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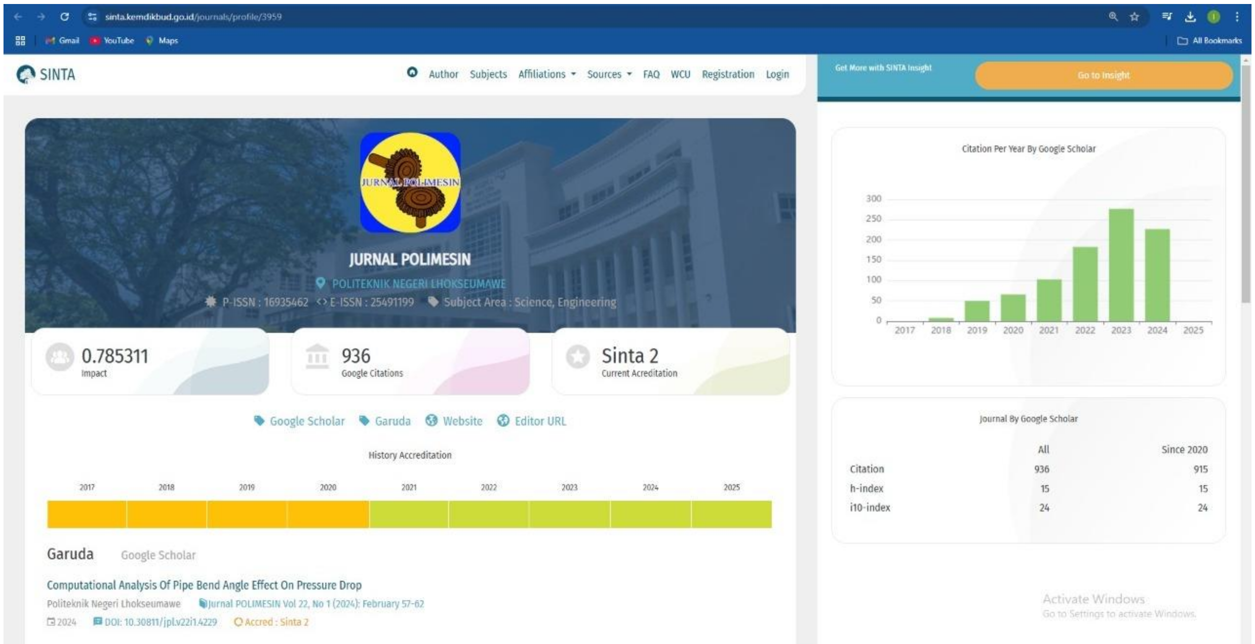

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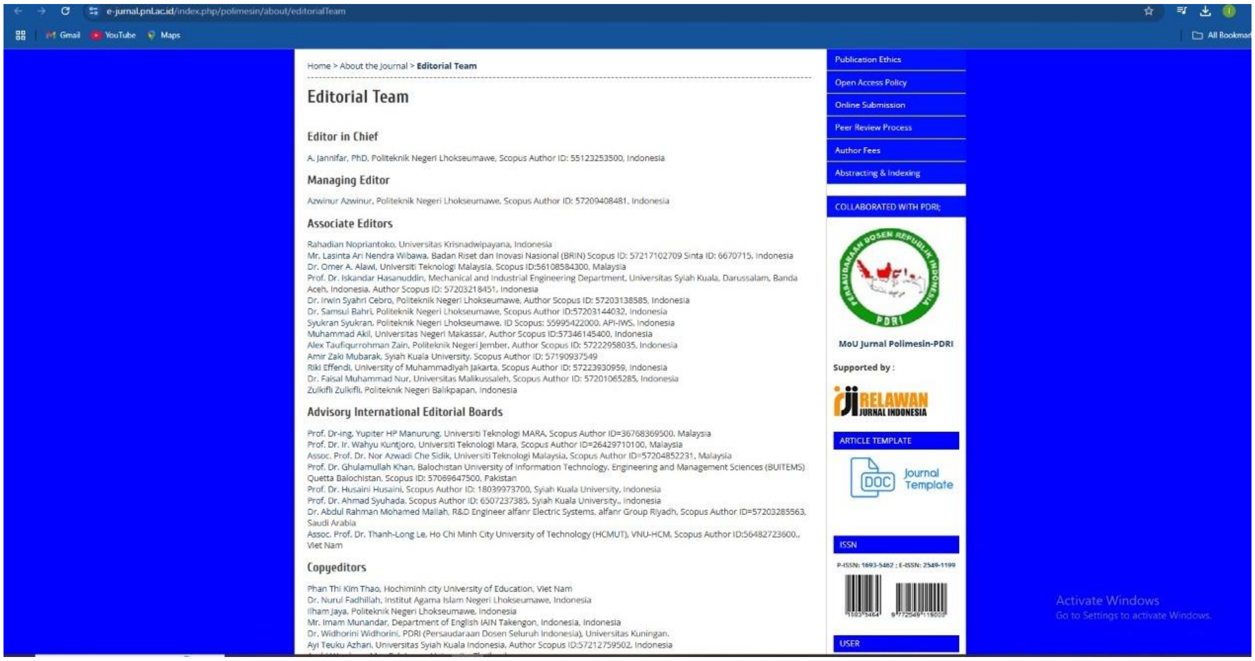

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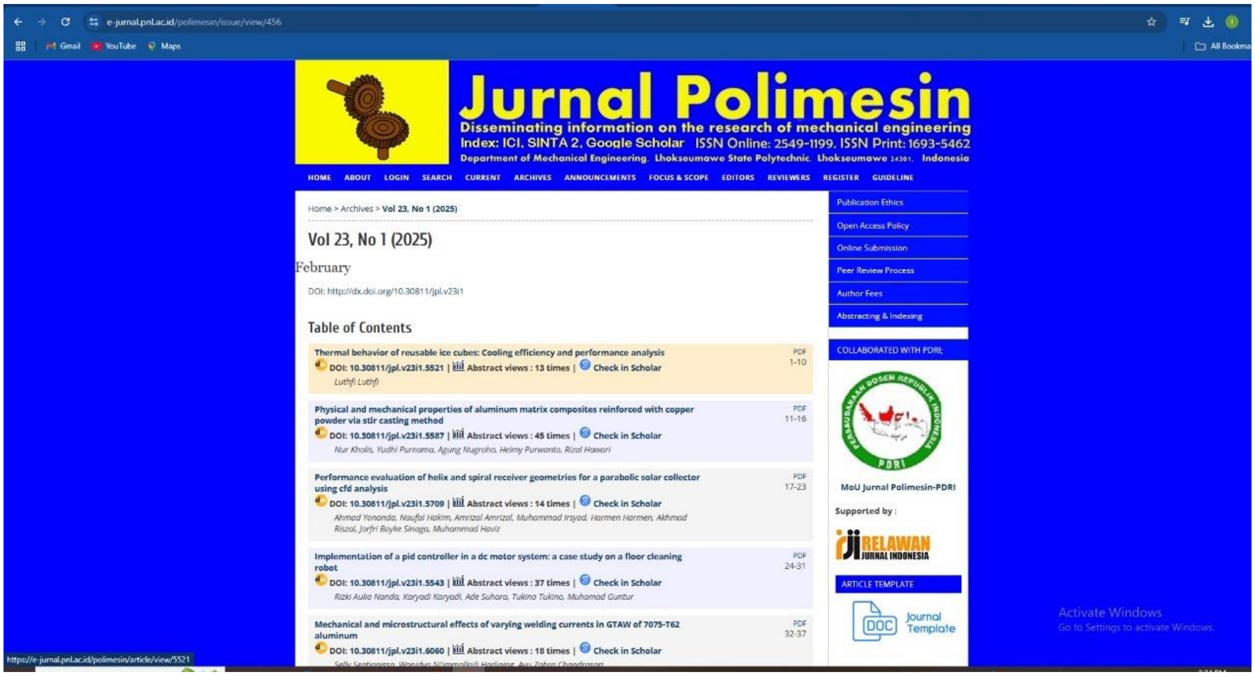

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Submission

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#6110 Summary

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Title and Abstract

Title: Enhancing seawater desalination performance using a vortex generator in a modified window air conditioner

Abstract

The growing demand for air conditioning systems has driven research into alternative applications, such as seawater desalination. This study evaluates the performance of a modified window air conditioner (WAC) integrated with a vortex generator for desalination. Experiments were conducted using R410A refrigerant under four conditions: closed container (CC), without vortex (WV), connected vortex (CV), and separated vortex (SV). Seawater was heated via the condenser to 55–60°C, controlled by a thermostat, and data was collected every five minutes over eight hours. The thermodynamic properties of R410A were analyzed using Refprop software to determine refrigeration effect (RE), compression work (CW), and coefficient of performance (COP). Results indicate that the SV configuration achieved the highest evaporation rate (5.01 kg) but led to a lower COP (3.91) due to increased condenser temperature and compressor workload. Conversely, CC yielded the highest COP (5.08) by stabilizing the evaporator air temperature and reducing compressor effort. These findings suggest that vortex generators enhance evaporation rates but reduce system efficiency. Further research is needed to optimize vortex generator configurations to improve desalination efficiency while minimizing COP reduction.

