$

η : Efficiency, %

$Q_{total} = Q_{water} + Q_{loss}$

Where η is the efficiency of the reservoir tank, $Q_{water}$ is the rate of heat transfer in the water in the reservoir tank and $Q_{Total}$ is $Q_{water}$ plus $Q_{loss}$.

Heat loss percenage

The percentage of heat loss can be calculated with the following equation[19]:

$$Hloss = 100 - \eta \quad (5)$$

with :

$H_{loss}$ : Percentage of heat loss (%)

## 3. Results and Discussion

The experiment of the Air Conditioner Water Heater is carried out with four variation. Data collection was carried out for 50 minutes. Data recording was carried out every 5 minutes. The temperature changes is shown in Figure 6.

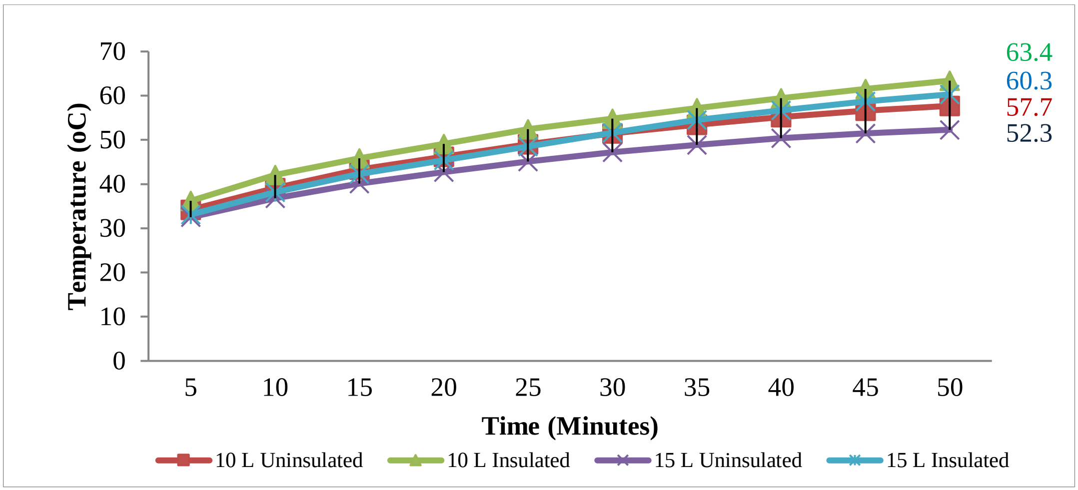


**Figure 6.** Water Temperatures in Various Condition

Figure 6 shows that adding Armaflex insulation to the outer wall of the reservoir tank affects the water temperature. The average increase of water temperature in the insulated reservoir tank was 3.54 °C and 3.23 °C for water volumes of 10 liters and 15 liters, respectively. While the average increase in water temperature in the uninsulated reservoir tank was 2.97 °C and 2.43 °C for water volumes of 10 liters and 15 liters, respectively. After 50 minutes, the hot water temperature in the insulated reservoir tank was 63.4°C and 60.3°C for water volumes of 10 liters and 15 liters, respectively. Meanwhile, the hot water temperature in the uninsulated reservoir tank was 57.5°C and 52.3°C for the water volumes of 10 liters and 15 liters, respectively. The water temperature achieved in this study is consistent with previous research, which found it to be above 40°C. The rate at which temperatures above 40°C are reached depends on the volume of water heated. The use of Armaflex insulators in reservoir tanks results in a higher average temperature increase compared to uninsulated tanks. This occurs because when heat is transferred from the AC refrigerant to the water through a heat exchanger, the absorbed heat is used to raise the water temperature. At the same time, some heat is lost to the environment. The amount of heat lost to the environment in uninsulated reservoir tanks is greater than in insulated reservoir tanks.

