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Study of Methanol and Ethanol Absorption on Vacuum Temperature of Adsorption Cooling Machine Adsorption Cycle

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ABSTRACT

Cooling machines are currently being used more and more in accordance with technological advances and increasing living standards. Common uses are for preserving food, air conditioning, cooling beverages, for making ice cubes, and others. The need for cooling systems in remote areas for various needs such as preservation or storage of food ingredients is felt to be increasing, while the existing conventional cooling systems cannot necessarily be used because not all remote areas have electricity networks, so a simple adsorption cooling system is an alternative for solving problems. A cooling system needs in remote areas like this. The purpose of this study was to obtain the optimum vacuum temperature in an adsorption cooler using activated carbon as adsorbent and methanol and ethanol as adsorbate. This study used the experimental method by analyzing the testing and data processing of methanol and ethanol. The results of this study indicate that the vacuum absorber temperature of the refrigerant (methanol) gets the maximum temperature: 123.53°C on a thermostat with a temperature of 200°C, it can absorb methanol as much as 6.35 ml/kg and produce a water temperature of 9.12°C. Meanwhile, the absorber vacuum temperature for refrigerant (ethanol) has a maximum temperature of: 123.26°C, on a thermostat with a temperature of 200°C, it can absorb ethanol as much as 6.35 ml/kg and produce a water temperature of 11,79°C.

Keywords: *Adsorption cycle, ethanol, methanol, refrigeration machine, vacuum temperature*

I. Introduction

The cooling process is an attempt to lower the temperature in the room or on the material. In other words, to get the desired conditions for the product or material, in this case, a low temperature so that the product or material can be stored for a relatively long time, both for consumption, production as well as trade [1]. Food storage and transportation, food and beverage processing, and ice making are some activities requiring cooling and freezing processes. The cooling process takes heat from a room or object to reduce its temperature by transferring the heat contained in the room or object. So the cooling process is a series of heat transfer processes [2-3]. The heat transfer process can occur by convection, conduction or radiation.

The development of the refrigeration system is very rapid, along with advances in technology. The type of collector used is a flat plate. The area of the adsorber is 0.25 m^2 with a plate thickness of 1 mm. This adsorber is filled with 8 kg of activated carbon. The collector angle limit used is 0°. The adsorber uses this heat to generate the system by absorbing the methanol/ethanol that evaporates from the evaporator. The water temperature will decrease along with the decrease in the methanol/ethanol temperature in the evaporator. During the day, the desorption process occurs, namely the adsorber receives heat from the lamp, and the

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methanol/ethanol will flow into the condenser and melt in the evaporator. At night the adsorber is cooled by the outside environment so that an adsorption process occurs. The methanol/ethanol will evaporate from the evaporator to the condenser and will be absorbed adsorber [4].

Refrigeration machines are now increasingly being used in accordance with technological advances and increasing living standards. A common use is to preserve food [5]. At ordinary temperatures (room temperature), food spoils quickly (because at normal temperatures, bacteria will grow quickly). Meanwhile, at a temperature of 4.4^{o}C or 40^{o}F (the usual temperature for cooling food), bacteria grow very slowly, so the food will last longer. So here, food can be preserved by cooling it [6-7].

Other uses of refrigeration machines are air conditioners, beverage coolers, to make ice cubes, and others. For preservation in larger quantities, for example, found in slaughterhouses, for storing shrimp, and others. Also in vehicles transporting meat/vegetables/fish to faraway places are equipped with refrigeration machines, so they don't rot until they reach their destination [8]. For a cooling process to occur, a refrigerant is needed that is easily changed from gas to liquid or from liquid to gas to take heat from the evaporator and throw it into the condenser. The need for cooling systems in remote areas for various needs such as preservation or storage of food ingredients is felt to be increasing, while the existing conventional cooling systems cannot necessarily be used because not all remote areas have electricity networks, so a simple adsorption cooling system is an alternative for solving problems. The cooling system needs in remote areas like this [9].

In recent years, research on methanol as a refrigerant and activated carbon as an adsorbent has been carried out to make a simple adsorption cooler that is inexpensive but can produce a refrigerant without pollution. Sitorus et al. showed that the experimental results showed that the adsorption pair system could produce an evaporator temperature of around 9.92°C, and the cooling load could be achieved by a heat source with a temperature range of 83.95°C and 95.39^{o}C [10]. The level of technology readiness in this research has been developed and allows it to be applied theoretically and empirically, so the characterization of the technology components to be developed can be determined properly. The performance of the elements developed will be useful for maximizing the use of solar energy, which is a renewable natural resource.