Indexing

Keywords: Window air conditioner, Vortex generator, Desalination, Refprop, COP

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References

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ABSTRACT			
1. It is better to explicitly mention all the performance variable to be determine	1		
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INTRODUCTION			
1. Where is the position of vortex in the experiment set up ?	**1**		
2.			
METHOD			
1. Some step to be corrected ?	**2**		
2.			
RESULT & DISCUSSION			
1. Show the data to back up the argue in the discussion, graph of data etc	**3**		
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CONCLUSION			
1. Only write the useful finding, the important conclusion of this research, better in number, not only the highest, the lowest number	**3**		
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CITED LITERATURE			
1. Try to find the latest 5 years references or near to 5 years	**3, 4**		
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Performance evaluation of a modified window air conditioner for seawater desalination

Abstract

The increasing use of air conditioning systems in everyday life has encouraged the development of alternative applications of these devices, one of which is seawater desalination. This study aims to evaluate the performance. of a modified window air conditioner (WAC) as a desalination device against seawater evaporation. Experiments were conducted using a WAC with R410A refrigerant modified with closed container (CC), without vortex (WV), connected vortex (CV), and separate vortex (SV) variables. Seawater was heated with a condenser until it reached a temperature of 55-60°C controlled by a thermostat. Data were collected every 5 minutes for eight hours of testing. The system performance was analysed using Refprop version 10.0.0.9b to calculate the thermodynamic properties of R410A, specifically enthalpy, which was then used to determine the refrigeration effect (RE), compression work (CW), and coefficient of performance (COP). The results showed that the use of vortex increased the evaporation rate, with SV showing the best evaporation due to the use of a greater number of vortex. The increase in evaporation resulted in a decrease in COP, which was due to an increase in condenser temperature requiring greater compression work. CC produces the highest refrigeration effect and reduces compression work, resulting in an optimal COP because it prevents evaporation in the condenser from affecting the temperature of the air entering the evaporator. The highest COP occurs in a closed container and the lowest in a separate vortex.

Keywords

Window air conditioner, R410A, Desalination, Refprop, COP

1 Introduction

Along with the improvement of the quality of life and the need for comfort, the use of air conditioning systems is increasing in daily life [1],[2]. Air conditioning systems also help remove moisture and airborne particles from the room [3]. Therefore, the use of air conditioners is no longer just part of a lifestyle, but rather aims to provide comfort when moving or doing activities indoors [4]. One of the most common types is the Window Air Conditioner (WAC), which uses a vapor compression cycle to take heat from the air inside and expel it outside through condensation [5]. This condensation water is usually disposed of as waste, but can be used to make clean water under certain conditions [6]. The high demand for clean water around the world, as well as environmental issues such as drought and limited availability of clean water resources, are major challenges that need to be addressed [7], [8], [9]. The use of a modified WAC as a desalination device is an option to consider. This modification allows the WAC to function as both an air conditioning unit and a system to separate salt from saltwater. Evaluating the performance of the WAC as a desalination device is essential to ensure the effectiveness of this system in removing salt from seawater.

Currently available desalination systems, such as Reverse Osmosis (RO) [10]. However, such technologies consume a lot of energy [11], especially on a large scale, making it inefficient for households or places with limited energy resources. On the other hand, WAC is a device that is widely used in many homes [12] and operates according to the principles that allow it to be used in desalination processes. The main problem is how to modify the WAC without compromising its cooling efficiency and ensuring optimal system performance during its switch to desalination function.

Research on the use of air conditioning for desalination processes is still in its infancy. Some of the research that has been conducted includes the integration of a split air conditioning system with a humidification-dehumidification (HDH) desalination unit utilizing solar energy, the utilization of solar heating to improve the performance of a hybrid desiccant air conditioning system coupled with an HDH desalination unit, and numerical analysis of a solar energy-assisted hybrid air conditioning system integrated with an HDH desalination system [13], [14], [15]. However, no previous research has explored the performance of a modified WAC as a desalination device against seawater evaporation. AC performance can be determined by assessing the Refrigeration Effect (RE), Compression Work (CW), and Coefficient of Performance (COP) [16].

Therefore, this study aims to determine the performance of the modified WAC as a desalination device against seawater evaporation. This study has analyzed the impact of various tested variables on seawater evaporation at a set temperature. This research focuses on measuring the Refrigeration Effect (RE), Compression Work (CW), and Coefficient of Performance (COP), which are the main indicators in assessing the device's ability as a desalination system. It is hoped that this research can provide in-depth insight into the potential of WAC modification to produce a more effective and efficient desalination system.

2 Method

This study used a Window Air Conditioner (WAC) to compare its performance as a desalination device. The experimental setup used in this study is presented in Fig. 1. The working fluid of the air conditioning system is R410A refrigerant [17] with the specifications shown in Table 1. This research was conducted at the Mechanical Engineering Laboratory, Faculty of Industrial Technology and Informatics, Universitas Muhammadiyah Prof. Dr. Hamka. In addition, the measurement tools used are listed in Table 2. Tests on the utilization of WAC as a desalination tool were carried out with variables of closed container (CC), without vortex (WV), connected vortex (CV), and separate vortex (SV).

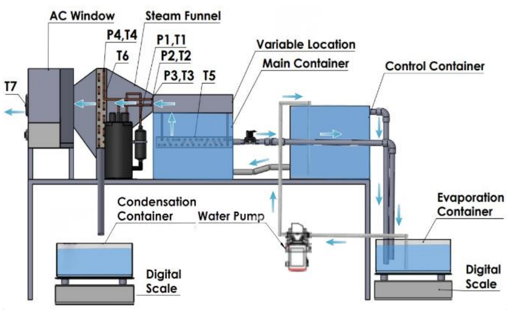

Fig. 1. Experimental Setup

Table 1. Refrigeration unit specifications

Item	Specification
Model WAC	Uchida MP – W9M
Voltage	1 Fase 220V – 50 Hz
PK Power	1 PK
Cooling Capacity	8600 BTU/h
Electrical power	840 W
Current	4.0 A
EER	10.01 BTU/h.W
Refrigerant R410A	360 g
Size	500×345×465 mm

Table 2. Measurement tools

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Tools	Function	Spesification
Thermostat XH-W3001	Water	-50°C -110°C,
Digital thermometer	Temperature	-50°C -110°C,
Manifold Gauge	Pressure	0 – 500 psia, 5
Digital scale 30 kg	Water Mass	0 – 30 kg,
Digital scale 20 kg	Condensed	0 – 20 kg, 1 gr

In this experiment, the seawater in the evaporation container is transferred to the control container via a pump. This step aims to deliver the water to the main container, where it will be heated using a condenser until the temperature reaches about 55-60°C, which is regulated by a thermostat. As the water evaporates, the resulting vapor is directed upwards through the steam funnel before finally entering into the evaporator.

The main container has an overflow mechanism that delivers water to the evaporation container to maintain the temperature in the range of 55-60°C. In addition, the control container is also equipped with an overflow system to the evaporation container to ensure the water level remains stable. With this mechanism, the water level in the control container can be maintained, while the water level in the evaporation container decreases as the evaporation process occurs [18]. The evaporation rate was measured by the mass of water in the evaporation container, which was assessed using a digital balance to confirm the mass of water reduced due to evaporation. In Fig. 1. data was collected at P1, T1, P2, T2, P3, T3, P4, T4, T5, T6, T7. Where P1,T1 is the compressor inlet pressure, temperature, P2,T2 is the compressor outlet pressure, temperature, P3,T3 is the expansion inlet pressure, temperature, P4,T4 is the expansion outlet pressure, temperature, T5 is the condenser temperature, T6 is the evaporator temperature, T7 is the evaporator outlet air temperature, and the variable location is used for a closed container by placing a plate on top of the container, a container without vortex, vortex connected, and vortex separated. Fig. 2-3 shows the vortex used in this study.

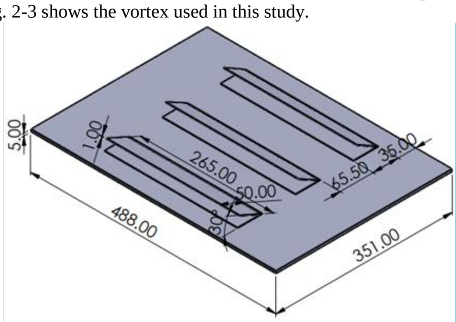

Fig. 2. Connected vortex (CV)

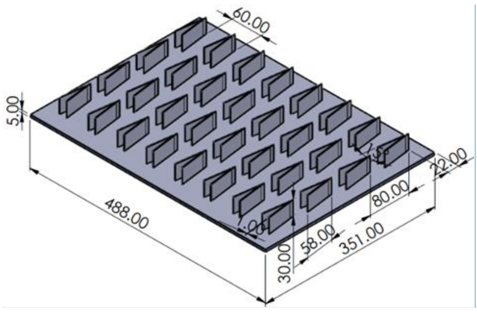

Fig. 3. Separated vortex (SV)

Refprop software version 10.0.0.9b is used to determine the properties of the refrigerant at enthalpy each point based on the cooling system performance data, by analyzing the saturation pressure, temperature, enthalpy, entropy, and density of the refrigerant [19], [20]. System performance is analyzed using pressure and temperature obtained through calculations on R410A refrigerant using Refprop software [21]. The effectiveness of an air conditioner is evaluated by determining the refrigeration effect, which is the difference in refrigerant enthalpy at the inlet and outlet of the evaporator, and the compression work, which is the difference in refrigerant enthalpy at the outlet and inlet of the compressor. Refrigeration Effect (RE), Compression Work (CW), and Coefficient of Performance (COP) are calculated by using the enthalpy results obtained [22].

