MECOMARE, 10 (3) (2021) pp. 121-130

Published by: TRIGIN Publisher

International Journal of Mechanical Computational and Manufacturing Research

Journal homepage: www.trigin.pelnus.ac.id

Testing of Solar Powered Adsorption Refrigeration Machine with Collector Area 1m^2 Collector Angle 0^o

Efsartua Butarbutar

Department of Mechanical Engineering, University of North Sumatra, Indonesia

ARTICLEINFO

Article history:

Received September 07, 2021
Revised October 07, 2021
Accepted November 28, 2021

Keywords:

Activated Carbon
Adsorption
Collector/Adsorber
Methanol
Refrigerant Machine
Solar Energy

ABSTRACT

The sun is one of potential renewable energy resources. One of the utilization of solar energy as the main source of energy for the adsorption refrigeration cycle cooling machine to produce cooling effect. In this research, the type of collector used is flat plate collector. Collector insulation on refrigeration machine use plywood, EVA foam, styrofoam, rockwool, and glass. The surface area of collector is 1 m2 with thick of the plate is 1 mm. In this reasearch carbon active used is technical carbon active/granular filled in collectors as much as 18,5 kg,methanol used is pro-analysis with purity 99,9% as much as 5 liters, and water as cooling medium as much as 6 liters. Tilt angle of collector in this reasearch is 0^o. From this reasearch obtained lowest temperature of water is 9,98^{o}C. Highest total energy absorbed by collector as much as 3,186 MJ with ambient temperature about 28,6 ^{o}C.

Corresponding Author:

Efsartua Butarbutar
Department of Mechanical Engineering
University of Northern Sumatra
Jln. Dr. T. Mansur No.9, Medan City, North Sumatra, 20222, Indonesia
Email: efsa@gmail.com

1. INTRODUCTION

As a country with a tropical climate, big cities in Indonesia generally need coolers for air conditioning (Karyono, 2001). Electrical energy consumption for cooling and air conditioning in commercial buildings in big cities in Indonesia can reach 60% (Ratnasari, 2022). Therefore, the solution that is currently being developed is a cooling technique by utilizing solar energy (Maysha & Trisno, 2013). The Indonesian archipelago is located at the equator, namely 60 LU – 110 LS, where the apparent trajectory of the sun does not change throughout the year (Junata & Nopember, n.d.). Then the territory of Indonesia will always be exposed to the sun an average of 10-12 hours a day (Pratama et al., 2018). According to Indonesia's white energy data in 2006, it is estimated that the average intensity of solar radiation that falls on the surface areas of the islands in Indonesia is around 4.8 kWh/m2 every day. This energy can be utilized in the form of direct electricity (photovoltic) as well as in thermal form (Widayana, 2012). Because the efficiency of energy conversion is still better, this research is focused on the utilization of solar energy thermally (Marwani et al., 2019). Utilization of solar thermal energy can be used for several applications, such as drying and cooling (solar cooling) (Sitorus, 2018). From the two facts above, the potential for solar energy is quite large and the need for cooling is quite large, which is the background of this research (Panjaitan, 2019). A major research theme is capturing solar radiation energy in thermal form and utilizing it to produce cooling (refrigeration) (Bako, 2016).

The objectives of this thesis research include: (1) Knowing the minimum temperature of cooled water (Pranoto et al., 2022). (2) Knowing the changes in the volume of methanol in the adsorption and desorption processes (Harjunowibowo et al., 2014). (3) Knowing the efficiency value of adsorption refrigeration engine components. (4) Knowing the actual COP value of the refrigeration machine (Damanik, 2016).The benefits of research from this thesis are: (1) As a discourse and reference for further research on solar-powered cooling machines, especially in terms of collector area and collector angle (Dewi, 2010). (2) Produce an energy-saving and environmentally friendly refrigeration machine (Wibisono, 2020). (3) It is hoped that later it can be developed to meet the needs of the community with the aim of saving the use of electrical energy (Mbolo, 2011).