II. Material and Methods

The tools used in this study are as follows: 1) Vacuum pump to vacuum and remove particles/dirt and remove water from the generator, condenser and evaporator. 2) Thermocouple is a cable connected to the device whose temperature is to be measured and connected directly to agilent. The thermocouple used in this study is a type J thermocouple, which is a cable that is resistant to heat; 3) Agilent; 4) Station data log Hobo Micro Station. HOBO Micro Station is a data recording device from 3 multi-channel microclimates recording sensors (solar radiation intensity, speed, wind, and relative humidity); 5) Manometer function to determine the pressure that occurs during the desorption and adsorption processes; 6) The lamp serves to heat the adsorber.

Table 1. Physical properties of refrigerant [11]

Refrigerant	Chemical formula	Normal boiling point (°C)	Molecular weight (mol)	Latent heat of vaporization L(kJ/kgK)	Density ρ(kg/m^3)	ρ x L (ml/m^3)
Ammonia	NH_3	-34	17	1368	681	932
Water	H_2O	100	18	2258	958	2163
Methanol	CH_3OH	65	32	1102	791	872
Ethanol	C_2H_5OH	79	46	842	789	665

Table 2. Specification of methanol

Specification	Value
Purity	99.9 %
Molar mass	32.04 g/mol
Density	0.791- 0.793 g/cm^3
Boiling point	64-65 ºC
Melting point	-97.8ºC
Viscosity	0.59 MPa at 20ºC

The materials used are made of stainless steel. The lamp was designed which be coated with rockwall to reduce heat loss to the outside environment. The design of the lightbox was adjusted to the height of the lamp on the surface of the adsorber. In this case, the lamp only functions to heat the adsorber, and then the lamp was removed so that there was a decrease in the temperature of the adsorber. The adsorption cycle cooling machine to be designed is shown in Figure 1.

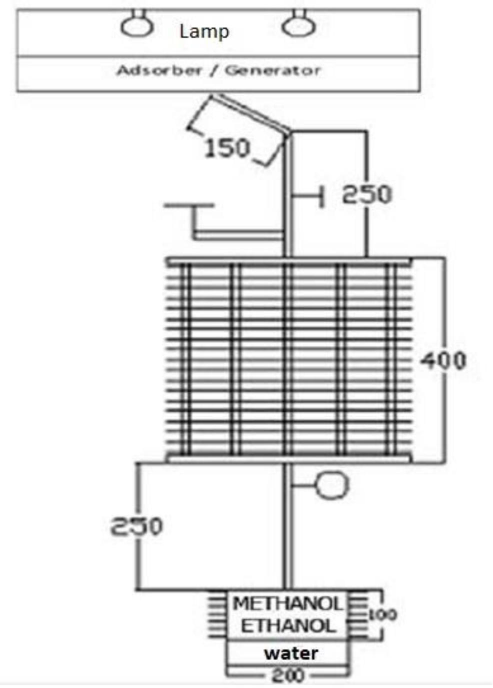

Fig. 1. The adsorption cycle cooling system model to be designed

After making the components of the adsorption cycle cooling machine, it looks like in Figure 2. This adsorption cycle refrigeration schematic clearly illustrates the processes that occur in the refrigeration machine. There are 2 main processes that occur, namely the desorption process and the adsorption process. The desorption process takes place during the day, and the adsorption process takes place at night. Both of these processes occur naturally as a result of heat transfer by natural convection. Furthermore, research on the adsorption cycle cooling machine was carried out.

A. Assembling

Assembling was carried out before testing because, previously, all components were still separate. The components of the refrigeration machine were connected/assembled between the collector, condenser and evaporator. In the connection pipe, the manometer valve and the bolts on the methanol/ethanol glass were glued properly to avoid leakage. Methanol/2 liters of ethanol is put into the evaporator. After that, the methanol inlet valve was tightly closed and glued firmly, so it didn't leak. As much as 2.5 liters of water was put in a water container, then it was well insulated to reduce heat loss. The water container is affixed under the methanol, then tightly wrapped with an insulating box.