The Refrigeration Effect (RE), Compression Work (CW), and Coefficient of Performance (COP) are determined using Eq. 1 - Eq. 3 [23].

$$RE = h_1 - h_4 \quad (1)$$

$$CW = h_2 - h_1 \quad (2)$$

$$COP = \frac{RE}{CW} = \frac{h1 - h4}{h2 - h1} \quad (3)$$

Where: h1 is enthalpy at compressor inlet, h2 is Enthalpy at compressor outlet, and h4 is enthalpy at the Evaporator inlet

3 Results and Discussion

This study examines the performance of WAC for utilization as a desalination tool with four variables: CC, WV, CV, and SV.

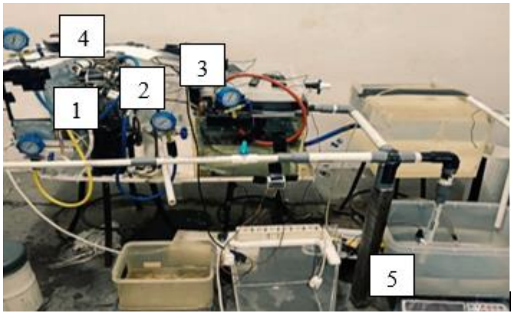

Figure 4. Window Air Conditioner (WAC) as a desalination device

Fig. 4 shows the data collection process. At points 1 to 4, data of P1, T1, P2, T2, P3, T3, P4, and T4 are collected sequentially. The digital scale at point 5 monitors the evaporation rate and provides accurate data. The seawater in the main container was heated by a condenser controlled by a thermostat to maintain a temperature between 55-60°C. Data was collected every 5 minutes for eight hours.

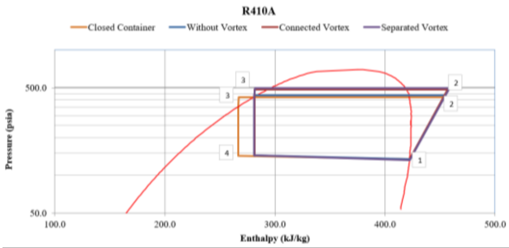

Fig. 5. P-h diagram for R410A with closed container, without vortex, connected vortex and separated vortex

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Fig. 5 shows the pressure-enthalpy (P-h) diagram for R410A refrigerant at various variables, namely CC, WV, CV, and SV. The enthalpy values are obtained from the calculation results using Refprop software, with input data in the form of pressure and temperature at each point: P1, T1, P2, T2, P3, T3, P4, and T4. The average evaporator exit air temperature for each variable is 17.8°C, 18.6°C, 18.7°C, and 18.9°C, respectively. Meanwhile, the condenser exit air temperatures were 55.7°C, 56.3°C, 56.9°C, and 57.1°C, respectively. Based on the enthalpy values obtained, the performance of the WAC system can be calculated, including the RE, CW, and COP values.

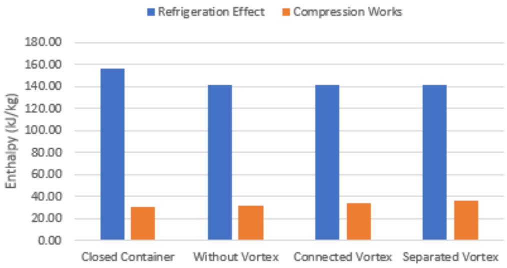

Fig. 6. Refrigeration effect and compression work with closed container, without vortex, connected vortex, and separated vortex.

In a refrigeration system, efficiency is very important to consider. One concept that plays a role in measuring the efficiency of a refrigeration system is the refrigeration effect (RE), which is the amount of heat absorbed by the refrigerant in the evaporator for each unit mass of cooling, which occurs in the process from 4 to 1 [24], [25]. By calculating using Eq. 1, the Refrigration Effect (RE) of R410A for various CC, WV, CV, and SV variables in the desalination process is shown in Fig. 6. The results show a decrease in RE; a lower refrigeration effect can lower COP [26]. Latent heat of vaporization in the air conditioning system (AC) comes from the evaporation of refrigerant refrigerants [27]. The closed container of R410A has the highest RE value. The high RE value is due to the latent heat of vaporization [28] and high enthalpy compared to the other variable R410A. As a result, the desalination process using closed-container R410A yields better cooling capacity than the other variable R410A.

Meanwhile, the Compression Work (CW) of R410A for various variables, the CW value in the figure is calculated using Eq.2. Unlike RE, CW has a constant increase. This is due to the increase in compressor pressure, refrigerant temperature [29], and enthalpy. Peningkatan tekanan refrigeran dapat meningkatkan kerja kompresor, sehingga menurunkan nilai COP [30]. CW of the closed container R410A is lower than that of the other variable R410A. This indicates that the R410A refrigerant in the sealed container has a lower temperature, so the compressor workload is lighter [31].

The COP is calculated using Eq. 3, and Fig. 7 shows that the COP value decreases as the evaporation increases. The use of a vortex increases the evaporation rate and efficiency in the desalination unit, resulting in faster evaporation [32]. SV showed better vaporization due to the use of a larger number of vortex, resulting in an increase in effectiveness [33]. On the other hand, an increase in refrigerant in the refrigeration machine can lead to an increase in temperature in the condenser, which requires greater compression effort [34]. The condenser located inside the main container helps to heat the water and increase evaporation as the temperature rises. The increased evaporation temperature from the condenser is then transferred to the evaporator through a vapor funnel designed to direct the incoming air to the evaporator.

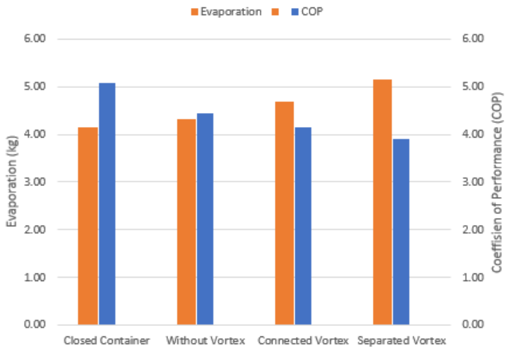

Fig. 7. Evaporation and COP with closed container, without vortex, connected vortex, and separated vortex.

The CC is secured with plates to prevent evaporation in the condenser from affecting the temperature of the air entering the evaporator. This causes a high refrigeration effect and reduces compression work, resulting in an optimal coefficient of performance (COP).

4 Conclusion

Based on the research that has been done, it can be concluded that the use of vortex can affect the evaporation of seawater during desalination. Separate vortex produces the highest evaporation compared to other variables, namely closed container, without vortex, and connected vortex. This shows the effect of vortex geometry on evaporation performance. Over eight hours, the highest coefficient of performance (COP) value (5.08) with the closed container; the lowest COP amount (3.91) with the separated vortex was due to the increase in condenser temperature. This temperature increase, when combined with the vortex at the evaporator inlet, results in increased airflow in the evaporation process. Based on the results, the modified WAC can serve as a small-scale desalination device. This is expected to improve the efficiency of cooling resource utilization for clean water production. Therefore, future research should optimize the vortex geometry and conduct large-scale testing to evaluate the system performance for more efficient desalination.

Acknowledgement

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Enhancing Seawater desalination performance using a vortex generator in a modified window air conditioner

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Abstract

The growing demand for air conditioning systems has driven research into alternative applications, such as seawater desalination. This study evaluates the performance of a modified Window Air Conditioner (WAC) integrated with a vortex generator for desalination. Experiments were conducted using R410A refrigerant under four conditions: Closed Container (CC), Without Vortex (WV), Connected Vortex (CV), and Separated Vortex (SV). Seawater was heated via the condenser to 55-60°C, controlled by a thermostat, and data was collected every five minutes over eight hours. The thermodynamic properties of R410A were analysed using Refprop™ software to determine the Refrigeration Effect (RE), Compression Work (CW), and Coefficient of Performance (COP). Results indicate that the SV configuration achieved the highest evaporation rate (5.01 kg) but led to a lower COP (3.91) due to increased condenser temperature and compressor workload. Conversely, CC yielded the highest COP (5.08) by stabilizing the evaporator air temperature and reducing compressor effort. These findings suggest that vortex generators enhance evaporation rates but reduce system efficiency. Further research is needed to optimize vortex generator configurations to improve desalination efficiency while minimizing COP reduction.

Keywords:
Window air conditioner, vortex generator, desalination, Refprop™, COP

1 Introduction

Along with the improvement of the quality of life and the need for comfort, the use of air conditioning systems is increasing in daily life [1], [2]. Air conditioning systems also help remove moisture and airborne particles from the room [3]. Therefore, the use of air conditioners is no longer just part of a lifestyle but rather aims to provide comfort when moving or doing activities indoors [4]. One of the most common types is the Window Air Conditioner (WAC), which uses a vapor compression cycle to take heat from the air inside and expel it outside through condensation [5]. This condensation water is usually disposed of as waste but can be used to make clean water under certain conditions [6]. The high demand for clean water around the world, as well as environmental issues such as drought and limited availability of clean water resources, are major challenges that need to be addressed [7], [8], [9]. The use of a modified WAC as a desalination device is an option to consider. This modification allows the WAC to function as both an air conditioning unit and a system to separate salt from saltwater. Evaluating the performance of the WAC as a desalination device is essential to ensure the effectiveness of this system in removing salt from seawater.

Desalination systems, such as reverse osmosis (RO), are currently available [10]. However, such technologies consume much energy [11], especially on a large scale, making it inefficient for households or places with limited energy resources. On the other hand, WAC is a device that is widely used in many homes [12] and operates according to the principles that allow it to be used in desalination processes. The main problem is how to modify the WAC without compromising its cooling efficiency and ensuring optimal system performance during its switch to desalination function.