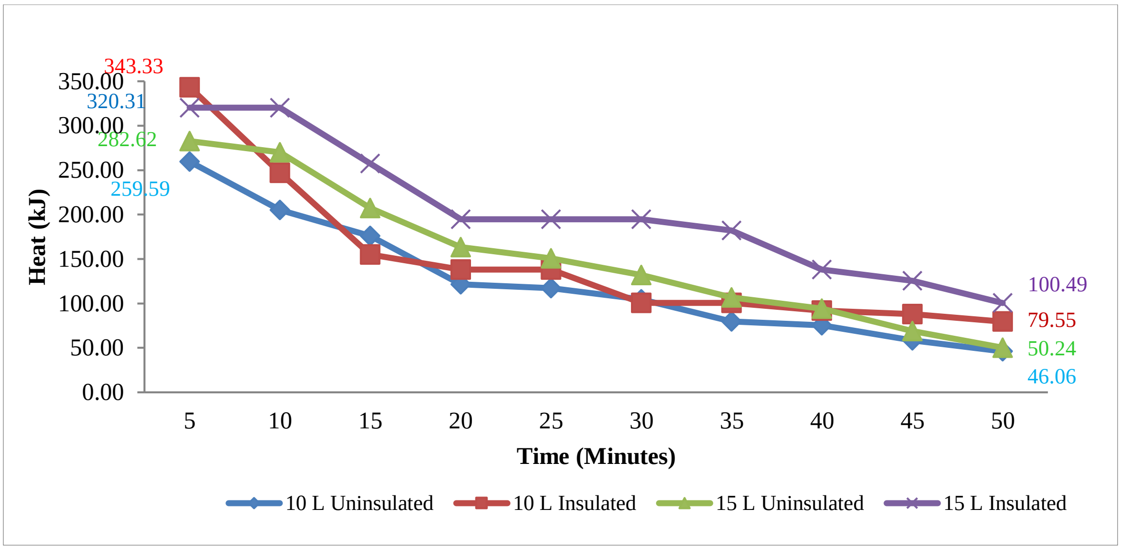


**Figure 7.** Heat Transferred to Water in Various Condition

Based on the Figure 7., the heat transferred to water of the reservoir tank with the Armaflex insulator at 50th was 79.55 kJ and 100.49 kJ for the water volumes of 10 liters and 15 liters, respectively, while the uninsulated reservoir tank was 46.06 kJ and 50.24 kJ for the water volumes of 10 liters and 15 liters, respectively. Figure 7., also shows that the heat transferred to the water decreases over time because the temperature change of water becomes smaller[19]. Figure 7 shows that overall the amount of heat transferred to the water in the insulated reservoir tank is higher than in the uninsulated reservoir tank.