B. Vacuum

Vacuuming was done to find out if the cooling machine was no longer leaking. Because the condition for the adsorption cycle to take place properly was at a vacuum pressure (-76 cmHg = -1 atm = -101.325 kPa). After the vacuum reaches the vacuum pressure (usually it never reaches -76 cmHg), the device is left for 2 × 24 hours. Next, see how much the pressure drops to find out whether the tool is leaking or not. If there was a leak (the pressure reaches 0 atm), then re-examine to find out where the leak was. After that, gluing is done so that it doesn't leak. If it doesn't leak anymore, then proceed to the next stage.

C. Adsorber Vacuum Process

After all components were connected perfectly, and there were no leaks. Preheating was carried out using an electric lamp of 300 W and 500 W. During heating, the adsorber valve was opened, and the evaporator valve was closed. Starting at 9.00 am. until 5.00 pm. Heating the adsorber for ± 8 hours was conducted until the temperature of the bottom of the collector reached 120^{o}C. The temperature of the thermostat was kept constant at 200^{o}C. After the bottom temperature of the collector was constant at 120^{o}C, the adsorber was vacuumed for 30 minutes (the lamp remains on) which functions to remove the gas and water vapor contained in the activated carbon. Before the vacuum ended, the evaporator valve was opened slowly. The methanol/ethanol appeared to be boiling, and the vacuum could be stopped. After vacuuming, the adsorber valve was closed, and the process was allowed to proceed naturally.

D. Adsorption Cycle

The adsorption process (at night), allowed the temperature of the adsorbent to decrease along with the decrease in the ambient temperature. At night when the adsorber temperature decreases, the activated carbon will absorb methanol/ethanol so that the refrigerant will evaporate in the evaporator and rise to activated carbon. With the evaporation of this refrigerant, the temperature of the evaporator will decrease which causes the temperature of the surrounding water to decrease. Pressure measurements were carried out at the beginning of the adsorption cycle.