Research on the use of air conditioning for desalination processes is still in its infancy. Some of the research that has been conducted includes the integration of a split air conditioning system with a Humidification-Dehumidification (HDH) desalination unit utilizing solar energy, the utilization of solar heating to improve the performance of a hybrid desiccant air conditioning system coupled with an HDH desalination unit, numerical analysis of a hybrid air conditioning system supported by solar energy and integrated with an HDH desalination system, and modified window air conditioner to produce potable water through humidification-dehumidification desalination process [13], [14], [15], [16]. These experiments show that combining an air conditioning system with a desalination unit can produce clean water. Nevertheless, these studies have not investigated the impact of vortex generators on desalination effectiveness, particularly in enhancing the evaporation rate. Multiple studies have investigated the application of vortex generators in desalination to enhance the evaporation rate [17], [18], given that vortex generators influence the convection heat transfer coefficient [19]. Previous research has not examined the performance of WAC modified with a vortex generator as a desalination tool against seawater evaporation. Desalination itself is the process of separating salt and minerals from seawater to produce freshwater [20]. Cooling system performance can be determined by assessing the Refrigeration Effect (RE), Compression Work (CW), and Coefficient of Performance (COP) [21].

Therefore, this study aims to determine the performance of the modified WAC as a desalination device against seawater evaporation. This research has analysed the impact of various tested variables on the evaporation of seawater at a given temperature. The desalination mechanism focuses on the evaporation process, where seawater is evaporated using the modified WAC. The performance assessment of this system uses the parameters RE, CW, and COP, which are the main indicators in assessing the ability of the device as a desalination system. It is hoped that this research can provide a deep insight into the potential of WAC modification to produce a more effective and efficient desalination system.

2 Method

This study used a WAC to compare its performance as a desalination device. The experimental setup used in this study is presented in Fig. 1. The working fluid of the air conditioning system is R410A refrigerant [22] with the specifications shown in Table 1. This research was conducted at the Mechanical Engineering Laboratory, Faculty of Industrial Technology and Informatics, Universitas Muhammadiyah Prof. Dr. Hamka. In addition, the measurement tools used are listed in Table 2. Tests on the utilization of WAC as a desalination tool were carried out with variables of Closed Container (CC), Without Vortex (WV), Connected Vortex (CV), and Separate Vortex (SV) (Fig. 2).

Refprop™ software version 10.0.0.9b is used to determine the properties of the refrigerant at enthalpy at each point based on the cooling system performance data by analyzing the saturation pressure, temperature, enthalpy, entropy, and density of the refrigerant [24], [25]. System performance is analyzed using pressure and temperature obtained through calculations on R410A refrigerant using Refprop™ software [26]. The effectiveness of an air conditioner is evaluated by determining the refrigeration effect, which is the difference in refrigerant enthalpy between the evaporator's inlet and outlet, and the compression work, which is the enthalpy difference between the compressor's outlet and inlet. The values of RE, CW, and Coefficient of COP are determined based on the obtained enthalpy results [27].

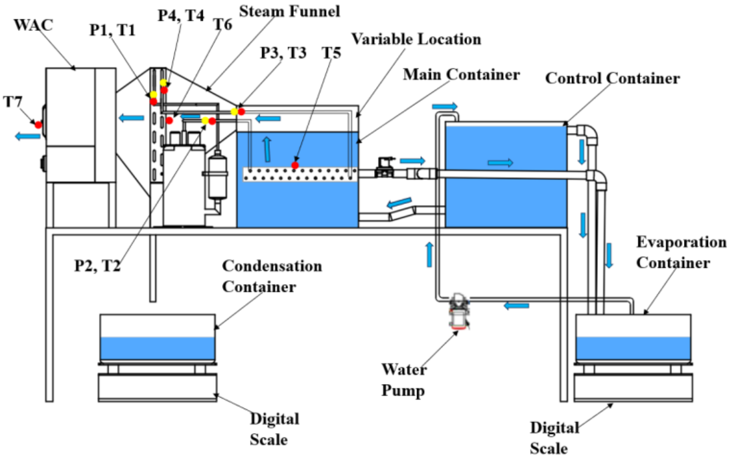


Fig. 1. Experimental setup

Table 1. Refrigeration unit specifications

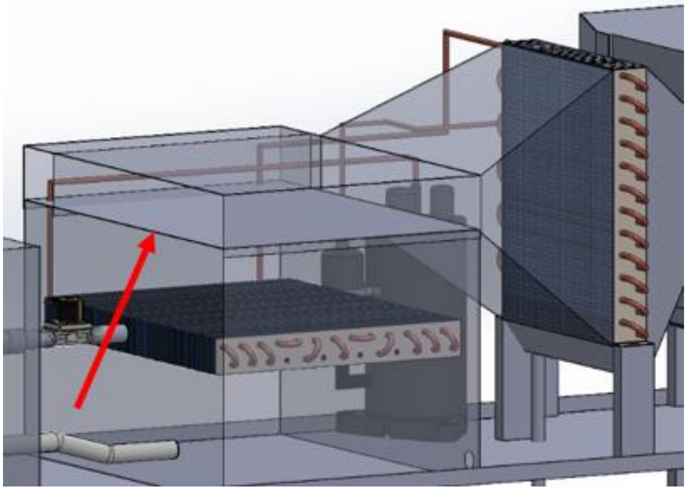
Dimension	Specification
Model WAC	Uchida MP – W9M
Voltage	1 Fase 220V – 50 Hz
PK Power	1 PK
Cooling Capacity	8600 BTU/h
Electrical power	840 W
Current	4.0 A
EER	10.01 BTU/hW
Refrigerant R410A	360 g
Size	500×345×465 mm

Table 2. Measurement tools

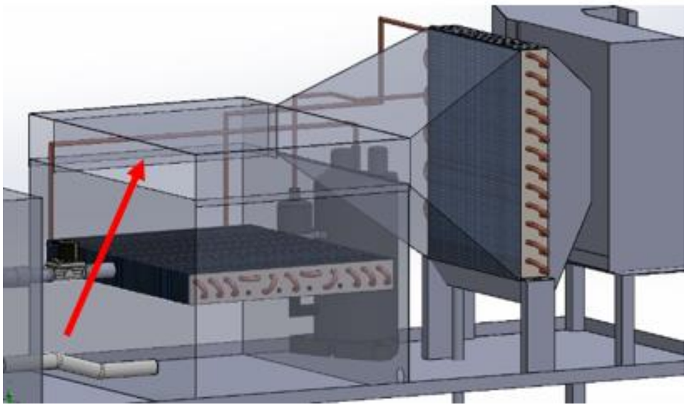
Tools	Function	Specification
Thermostat XH-W3001	Water temperature	-50°C -110°C, ±0.1°C.
Digital thermometer	Temperature	-50°C -110°C, ±0.1°C.
Manifold Gauge	Pressure	0 – 500 psi, 5 psi
Digital scale 30 kg	Water Mass	0 – 30 kg, 0.005 kg

In this experiment, the seawater in the evaporation container is transferred to the control container via a pump. This step aims to deliver the water to the main container, where it will be heated using a condenser until the temperature reaches about 55-60°C, which is regulated by a thermostat. As the water evaporates, the resulting vapor is directed upwards through the steam funnel before finally entering the evaporator.

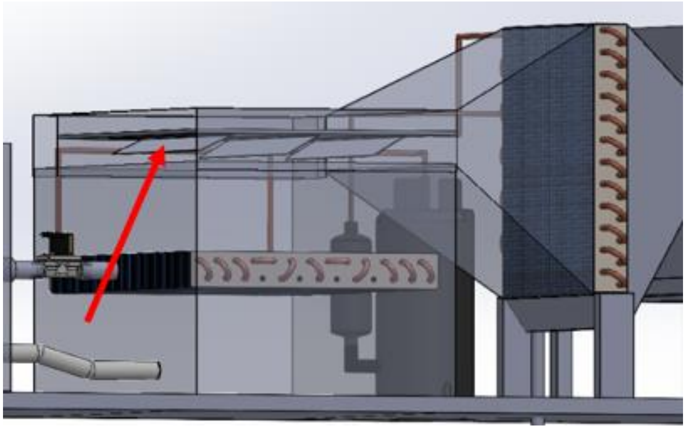
The main container has an overflow mechanism that delivers water to the evaporation container to maintain the temperature in the range of 55-60°C. In addition, the control container is also equipped with an overflow system for the evaporation container to ensure the water level remains stable. This system allows the control container's water level to remain constant while the evaporation container's water level drops due to the evaporation process [23]. The evaporation rate was determined by the mass of water in the evaporation container, which was measured with a digital scale to confirm the amount of water lost owing to evaporation. In Fig. 1 data was collected at P_1, T_1, P_2, T_2, P_3, T_3, P_4, T_4, T_5, T_6, T_7. Where P_1, T_1 is the compressor inlet pressure, temperature, P_2, T_2 is the compressor outlet pressure, temperature, P_3, T_3 is the expansion inlet pressure, temperature, P_4, T_4 is the expansion outlet pressure, temperature, T_5 is the condenser temperature, T6 is the evaporator temperature, T_7 is the evaporator outlet air temperature, and the variable location is used for a closed container by placing a plate on top of the container, a container without vortex, vortex connected, and vortex separated. Figs 3-4 shows the vortex used in this study.