2. RESEARCH METHOD

2.1 Research Implementation Method

In the implementation of this research, activities include the following stages:

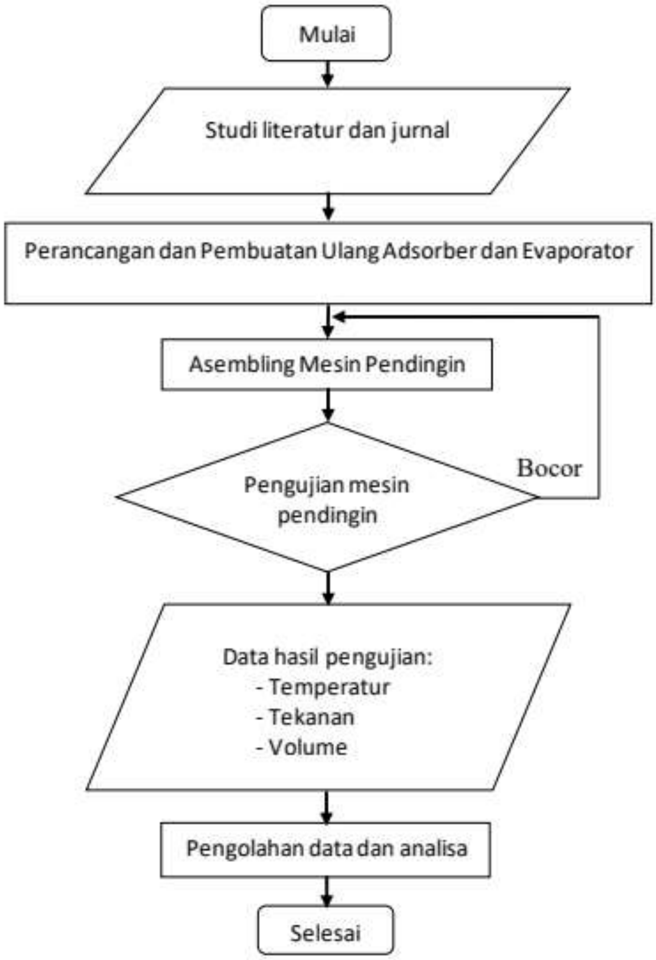

Figure 1. Research Flowchart

3. RESULTS AND DISCUSSION

3.1. Test result

3.1.1. First Day Test

Table 1. Adsorption Cycle (22 - 23 September 2016)

Pukul (WIB)	Kolektor P (bar)	Kolektor T (°C)	Kondensor T (°C) Tin (°C)	Kondensor T (°C) Tout (°C)	Evaporator P (bar)	Evaporator T (°C)	Air T (°C)	Intensitas Radiasi Matahari (W/m^2)
18:00	0.11	57.37	28.34	25.1	0.13	17.28	17.46	4.4
18:30	0.11	52.37	28.28	24.76	0.11	15.00	14.95	0.6
19:00	0.11	48	27.16	24.24	0.10	13.74	13.69	0.6
19:30	0.11	43.98	26.27	23.37	0.09	12.67	12.59	0.6
20:00	0.09	40.15	24.77	22.45	0.09	11.82	11.73	0.6
20:30	0.09	36.32	24.3	22.46	0.07	11.17	11.03	0.6
21:00	0.09	33.21	24.28	22.6	0.07	10.65	10.48	0.6
21:30	0.08	31	24.23	22.8	0.07	10.38	10.22	0.6
22.00	0.08	29.34	24.06	22.88	0.07	10.24	10.04	0.6
22:30	0.08	28.08	24.06	23.03	0.07	10.23	10.02	0.6
23:00	0.08	27.1	24.08	23.19	0.07	10.31	10.1	0.6
23:30	0.08	26.4	24	23.17	0.07	10.44	10.22	0.6
00:00	0.08	25.9	23.88	23.02	0.08	10.62	10.39	0.6
00:30	0.08	25.33	23.61	22.95	0.08	10.77	10.46	0.6
01:00	0.08	24.93	23.54	22.9	0.08	10.92	10.61	0.6
01:30	0.08	24.54	23.49	22.95	0.08	11.18	10.85	0.6
02:00	0.08	24.19	23.42	22.87	0.08	11.38	11.06	0.6
02:30	0.09	23.88	23.26	22.69	0.08	11.51	11.17	0.6
03:00	0.09	23.67	23.14	22.56	0.08	11.68	11.36	0.6
03:30	0.09	23.45	23.03	22.42	0.08	11.81	11.51	0.6
04:00	0.09	23.24	23.43	22.33	0.09	12.01	11.67	0.6
04:30	0.09	23.03	22.83	22.25	0.09	12.15	11.84	0.6
05:00	0.09	22.83	22.8	22.29	0.09	12.23	11.93	0.6
05:30	0,09	22.81	22.83	22.44	0,09	12.41	12.1	0,6
06:00	0,09	22.83	22.87	22.55	0,09	12.55	12.26	0,6