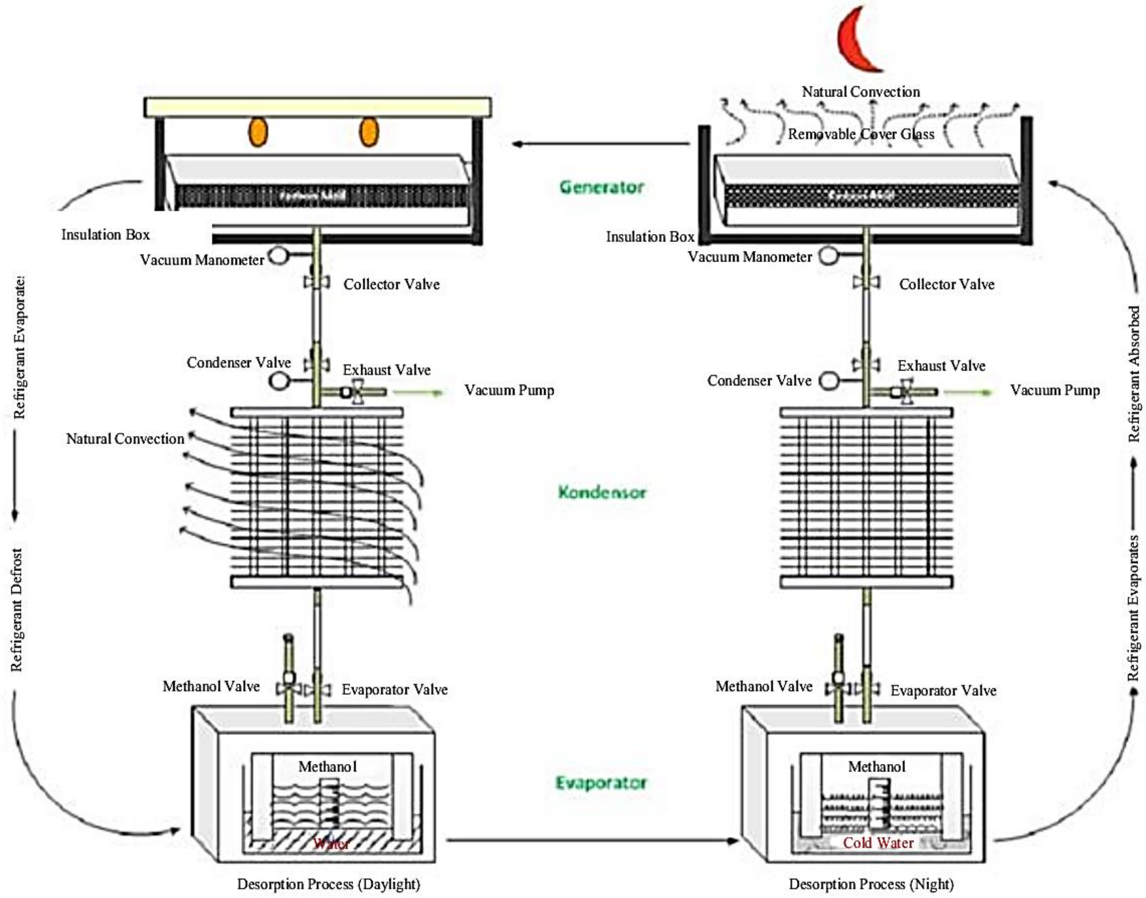

Fig. 2. Schematic of adsorption cycle refrigeration machine

E. Desorption Cycle

In the desorption process (during the day), a heater with electric lamp radiation was installed and isolated perfectly so that there is no air flowing in the adsorption. The isolation box is ensured to be well insulated from all sides. Then vacuum the adsorbent starting from a vacuum temperature of 100°C to 200°C. With the increase in the temperature of the adsorber, it was expected that a desorption process would occur. The refrigerant (methanol/ethanol) would evaporate and flow to the condenser and condenser. The methanol/ethanol vapor melts and returns to the evaporator. The adsorber pressure was recorded at the beginning of the desorption cycle.

F. Heat transfer

1) Conduction

The equation for the conduction heat transfer rate is generally expressed in the form of the differential equation (1)-(4) [12-14]:

$$q = -k\frac{dt}{dx} \qquad (1)$$

$$Q_{cond,dinding} = kA\frac{T_1 - T_2}{L} \qquad (2)$$

Where,

q = energy flow rate (W)

A = cross-sectional area (m^2)
t = temperature difference (K)
L = length (m)
k = thermal conductivity (conductivity) (W/m.K)
$\frac{dt}{dx}$ = the rate of change of temperature T with distance in the direction of heat flow x

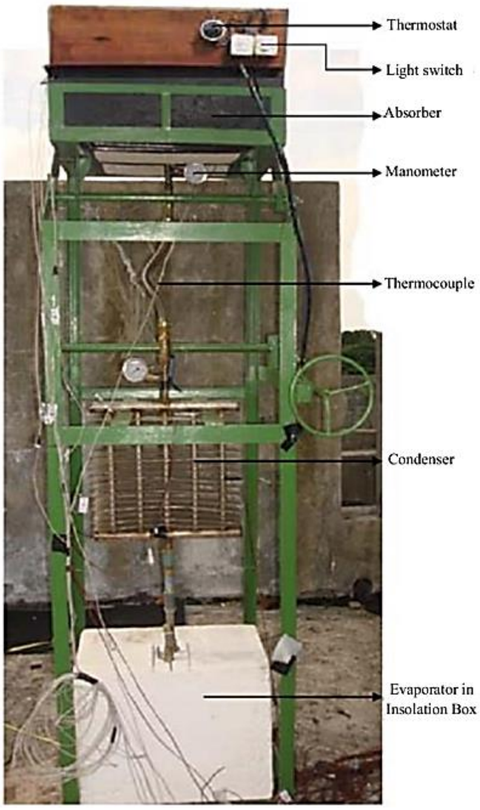

Fig. 3. Adsorption cycle cooling machine

2) Convection

$$Q_{conv} = h A_S (T_S - T_\infty) \quad (3)$$

Where,
h = convection coefficient (W/m^2K)
T_s = surface temperature (K)
T_∞ = fluid temperature (K)

3) Radiation

$$q = \sigma A T^4 \quad (4)$$

Where,
σ = Stephan–Boltzman coefficient ($5{,}67 \times 10^{-8} W/m^2K^4$)

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III. Results and Discussions

Analysis of testing and data processing of methanol. Vacuum adsorber with vacuum temperature of 100°C. In this section, which is to determine the absorption of the adsorber on methanol, the test on the desorption process is carried out in the morning until the afternoon which produces the maximum adsorber temperature on the first day, which is 80.27°C, then vacuum is carried out every hour for 15 minutes during the test and produces an adsorber pressure of -40 cmHg, condenser and evaporator pressure -36 cmHg. The test on the second day of vacuuming the adsorber with a vacuuming temperature of 120°C resulted in maximum adsorber temperature of 89.55°C, adsorber pressure -40 cmHg, condenser pressure and Evaporator -36 cmHg. The test on the third day of vacuuming the adsorber with vacuum temperature of 140°C resulted in a maximum adsorber temperature of 95.82°C, adsorber pressure -40 cmHg, condenser pressure and evaporator -36 cmHg.