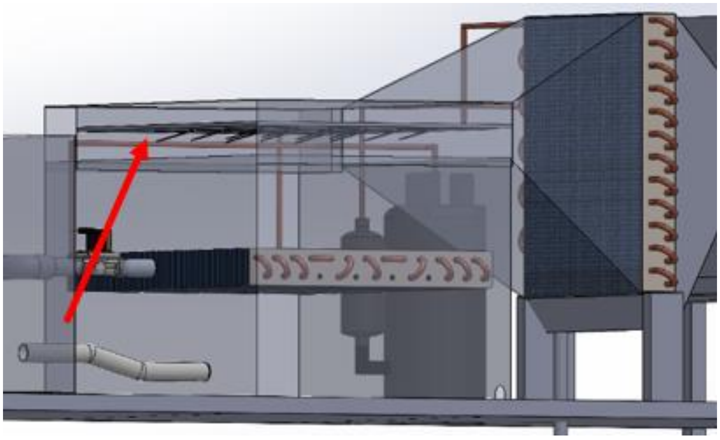
(a) Closed container (CC) location



(b) Without vortex (WV) location



(c) Connected vortex (CV) location



(d) Separated vortex (SV) location

Fig. 2. Variable location

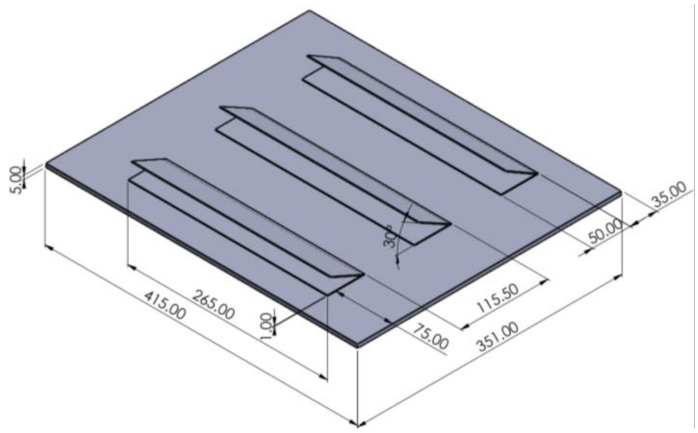


Fig. 3. Connected vortex (CV)

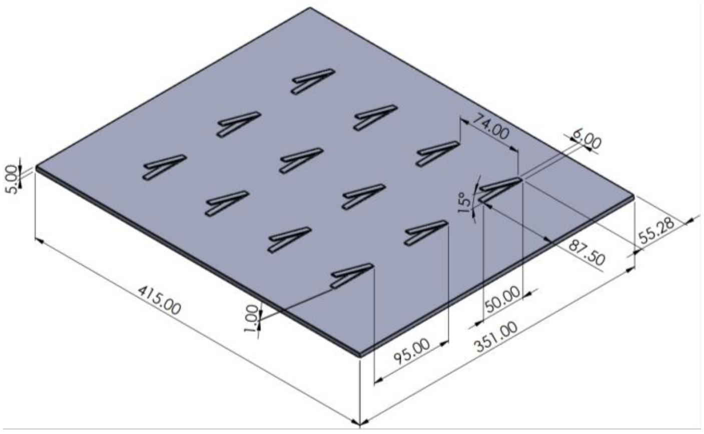


Fig. 4. Separated vortex (SV)

Refprop™ software version 10.0.0.9b is used to determine the properties of the refrigerant at enthalpy at each point based on the cooling system performance data by analyzing the saturation pressure, temperature, enthalpy, entropy, and density of the refrigerant [24], [25]. System performance is analysed using pressure and temperature obtained through calculations on R410A refrigerant using Refprop™ software [26]. The effectiveness of an air conditioner is evaluated by determining the refrigeration effect, which is the difference in refrigerant enthalpy between the evaporator's inlet and outlet, and the compression work, which is the enthalpy difference between the compressor's outlet and inlet. The values of RE, CW, and COP are determined based on the obtained enthalpy results [27]. The RE, CW, COP are determined using Eqs(1-3) [28].Where: h_1 is enthalpy at the compressor inlet, h_2 is Enthalpy at the compressor outlet, and h_4 is enthalpy at the Evaporator inlet.

$$RE = h_1 - h_4 \quad (1)$$

$$CW = h_2 - h_1 \quad (2)$$

$$COP = \frac{RE}{CW} = \frac{h1 - h4}{h2 - h1} \quad (3)$$

3 Results and Discussion

This study examines the performance of WAC for utilization as a desalination tool with four variables: CC, WV, CV, and SV. Fig. 5 shows the data collection process. At points 1 to 4, data of P_1, T_1, P_2, T_2, P_3, T_3, P_4, and T_4 are collected sequentially. The digital scale at point 5 is used to measure the mass of water in the evaporation container to determine the decrease in mass due to evaporation. The seawater in the main container was heated by a condenser controlled by a thermostat to maintain a temperature between 55-60°C. Data was collected every 5 minutes for 8 hours. The system performance is greatly affected by the evaporation rate, which impacts the COP value of the WAC. In addition, this process demonstrates how the integration of vortex generators can improve desalination efficiency.

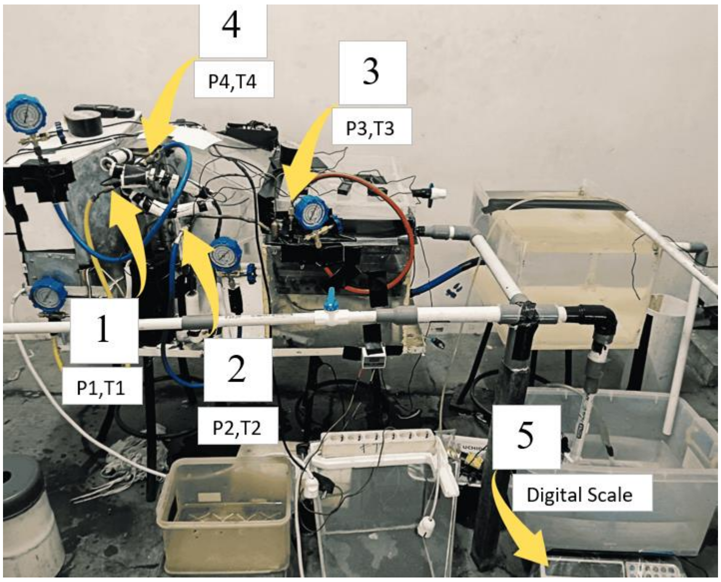


Fig. 5. WAC as a desalination devices

Fig. 6 shows the pressure-enthalpy (P-h) diagram for R410A refrigerant at various variables, namely CC, WV, CV, and SV. The enthalpy values are obtained from the calculation results using Refprop™ software, with input data in the form of pressure and temperature at each point: P_1, T_1, P_2, T_2, P_3, T_3, P_4, and T_4. The average evaporator exit air temperature for each variable is 17.8°C, 18.6°C, 18.7°C, and 18.9°C, respectively. Meanwhile, the condenser exit air temperatures were 55.7°C, 56.3°C, 56.9°C, and 57.1°C, respectively. Based on the enthalpy values obtained, the performance of the WAC system can be calculated, including the RE, CW, and COP values.

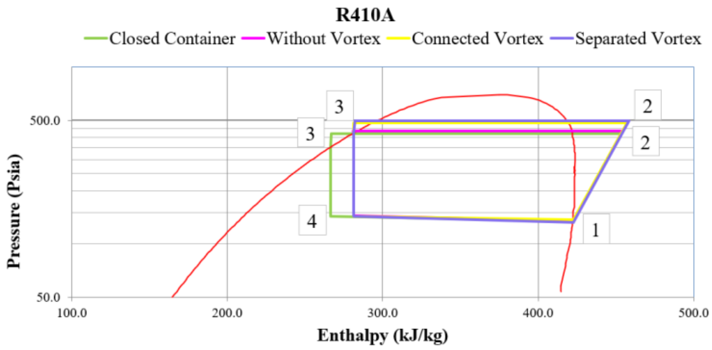


Fig. 6. P-h diagram for R410A with a closed container, without vortex, connected vortex, and separated vortex

In a refrigeration system, efficiency is crucial to consider. One concept that plays a role in measuring the efficiency of a refrigeration system is the RE, which is the amount of heat absorbed by the refrigerant in the evaporator for each unit mass of cooling, which occurs in the process from 4 to 1 [29], [30]. By calculating using Eq. 1, the RE of R410A for various CC, WV, CV, and SV variables in the desalination process is shown in Fig. 7. The results show a decrease in RE; a lower refrigeration effect can lower COP [31]. The latent heat of vaporization in the Air Conditioning (AC) system comes from the evaporation of refrigerant [32]. The closed container of R410A has the highest RE value. The high RE value is due to the latent heat of vaporization [33] and high enthalpy compared to the other variable, R410A. As a result, the desalination process using closed-container R410A yields better cooling capacity than the other variable, R410A.

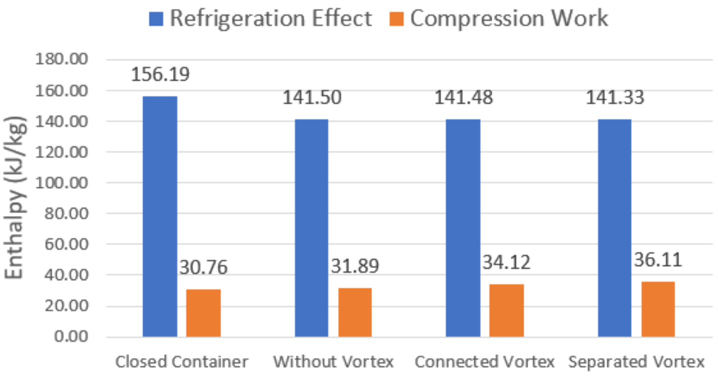


Fig. 7. Refrigeration effect and compression work with closed container, without vortex, connected vortex, and separated vortex.