3.1.2. Second Day Test

Table 2. Adsorption Cycle (26-27 September 2016)

Pukul (WIB)	Kolektor P (bar)	Kolektor T (°C)	Kondensor T (°C) Tin (°C)	Kondensor T (°C) Tout (°C)	Evaporator P (bar)	Evaporator T (°C)	Air T (°C)	Intensitas Radiasi Matahari (W/m^2)
18:00	0.39	60.97	31.78	28.87	0.40	26.91	26.67	0.6
18:30	0.33	51.89	30.81	28.27	0.33	26.95	26.78	0.6
19:00	0.28	46.43	30.46	27.99	0.29	21.105	20.83	0.6
19:30	0.21	43.92	29.79	27.58	0.23	19.64	19.44	0.6
20:00	0.16	41.01	27.25	24.94	0.17	18.725	18.55	0.6
20:30	0.15	37.88	26.43	24.29	0.16	18.08	17.88	0.6
21:00	0.15	35.38	26.35	24.06	0.16	17.705	17.53	0.6
21:30	0.15	33.43	25.27	23.43	0.16	17.535	17.35	0.6
22.00	0.15	31.66	24.69	23.07	0.15	17.41	17.24	0.6
22:30	0.15	30.2	24.73	23.29	0.15	17.41	17.25	0.6
23:00	0.15	29.02	24.61	23.48	0.15	17.46	17.27	0.6
23:30	0.15	28.03	24.51	23.45	0.15	17.525	17.32	0.6
00:00	0.15	27.22	24.29	23.32	0.15	17.64	17.42	0.6
00:30	0.15	26.54	23.94	23.08	0.16	17.73	17.5	0.6
01:00	0.15	25.89	23.76	23	0.16	17.805	17.58	0.6
01:30	0.15	25.32	23.68	22.97	0.16	17.89	17.66	0.6
02:00	0.16	24.76	23.61	22.90	0.16	17.97	17.75	0.6

02:30	0.16	24.36	23.53	22.84	0.16	18.05	17.83	0.6
03:00	0.16	24.22	23.46	22.78	0.16	18.13	17.92	0.6
03:30	0.16	24.08	23.39	22.72	0.16	18.21	18.00	0.6
04:00	0.16	23,92	23,35	22,85	0.16	18.23	18,03	0.6
04:30	0.16	23,78	23,34	22,90	0.16	18.26	18,09	0.6
05:00	0.16	23,63	23,26	22,80	0.16	18.37	18,19	0.6
05:30	0,16	23.53	23.10	22.64	0,16	18.44	18.18	0,6
06:00	0,16	23.28	22.92	22.43	0,16	18.45	19.24	0,6

3.1.3. Third Day Test

Table 3. Desorption Cycle (27 September 2016)

Pukul (WIB)	**Kolektor**		**Kondensor T (°C)**		**Evaporator**		**Air T (°C)**	**Intensitas Radiasi Matahari (W/m²)**
	P (bar)	T (°C)	Tin (°C)	Tout (°C)	P (bar)	T (°C)		
08:00	0.17	27,40	25,52	26,34	0.173	18.65	18.5	109.4
08:30	0.21	32,02	26,46	26,82	0.21	18.76	18.59	301.9
09:00	0.27	36,17	27,23	27,51	0.27	18.82	18.64	404.4
09:30	0.31	39,95	28,69	29,21	0.31	18.92	18.74	431.9
10:00	0.39	46,02	30,61	31,07	0.39	19.02	18.8	456.9
10:30	0.54	56,71	33,02	32,53	0.54	19.13	18.91	545.6
11:00	0.75	68,05	35,89	33,45	0.74	19.28	19.03	490.6
11:30	0.87	76.34	34.94	32.54	0.87	19.5	19.19	523.1
12.00	0.96	81,49	37,74	34,19	0.95	19.59	19.29	473.1
12:30	1.01	86,40	38,71	35,81	1.01	19.78	19.49	295.6
13:00	1.01	86,32	39,25	35,84	1.01	20.01	19.67	333.1
13:30	1.01	86,40	40,79	35,80	1.01	20.14	19.82	289.4
14:00	1.01	87,10	39,70	35,29	1.01	20.25	19.88	141.9
14:30	1.01	86,98	39,84	36,29	1.01	20.42	20.06	196.9
15:00	1.01	87,27	41,54	36,75	1.01	20.6	20.24	65.6
15:30	0.85	86,32	36,90	33,84	0.93	20.85	20.45	106.9
16:00	0.59	75,35	34,28	30,70	0.93	20.97	20.61	-
16:30	0.53	64,17	33,22	30,47	0.93	21.18	20.83	-
17:00	0.48	55,40	32,37	30,99	0.93	21.31	20.98	-
17:30	0.46	48,85	31,20	29,56	0.47	21.45	21.12	-