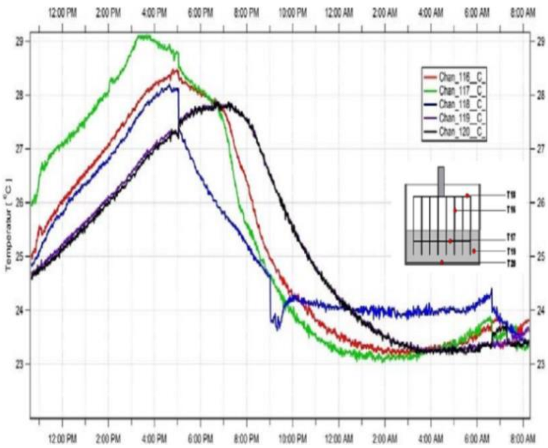

Fig. 4. Graph of evaporator temperature and time for 100°C vacuum temperature with refrigerant (methanol)

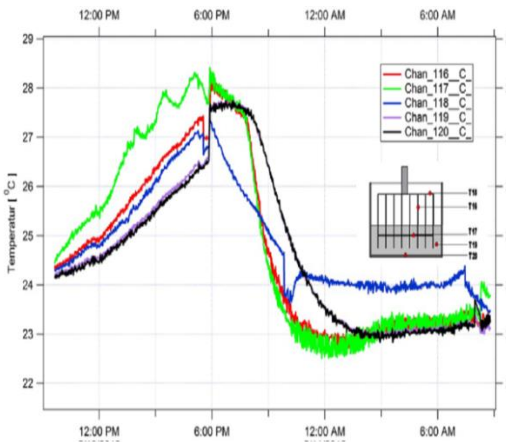

Fig. 5. Graph of evaporator temperature and time for 120°C vacuum temperature with refrigerant (methanol)

The test on the fourth day of vacuuming the adsorber with a vacuum temperature of 160°C resulted in maximum adsorber temperature of 103.82°C, adsorber pressure -40 cmHg, condenser pressure and evaporator -36 cmHg. The test on the fifth day of vacuuming the adsorber with vacuum temperature of 180°C resulted in maximum adsorber temperature of 119.64°C, adsorber pressure -40 cmHg, condenser pressure and evaporator -36 cmHg. The test on the sixth day of vacuuming the adsorber with vacuum temperature of 200°C resulted in maximum adsorber temperature of 123.53°C, adsorber pressure -40 cmHg, condenser and evaporator pressure -36 cmHg.

Tests during the adsorption process with a vacuum temperature of 160°C on the fourth day resulted in a minimum water temperature of 16.34°C and methanol absorbed as much as 2.5 ml/kg after the adsorber was heated, the methanol absorbed would return as much as 2.5 ml/kg (Figure 7). Testing during the adsorption process with a vacuum temperature of 180°C on the fifth day resulted in a minimum water temperature of 15.09°C and 3.75 ml/kg of methanol absorbed after the adsorber was heated, the methanol absorbed would return to 3.75 ml/kg (Figure 8). Tests during the adsorption process with a vacuum temperature of 200°C on the sixth day resulted in a minimum water temperature of 9.12°C and 6.35 ml/kg of methanol absorbed after the adsorber was heated, the methanol absorbed would return as much as 6.35 ml/kg (Figure 9).

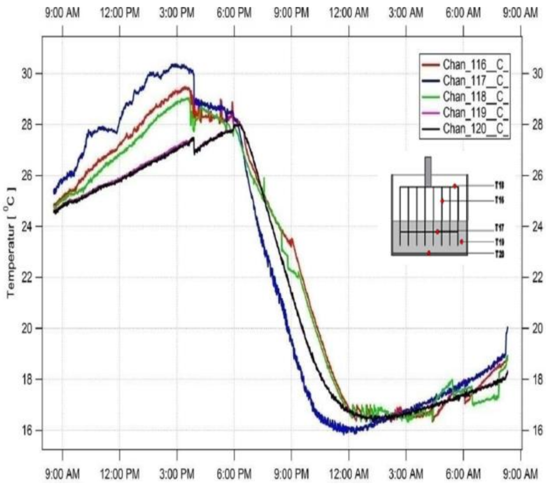

Fig. 6. Graph of evaporator temperature and time for 140°C vacuum temperature with refrigerant (methanol)