Meanwhile, the CW of R410A for various variables, the CW value in the figure is calculated using Eq.2. Unlike RE, CW has a constant increase. This is due to the increase in compressor pressure, the refrigerant temperature [34], and enthalpy. An increase in refrigerant pressure can increase compressor work, thus decreasing the COP value [35]. CW of the closed container R410A is lower than that of the other variable R410A. This indicates that the R410A refrigerant in the sealed container has a lower temperature, so the compressor workload is lighter [36].

The COP is calculated using Eq. 3, and Fig. 8 shows that the COP value decreases as the evaporation increases. The use of a vortex increases the evaporation rate and efficiency in the desalination unit, resulting in faster evaporation [37], [38]. CV and SV have different geometry so it can affect the characteristics of airflow. CV has fewer and connected, while SV with more separated numbers produces better evaporation and increased effectiveness [39].

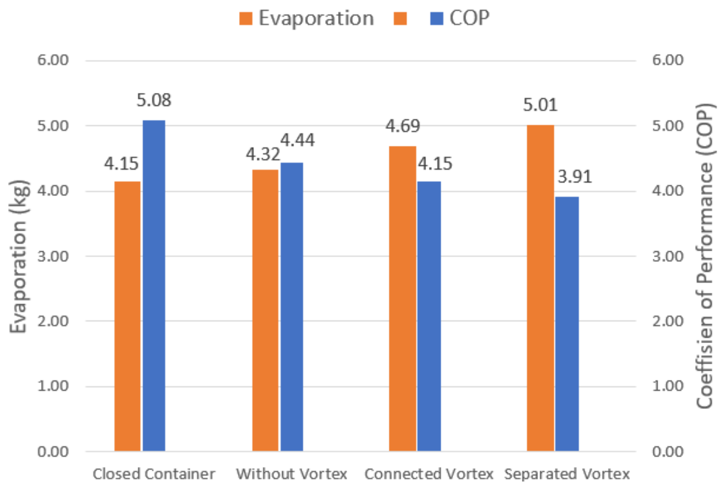


Fig. 8. Evaporation and COP with closed container, without vortex, connected vortex, and separated vortex.

On the other hand, an increase in refrigerant in the refrigeration machine can lead to an increase in temperature in the condenser, which requires greater compression effort [40]. The condenser located inside the main container helps to heat the water and increase evaporation as the temperature rises. The increased evaporation temperature from the condenser is then transferred to the evaporator through a steam funnel designed to direct the incoming air to the evaporator. The CC is secured with plates to prevent evaporation in the condenser from affecting the temperature of the air entering the evaporator. This causes a high refrigeration effect and reduces compression work, resulting in an optimal COP.

4 Conclusion

This study demonstrates that incorporating a vortex generator into a modified WAC significantly impacts seawater evaporation rates in desalination. The SV configuration produced the highest evaporation rate (5.01 kg) but reduced system efficiency by increasing compressor workload, leading to a lower COP (3.91). Conversely, the CC condition achieved the highest COP (5.08) by minimizing heat loss and stabilizing air temperature entering the evaporator. These findings highlight the trade-off between evaporation enhancement and system efficiency.

Future research should explore alternative vortex configurations, large scale testing, and environmental variations to optimize WAC-based desalination systems.

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Enhancing Seawater desalination performance using a vortex generator in a modified window air conditioner

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Abstract

The growing demand for air conditioning systems has driven research into alternative applications, such as seawater desalination. This study evaluates the performance of a modified Window Air Conditioner (WAC) integrated with a vortex generator for desalination. Experiments were conducted using R410A refrigerant under four conditions: Closed Container (CC), Without Vortex (WV), Connected Vortex (CV), and Separated Vortex (SV). Seawater was heated via the condenser to 55-60°C, controlled by a thermostat, and data was collected every five minutes over eight hours. The thermodynamic properties of R410A were analysed using Refprop™ software to determine the Refrigeration Effect (RE), Compression Work (CW), and Coefficient of Performance (COP). Results indicate that the SV configuration achieved the highest evaporation rate (5.01 kg) but led to a lower COP (3.91) due to increased condenser temperature and compressor workload. Conversely, CC yielded the highest COP (5.08) by stabilizing the evaporator air temperature and reducing compressor effort. These findings suggest that vortex generators enhance evaporation rates but reduce system efficiency. Further research is needed to optimize vortex generator configurations to improve desalination efficiency while minimizing COP reduction.

Keywords:
Window air conditioner, vortex generator, desalination, Refprop™, COP

1 Introduction

Along with the improvement of the quality of life and the need for comfort, the use of air conditioning systems is increasing in daily life [1], [2]. Air conditioning systems also help remove moisture and airborne particles from the room [3]. Therefore, the use of air conditioners is no longer just part of a lifestyle but rather aims to provide comfort when moving or doing activities indoors [4]. One of the most common types is the Window Air Conditioner (WAC), which uses a vapor compression cycle to take heat from the air inside and expel it outside through condensation [5]. This condensation water is usually disposed of as waste but can be used to make clean water under certain conditions [6]. The high demand for clean water around the world, as well as environmental issues such as drought and limited availability of clean water resources, are major challenges that need to be addressed [7], [8], [9]. The use of a modified WAC as a desalination device is an option to consider. This modification allows the WAC to function as both an air conditioning unit and a system to separate salt from saltwater. Evaluating the performance of the WAC as a desalination device is essential to ensure the effectiveness of this system in removing salt from seawater.

Desalination systems, such as reverse osmosis (RO), are currently available [10]. However, such technologies consume much energy [11], especially on a large scale, making it inefficient for households or places with limited energy resources. On the other hand, WAC is a device that is widely used in many homes [12] and operates according to the principles that allow it to be used in desalination processes. The main problem is how to modify the WAC without compromising its cooling efficiency and ensuring optimal system performance during its switch to desalination function.

Research on the use of air conditioning for desalination processes is still in its infancy. Some of the research that has been conducted includes the integration of a split air conditioning system with a Humidification-Dehumidification (HDH) desalination unit utilizing solar energy, the utilization of solar heating to improve the performance of a hybrid desiccant air conditioning system coupled with an HDH desalination unit, numerical analysis of a hybrid air conditioning system supported by solar energy and integrated with an HDH desalination system, and modified window air conditioner to produce potable water through humidification-dehumidification desalination process [13], [14], [15], [16]. These experiments show that combining an air conditioning system with a desalination unit can produce clean water. Nevertheless, these studies have not investigated the impact of vortex generators on desalination effectiveness, particularly in enhancing the evaporation rate. Multiple studies have investigated the application of vortex generators in desalination to enhance the evaporation rate [17], [18], given that vortex generators influence the convection heat transfer coefficient [19]. Previous research has not examined the performance of WAC modified with a vortex generator as a desalination tool against seawater evaporation. Desalination itself is the process of separating salt and minerals from seawater to produce freshwater [20]. Cooling system performance can be determined by assessing the Refrigeration Effect (RE), Compression Work (CW), and Coefficient of Performance (COP) [21].

Therefore, this study aims to determine the performance of the modified WAC as a desalination device against seawater evaporation. This research has analysed the impact of various tested variables on the evaporation of seawater at a given temperature. The desalination mechanism focuses on the evaporation process, where seawater is evaporated using the modified WAC. The performance assessment of this system uses the parameters RE, CW, and COP, which are the main indicators in assessing the ability of the device as a desalination system. It is hoped that this research can provide a deep insight into the potential of WAC modification to produce a more effective and efficient desalination system.

2 Method

This study used a WAC to compare its performance as a desalination device. The experimental setup used in this study is presented in Fig. 1. The working fluid of the air conditioning system is R410A refrigerant [22] with the specifications shown in Table 1. This research was conducted at the Mechanical Engineering Laboratory, Faculty of Industrial Technology and Informatics, Universitas Muhammadiyah Prof. Dr. Hamka. In addition, the measurement tools used are listed in Table 2. Tests on the utilization of WAC as a desalination tool were carried out with variables of Closed Container (CC), Without Vortex (WV), Connected Vortex (CV), and Separate Vortex (SV) (Fig. 2).

Refprop™ software version 10.0.0.9b is used to determine the properties of the refrigerant at enthalpy at each point based on the cooling system performance data by analyzing the saturation pressure, temperature, enthalpy, entropy, and density of the refrigerant [24], [25]. System performance is analyzed using pressure and temperature obtained through calculations on R410A refrigerant using Refprop™ software [26]. The effectiveness of an air conditioner is evaluated by determining the refrigeration effect, which is the difference in refrigerant enthalpy between the evaporator's inlet and outlet, and the compression work, which is the enthalpy difference between the compressor's outlet and inlet. The values of RE, CW, and Coefficient of COP are determined based on the obtained enthalpy results [27].