Table 4. Adsorption Cycle (27 - 28 September 2016)

Pukul (WIB)	Kolektor		Kondensor T (°C)		Evaporator		Air T (°C)	Intensitas Radiasi Matahari (W/m²)
	P (bar)	T (°C)	Tin (°C)	Tout (°C)	P (bar)	T (°C)		
18:00	0.43	43.42	30.26	28.51	0.44	21.46	21.2	-
18:30	0.39	40.24	27.91	26.63	0.39	19.33	19.09	-
19:00	0.35	37.62	24.21	21.31	0.35	18.58	18.33	-
19:30	0.30	35.3	23.66	21.32	0.30	18.75	18.4	-
20:00	0.28	33.55	23.65	22.15	0.29	18.86	18.51	-
20:30	0.28	32.04	24.07	22.62	0.29	18.92	18.59	-
21:00	0.28	30.72	23.89	22.66	0.28	19.01	18.71	-
21:30	0.28	29	23.92	22.78	0.28	19.03	18.75	-
22.00	0.28	27.58	23.58	22.53	0.28	19.08	18.84	-
22:30	0.27	26.37	23.1	22.32	0.28	19.1	18.86	-
23:00	0.27	25.36	23.19	22.46	0.28	19.2	19	-
23:30	0.27	24.68	23.11	22.5	0.28	19.22	19.03	-
00:00	0.27	24.19	23.12	22.57	0.28	19.26	19.07	-
00:30	0.28	23.84	23.11	22.61	0.28	19.29	19.12	-
01:00	0.29	23.52	22.96	22.55	0.28	19.34	19.16	-
01:30	0.29	23.28	22.86	22.45	0.28	19.37	19.19	-
02:00	0.29	23.05	22.88	22.52	0.29	19.43	19.25	-
02:30	0.29	22.95	22.89	22.58	0.29	19.48	19.29	-
03:00	0.29	22.88	22.9	22.62	0.29	19.49	19.32	-
03:30	0.29	22.81	22.97	22.72	0.29	19.55	19.39	-
04:00	0.29	22.79	23.02	22.8	0.29	19.59	19.42	-
04:30	0.29	22.75	22.9	22.64	0.29	19.63	19.47	-
05:00	0.29	22.73	22.93	22.67	0.29	19.68	19.49	-
05:30	0,29	22.7	22.94	22.69	0,29	19.74	19.56	-
06:00	0,29	22.77	22.99	22.76	0,29	19.76	19.58	-

3.2. Graphic Analysis

3.2.1. Weather Conditions During Testing

The process of this research is related to the weather conditions during the test, where the intensity of solar radiation and environmental temperature are related to this research. Then used HOBO to get the data. The following data is obtained from HOBO. The following data were obtained from HOBO on days I, II, and III.