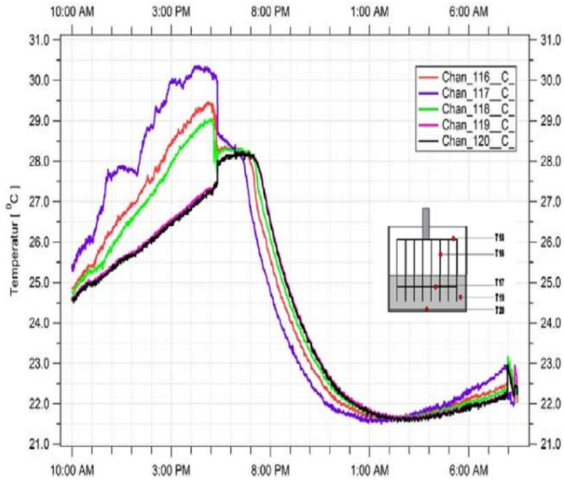

Fig. 7. Graph of evaporator temperature and time for 160°C vacuum temperature with refrigerant (methanol)

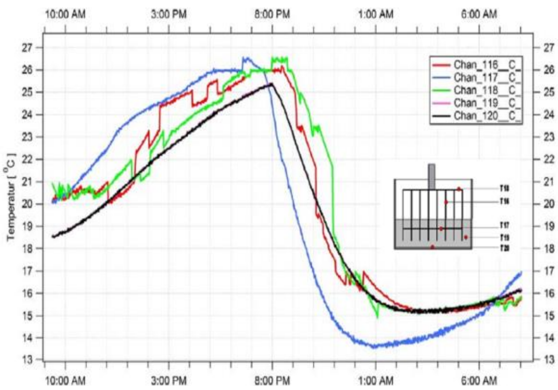

Fig. 8. Graph of evaporator temperature and time for 180°C vacuum temperature with refrigerant (methanol)

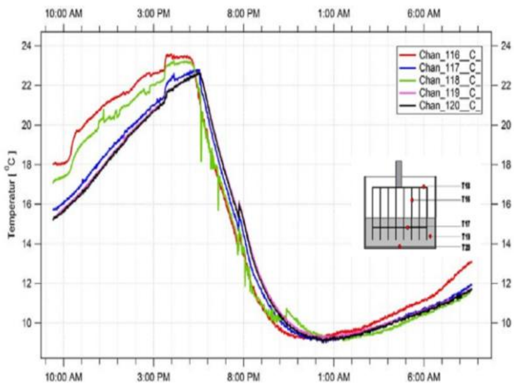

Fig. 9. Graph of evaporator temperature and time for 200°C vacuum temperature with refrigerant (methanol)

Analysis of tests and data processing on ethanol. Vacuum adsorber with vacuum temperature of 100°C. In this section, which is to determine the absorption of the adsorber on ethanol, the test on the desorption process is carried out in the morning until the afternoon which produces the maximum adsorber temperature on the first day, which is 79.98°C, then vacuum is carried out every hour for 15 minutes and produces an Adsorber pressure of -36 cmHg, condenser pressure and evaporator -34 cmHg. The test on the second day of vacuuming the adsorber with vacuuming temperature of 120°C resulted in maximum adsorber temperature of 87.98°C, adsorber pressure -36 cmHg, condenser pressure and evaporator -34 cmHg. The test on the third day of vacuuming the adsorber with vacuuming temperature of 140°C resulted in a maximum adsorber temperature of 93.99°C, adsorber pressure -36 cmHg, condenser pressure and evaporator -34 cmHg. The test on the fourth day of vacuuming the adsorber with vacuum temperature of 160°C resulted in maximum adsorber temperature of 103.75°C, adsorber pressure -36 cmHg, condenser pressure and Evaporator -34 cmHg. The test on the fifth day of vacuuming the adsorber with vacuum temperature of 180°C resulted in maximum adsorber temperature of 118.88°C, adsorber pressure -36 cmHg, condenser pressure and evaporator -34 cmHg.