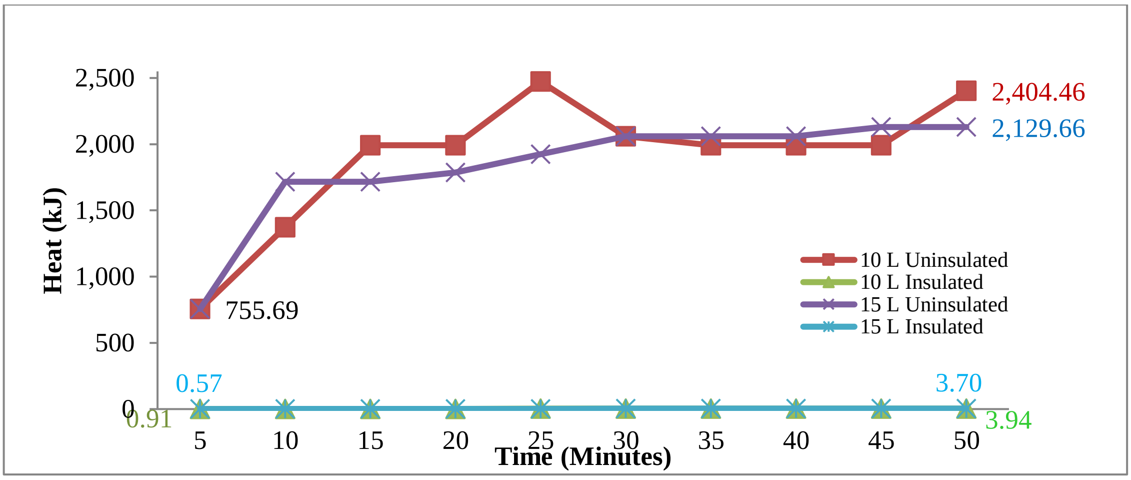


**Figure 8.** Heat Transferred to Environment in Various Condition

The Figure 8. shows that the reservoir tank with the Armaflex insulator has very low conduction heat loss, while the uninsulated reservoir tank has very high conduction heat loss. During the water heating process, conduction heat loss increases. This occurs because the difference in water temperature (represented by the inner wall temperature) and the outer wall temperature of the reservoir tank increases. The conduction heat loss in the reservoir tank with the Armaflex insulator at the 50th minute was 3.94 kJ for a water volume of 10 liters and 3.70 kJ for a water volume of 15 liters, while the conduction heat loss in the uninsulated reservoir tank was 2,404.46 kJ for a water volume of 10 liters and 2,129.66 kJ for a water volume of 15 liters. This indicates that the use of the Armaflex insulator has a very significant effect in reducing heat loss to the environment. The use of Armaflex insulators reduces the heat loss by 610.3 times for a water volume of 10 liters and 575.8 times for a water volume of 15 liters.

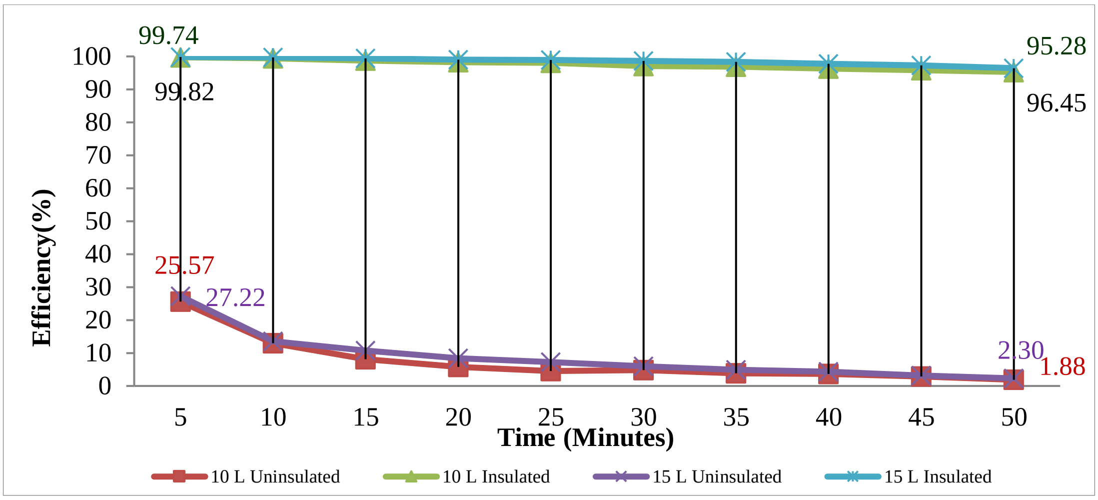


**Figure 9.** Thermal Efficiency

Figure 9 shows that the use of Armaflex Isolator provides very high efficiency for both 10 liter and 15 liter water volumes, but over time as the water temperature increases up to 50 minutes, the efficiency decreases but is still greater than 95%. Despite the decrease, the efficiency remains greater than the efficiency of the uninsulated tank. This occurs because the amount of heat lost to the environment is also small due to the large thermal resistance of the insulator. While the uninsulated reservoir tank provides a much smaller efficiency of 27.22% and 25.57% for 10 liters and 15 liters water volumes respectively in the first 5 minutes of AC operation and continues to decrease to 1.88% and 2.30% at the 50th minute. This occurs because the amount of heat lost to the environment is very large from the start of AC operation. The use of Armaflex insulation causes a small decrease in efficiency from the start of AC operation until the end of the 50th minute, while without the use of insulation causes a sharp decrease in efficiency from the 5th to the 15th minute. It can be stated that the use of Armaflex insulation can maintain water temperature for extended periods, even when the split AC unit is not in operation.