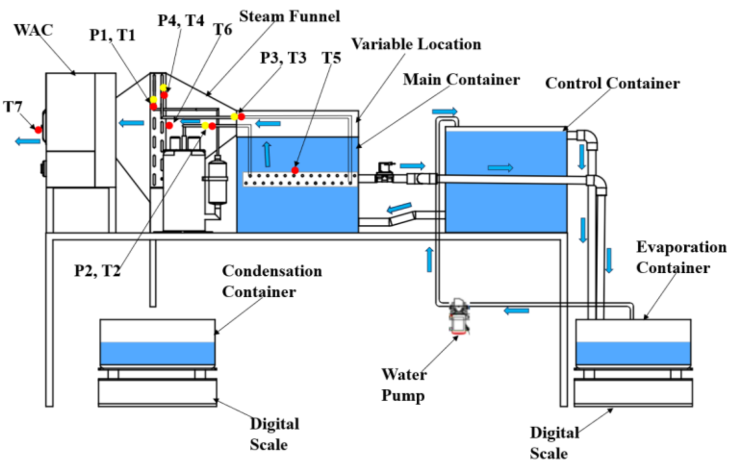


Fig. 1. Experimental setup

Table 1. Refrigeration unit specifications

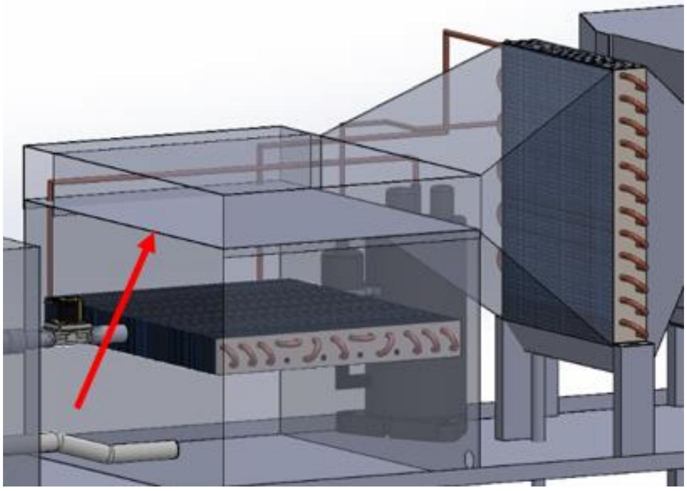
Dimension	Specification
Model WAC	Uchida MP – W9M
Voltage	1 Fase 220V – 50 Hz
PK Power	1 PK
Cooling Capacity	8600 BTU/h
Electrical power	840 W
Current	4.0 A
EER	10.01 BTU/hW
Refrigerant R410A	360 g
Size	500×345×465 mm

Table 2. Measurement tools

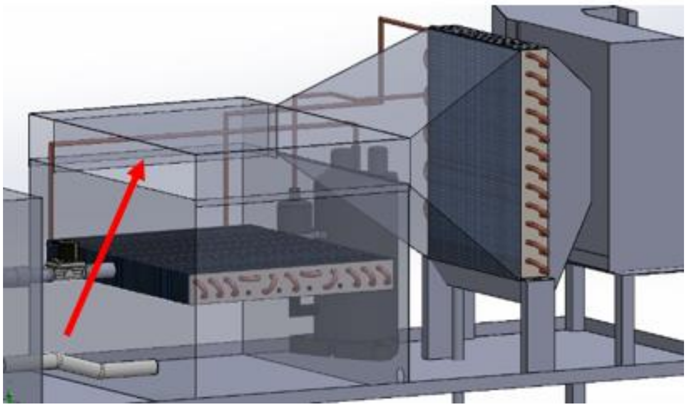
Tools	Function	Specification
Thermostat XH-W3001	Water temperature	-50°C -110°C, ±0.1°C.
Digital thermometer	Temperature	-50°C -110°C, ±0.1°C.
Manifold Gauge	Pressure	0 – 500 psi, 5 psi
Digital scale 30 kg	Water Mass	0 – 30 kg, 0.005 kg

In this experiment, the seawater in the evaporation container is transferred to the control container via a pump. This step aims to deliver the water to the main container, where it will be heated using a condenser until the temperature reaches about 55-60°C, which is regulated by a thermostat. As the water evaporates, the resulting vapor is directed upwards through the steam funnel before finally entering the evaporator.

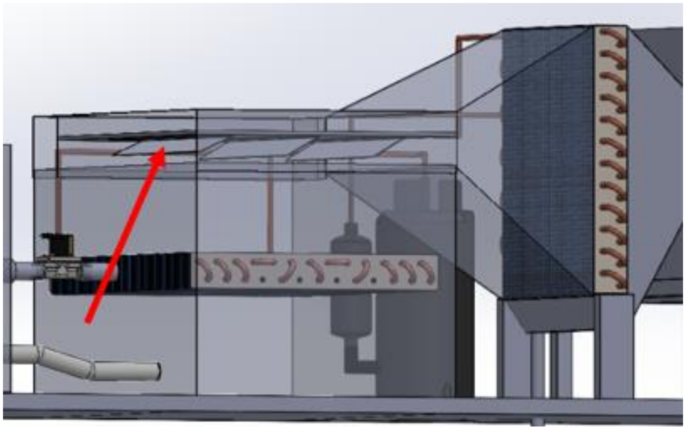
The main container has an overflow mechanism that delivers water to the evaporation container to maintain the temperature in the range of 55-60°C. In addition, the control container is also equipped with an overflow system for the evaporation container to ensure the water level remains stable. This system allows the control container's water level to remain constant while the evaporation container's water level drops due to the evaporation process [23]. The evaporation rate was determined by the mass of water in the evaporation container, which was measured with a digital scale to confirm the amount of water lost owing to evaporation. In Fig. 1 data was collected at P_1, T_1, P_2, T_2, P_3, T_3, P_4, T_4, T_5, T_6, T_7. Where P_1, T_1 is the compressor inlet pressure, temperature, P_2, T_2 is the compressor outlet pressure, temperature, P_3, T_3 is the expansion inlet pressure, temperature, P_4, T_4 is the expansion outlet pressure, temperature, T_5 is the condenser temperature, T6 is the evaporator temperature, T_7 is the evaporator outlet air temperature, and the variable location is used for a closed container by placing a plate on top of the container, a container without vortex, vortex connected, and vortex separated. Figs 3-4 shows the vortex used in this study.



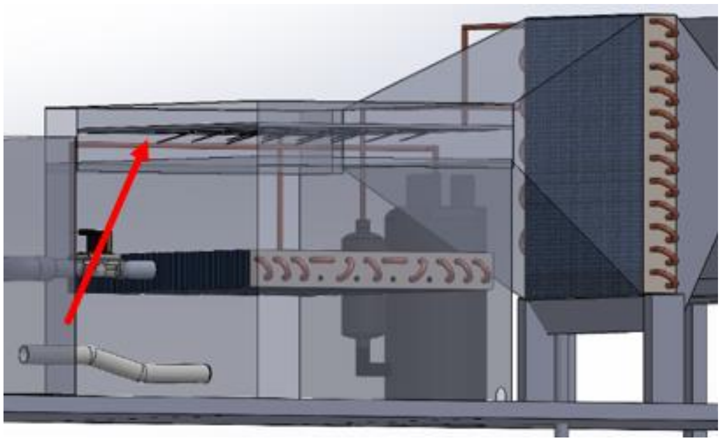
(a) Closed container (CC) location



(b) Without vortex (WV) location



(c) Connected vortex (CV) location



(d) Separated vortex (SV) location

Fig. 2. Variable location

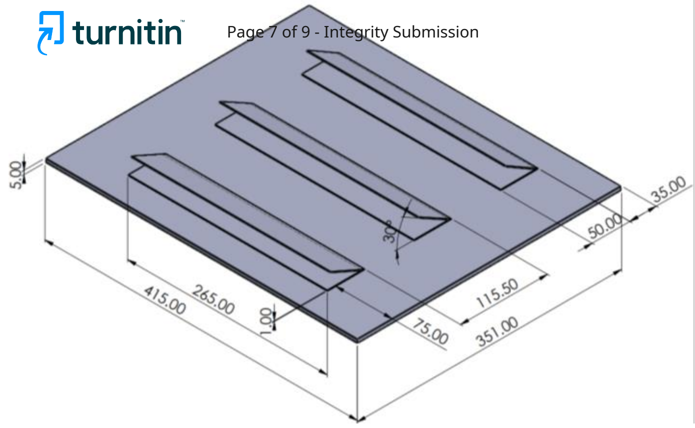


Fig. 3. Connected vortex (CV)

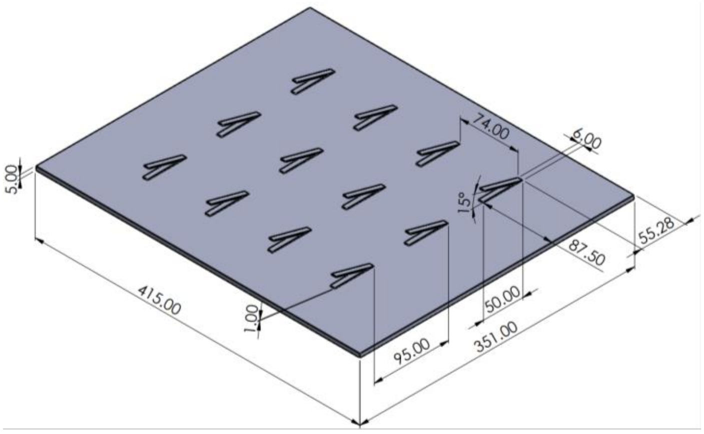


Fig. 4. Separated vortex (SV)