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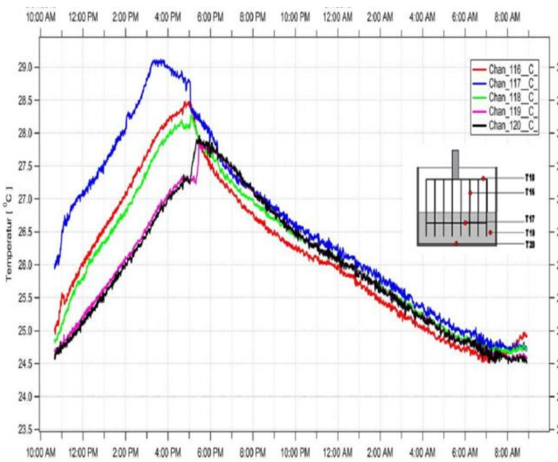

Fig. 10. Graph of evaporator temperature and time for 100°C vacuum temperature with refrigerant (ethanol)

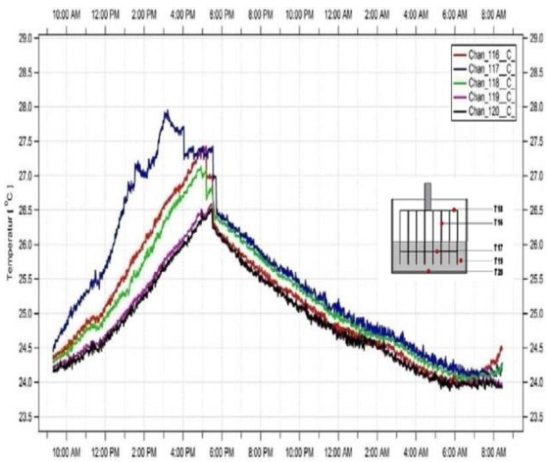

Fig. 11. Graph of evaporator temperature and time for 120°C vacuum temperature with refrigerant (ethanol)

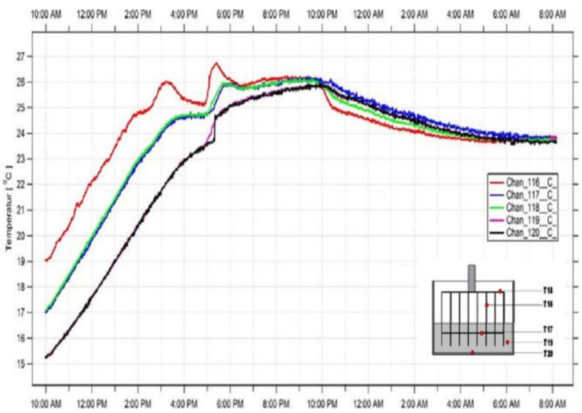

Fig. 12. Graph of evaporator temperature and time for 140°C vacuum temperature with refrigerant (ethanol)

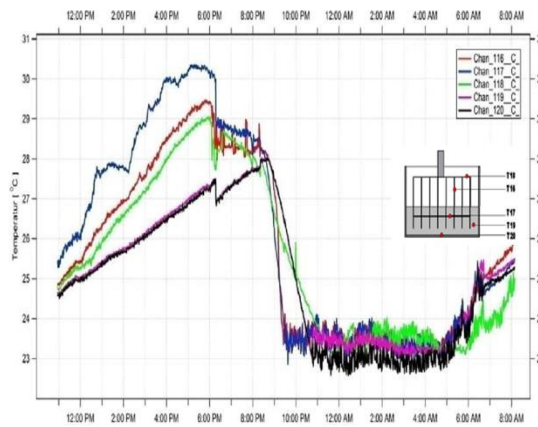

Fig. 13. Graph of evaporator temperature and time for 160°C vacuum temperature with refrigerant (ethanol)

The test on the sixth day of vacuuming the adsorber with vacuum temperature of 200°C resulted in maximum adsorber temperature of 123.26°C, adsorber pressure -36 cmHg, condenser pressure and evaporator -34 cmHg. Tests during the adsorption process with a vacuum temperature of 100°C were carried out at night and resulted in a minimum water temperature of 24.50°C ethanol absorbed as much as 1.25 ml/kg after the adsorber was heated, the absorbed ethanol would return as much as 1.25 ml/kg (Figure 10). Tests during the adsorption process with a vacuum temperature of 120°C on the second day resulted in a minimum water temperature of 23.88°C and ethanol absorbed as much as 2.5 ml/kg after the adsorber was heated, the ethanol absorbed would return as much as 2.5 ml/kg (Figure 11). Tests during the adsorption process with a vacuum temperature of 140°C on the third day resulted in a minimum water temperature of 23.56°C and 2.5 ml/kg of ethanol absorbed after the adsorber was heated, the ethanol absorbed would return as much as 2.5 ml/kg (Figure 12).