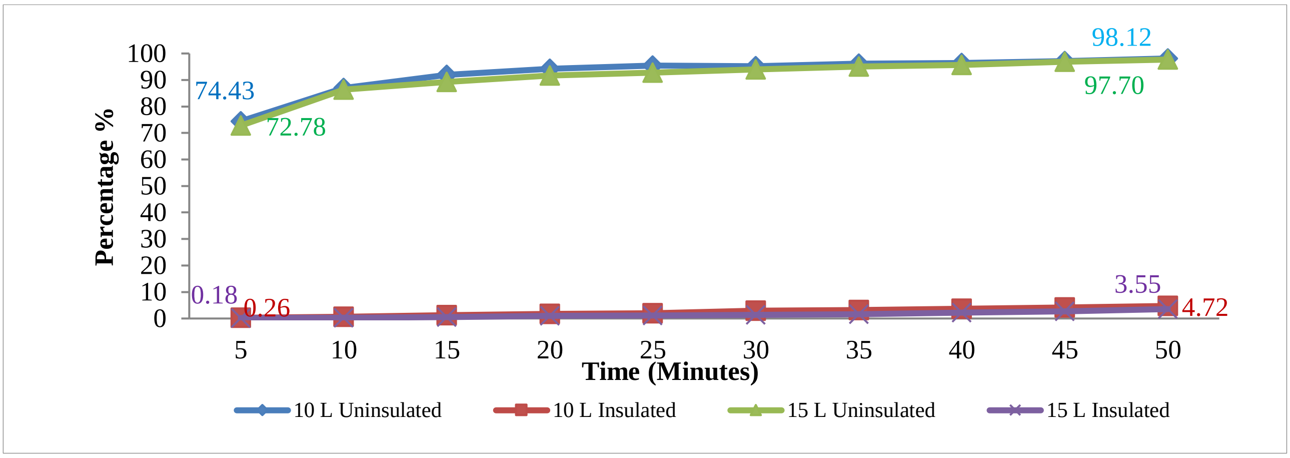


**Figure 10.** Percentage of Heat Loss

The heat loss percentage indicates how much heat is lost to the environment out of the total heat that could be absorbed from the AC refrigerant. Figure 10. shows that the heat loss percentage in the reservoir tank with the Armaflex insulator is very low, reaching 4.72% and 3.55% for water volumes of 10 liters and 15 liters, respectively, at the 50th minute. Meanwhile, heat loss in the uninsulated reservoir tank is very high, reaching 98.12% and 97.70% for water volumes of 10 liters and 15 liters, respectively, at the 50th minute. Therefore, the use of the Armaflex insulator can maintain water temperature by minimizing heat loss.

## 4. Conclusion

The use of Armaflex insulators in reservoir tanks results in a higher average temperature increase compared to uninsulated tanks. The average increase of water temperature in the insulated reservoir tank was 3.54 °C and 3.23 °C for water volumes of 10 liters and 15 liters, respectively. While the average increase in water temperature in the uninsulated reservoir tank was 2.97 °C and 2.43 °C for water volumes of 10 liters and 15 liters, respectively. After 50 minutes, the hot water temperature in the insulated reservoir tank was 63.4°C and 60.3°C for water volumes of 10 liters and 15 liters, respectively. Meanwhile, the hot water temperature in the uninsulated reservoir tank was 57.5°C and 52.3°C for the water volumes of 10 liters and 15 liters, respectively. The reservoir tank with the Armaflex insulator has very low conduction heat loss, while the uninsulated reservoir tank has very high conduction heat loss. The conduction heat loss in the reservoir tank with the Armaflex insulator at the 50th minute was 3.94 kJ for a water volume of 10 liters and 3.70 kJ for a water volume of 15 liters, while the conduction heat loss in the uninsulated reservoir tank was 2,404.46 kJ for a water volume of 10 liters and 2,129.66 kJ for a water volume of 15 liters. The use of Armaflex isolator provides very high efficiency for both 10 liter and 15 liter water volumes, but over time as the water temperature increases up to 50 minutes, the efficiency decreases but is still greater than 95%. Despite the decrease, the efficiency remains greater than the efficiency of the uninsulated tank namely 1.88% and 2.30% at the 50th minute.

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