Refprop™ software version 10.0.0.9b is used to determine the properties of the refrigerant at enthalpy at each point based on the cooling system performance data by analyzing the saturation pressure, temperature, enthalpy, entropy, and density of the refrigerant [24], [25]. System performance is analysed using pressure and temperature obtained through calculations on R410A refrigerant using Refprop™ software [26]. The effectiveness of an air conditioner is evaluated by determining the refrigeration effect, which is the difference in refrigerant enthalpy between the evaporator's inlet and outlet, and the compression work, which is the enthalpy difference between the compressor's outlet and inlet. The values of RE, CW, and COP are determined based on the obtained enthalpy results [27]. The RE, CW, COP are determined using Eqs(1-3) [28].Where: h_1 is enthalpy at the compressor inlet, h_2 is Enthalpy at the compressor outlet, and h_4 is enthalpy at the Evaporator inlet.

$$RE = h_1 - h_4 \quad (1)$$

$$CW = h_2 - h_1 \quad (2)$$

$$COP = \frac{RE}{CW} = \frac{h1 - h4}{h2 - h1} \quad (3)$$

3 Results and Discussion

This study examines the performance of WAC for utilization as a desalination tool with four variables: CC, WV, CV, and SV. Fig. 5 shows the data collection process. At points 1 to 4, data of P_1, T_1, P_2, T_2, P_3, T_3, P_4, and T_4 are collected sequentially. The digital scale at point 5 is used to measure the mass of water in the evaporation container to determine the decrease in mass due to evaporation. The seawater in the main container was heated by a condenser controlled by a thermostat to maintain a temperature between 55-60°C. Data was collected every 5 minutes for 8 hours. The system performance is greatly affected by the evaporation rate, which impacts the COP value of the WAC. In addition, this process demonstrates how the integration of vortex generators can improve desalination efficiency.

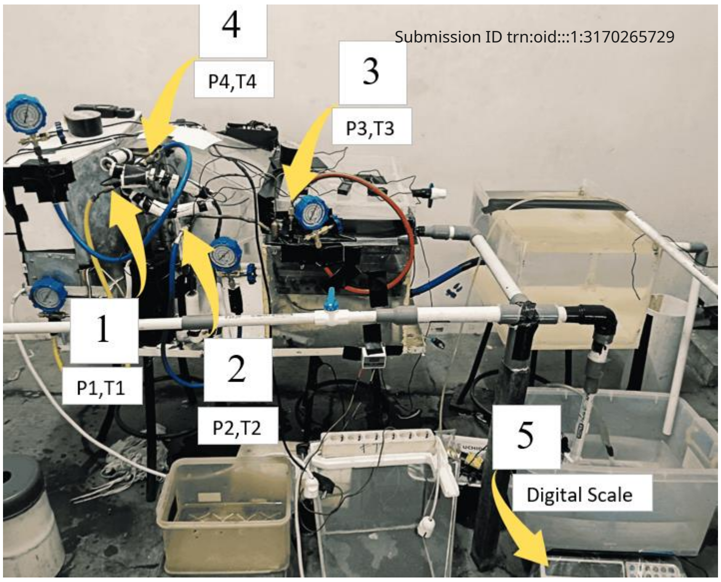


Fig. 5. WAC as a desalination devices

Fig. 6 shows the pressure-enthalpy (P-h) diagram for R410A refrigerant at various variables, namely CC, WV, CV, and SV. The enthalpy values are obtained from the calculation results using Refprop™ software, with input data in the form of pressure and temperature at each point: P_1, T_1, P_2, T_2, P_3, T_3, P_4, and T_4. The average evaporator exit air temperature for each variable is 17.8°C, 18.6°C, 18.7°C, and 18.9°C, respectively. Meanwhile, the condenser exit air temperatures were 55.7°C, 56.3°C, 56.9°C, and 57.1°C, respectively. Based on the enthalpy values obtained, the performance of the WAC system can be calculated, including the RE, CW, and COP values.

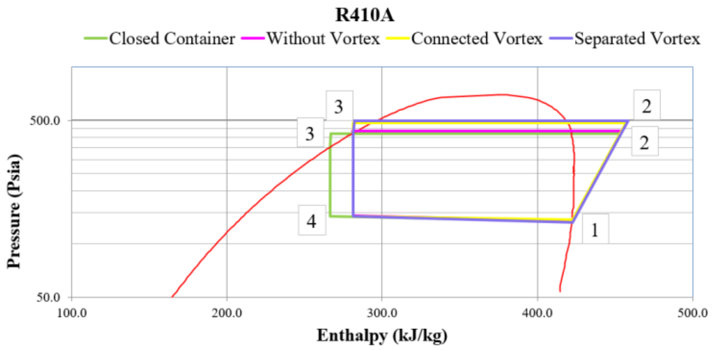


Fig. 6. P-h diagram for R410A with a closed container, without vortex, connected vortex, and separated vortex

In a refrigeration system, efficiency is crucial to consider. One concept that plays a role in measuring the efficiency of a refrigeration system is the RE, which is the amount of heat absorbed by the refrigerant in the evaporator for each unit mass of cooling, which occurs in the process from 4 to 1 [29], [30]. By calculating using Eq. 1, the RE of R410A for various CC, WV, CV, and SV variables in the desalination process is shown in Fig. 7. The results show a decrease in RE; a lower refrigeration effect can lower COP [31]. The latent heat of vaporization in the Air Conditioning (AC) system comes from the evaporation of refrigerant [32]. The closed container of R410A has the highest RE value. The high RE value is due to the latent heat of vaporization [33] and high enthalpy compared to the other variable, R410A. As a result, the desalination process using closed-container R410A yields better cooling capacity than the other variable, R410A.

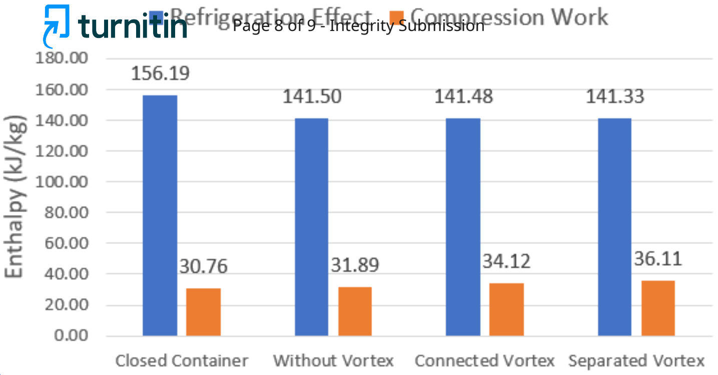


Fig. 7. Refrigeration effect and compression work with closed container, without vortex, connected vortex, and separated vortex.

Meanwhile, the CW of R410A for various variables, the CW value in the figure is calculated using Eq.2. Unlike RE, CW has a constant increase. This is due to the increase in compressor pressure, the refrigerant temperature [34], and enthalpy. An increase in refrigerant pressure can increase compressor work, thus decreasing the COP value [35]. CW of the closed container R410A is lower than that of the other variable R410A. This indicates that the R410A refrigerant in the sealed container has a lower temperature, so the compressor workload is lighter [36].

The COP is calculated using Eq. 3, and Fig. 8 shows that the COP value decreases as the evaporation increases. The use of a vortex increases the evaporation rate and efficiency in the desalination unit, resulting in faster evaporation [37], [38]. CV and SV have different geometry so it can affect the characteristics of airflow. CV has fewer and connected, while SV with more separated numbers produces better evaporation and increased effectiveness [39].

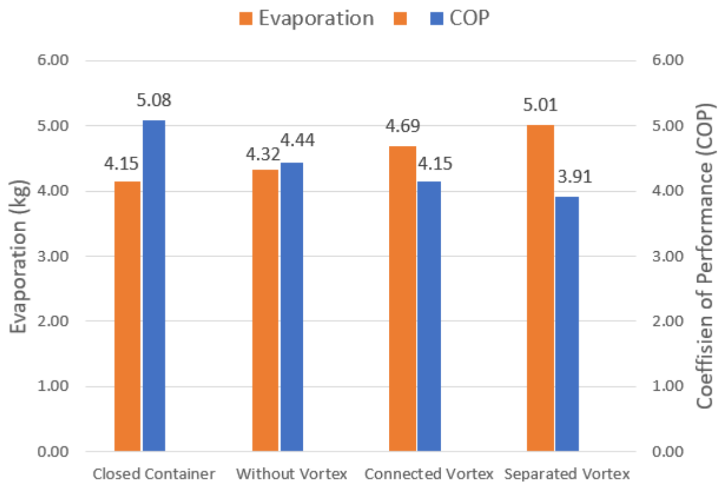


Fig. 8. Evaporation and COP with closed container, without vortex, connected vortex, and separated vortex.

On the other hand, an increase in refrigerant in the refrigeration machine can lead to an increase in temperature in the condenser, which requires greater compression effort [40]. The condenser located inside the main container helps to heat the water and increase evaporation as the temperature rises. The increased evaporation temperature from the condenser is then transferred to the evaporator through a steam funnel designed to direct the incoming air to the evaporator. The CC is secured with plates to prevent evaporation in the condenser from affecting the temperature of the air entering the evaporator. This causes a high refrigeration effect and reduces compression work, resulting in an optimal COP.

4 Conclusion

This study demonstrates that incorporating a vortex generator into a modified WAC significantly impacts seawater evaporation rates in desalination. The SV configuration produced the highest evaporation rate (5.01 kg) but reduced system efficiency by increasing compressor workload, leading to a lower COP (3.91). Conversely, the CC condition achieved the highest COP (5.08) by minimizing heat loss and stabilizing air temperature entering the evaporator. These findings highlight the trade-off between evaporation enhancement and system efficiency.

Future research should explore alternative vortex configurations, large scale testing, and environmental variations to optimize WAC-based desalination systems.

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