Testing during the adsorption process with a vacuum temperature of 160°C on the fourth day resulted in a minimum water temperature of 22.23°C and 2.5 ml/kg of ethanol absorbed after the adsorber was heated, the ethanol absorbed would return as much as 2.5 ml/kg

(Figure 13). Testing during the adsorption process with a vacuum temperature of 180°C on the fifth day resulted in a minimum water temperature of 16.37°C and 3.75 ml/kg of ethanol absorbed after the adsorber was heated, the ethanol absorbed would return 3.75 ml/kg (Figure 14). Testing during the adsorption process with a vacuum temperature of 200°C on the sixth day resulted in a minimum water temperature of 11.79°C and ethanol absorbed as much as 6.35 ml/kg after the adsorber was heated, the ethanol absorbed would return as much as 6.35 ml/kg (Figure 15).

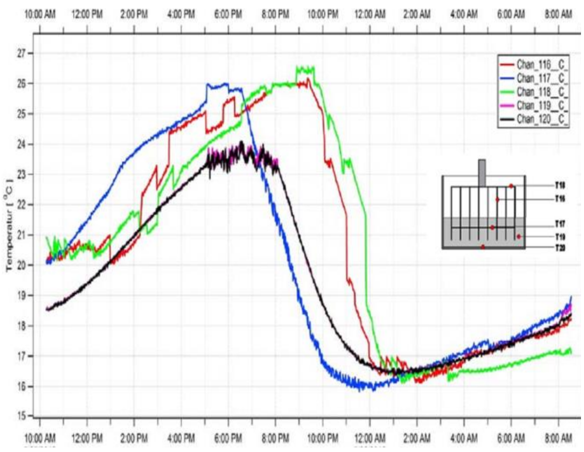

Fig. 14. Graph of evaporator temperature and time for 180°C vacuum temperature with refrigerant (ethanol)

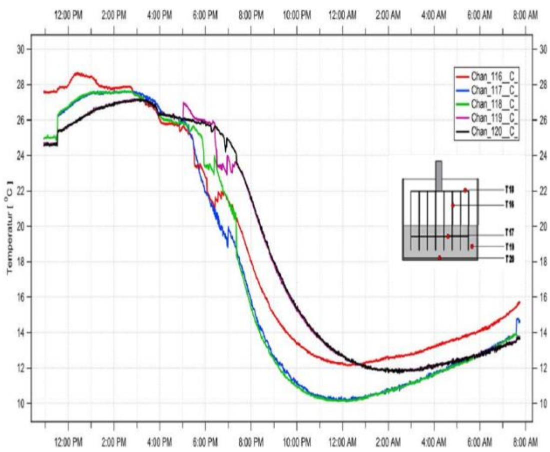

Fig. 15. Graph of evaporator temperature and time for 200°C vacuum temperature with refrigerant (ethanol)

Sitorus et al. [10] showed that the experimental results showed that the adsorption pair system could produce an evaporator temperature of around 9.92°C and the cooling load could be achieved by a heat source with a temperature range of 83.95°C and 95.39°C, while In this study, data analysis was carried out, it can be concluded that the temperature of the vacuum adsorber to the refrigerant (methanol) gets the maximum temperature: 123.43°C on a thermostat with a temperature of 200°C can absorb methanol as much as 6.25 ml/kg and produce a water temperature of 9.02°C , that this research is better than previous studies, it can be seen from the previous evaporator temperature of 9.92°C while this study obtained the evaporator temperature of 9.02°C.

IV. Conclusions

From the results of the study, more methanol was absorbed by the absorber to cool water than ethanol. Based on the research and data analysis carried out, it can be concluded that the temperature of the vacuum adsorber to the refrigerant (methanol) gets the maximum temperature: 123,43°C on a thermostat with a temperature of 200°C, it can absorb methanol as much as 6.25 ml/kg and produce a water temperature of 9.02°C. Meanwhile, the absorber vacuum temperature for refrigerant (ethanol) gets the maximum temperature: 123.16°C on a thermostat with a temperature of 200°C. It can absorb ethanol as much as 6.25 ml/kg and produce a water temperature of 11.69°C. To get the fluid to be absorbed more, it is better to use a thermostat above a temperature of 200°C. Vacuuming is carried out with the correct method so that the water vapor content in the activated carbon and the system as a whole can be removed so that the adsorption cycle cooling machine works well, and to get a better water temperature. The evaporator fins should be modified again because they drink 2.5 liters of cooled water.

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