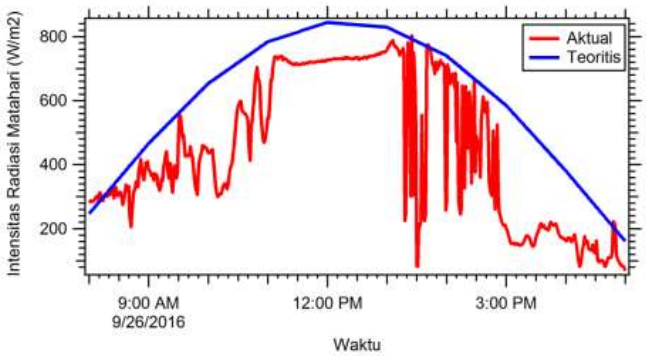

Figure 2. First Day Solar Radiation Intensity

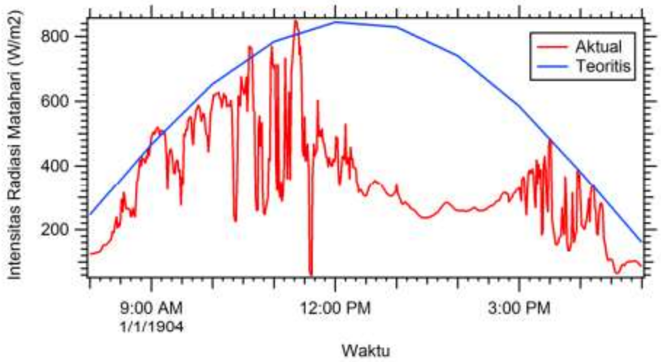

Figure 3. Second Day Solar Radiation Intensity

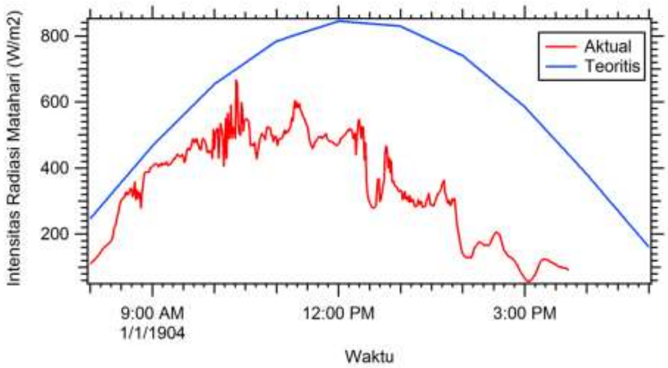

Figure 4. Third Day Solar Radiation Intensity

From the data above, the highest intensity of solar radiation was obtained on the first day of 803.1 W/m2, on the second day of 849.4 W/m2, and on the third day of 665.6 W/m2.

3.2.2. Analysis of Water Changes to Ice

In the tests carried out, the lowest water temperature was 9.98 oC, the evaporator plate temperature was 10.22 oC and the evaporator pressure was 0.07 bar. At this temperature the water has not turned into ice. This is because the freezing point of water is 0 oC. At the evaporator pressure reaches 0.07 bar, the boiling point of methanol is only 8 oC. In order for water to reach its freezing point, methanol as an adsorbate must at least reach a boiling point of 0 oC. In this case the evaporator as a methanol container must reach a pressure of 0.043 bar.This is done so that methanol absorbs heat from the environment in this case the evaporator plate and water, so that the water temperature will drop following the lowering of the boiling point of methanol and the water will reach its freezing point.

3.3. Methanol Volume

The volume of methanol was measured during the adsorption and desorption processes. Where the desorption process starts at 08.00 and the adsorption process starts at 17.30. The following is the methanol volume measurement data taken during the test

Table 7. First Day Methanol Volume

Waktu	Volume (L)
17:30	4.81
18:30	4.32
19:30	4.27
20:30	4.18
21:30	4.03
22:30	4.03
23:30	3.98
0:30	3.98
1:30	3.98
2:30	3.98
3:30	3.98
4:30	3.98
5:30	3.98

Table 8. Second Day Methanol Volume

Waktu	Volume (L)
8:00	3.74
9:00	3.74
10:00	3.74
11:00	3.98
12:00	3.98
13:00	3.98
14:00	3.94
15:00	3.94
16:00	3.94
17:00	3.94
18:00	4.52
19:00	4.52
20:00	4.48
21:00	4.48
22:00	4.52
23:00	4.48
0:00	4.44
1:00	4.44
2:00	4.40
3:00	4.40
4:00	4.37
5:00	4.37
6:00	4.37

Table 9. Third Day Methanol Volume

Waktu	Volume (L)
8:00	4.37
9:00	4.52
10:00	4.52
11:00	4.47
12:00	4.47
13:00	4.37
14:00	4.52
15:00	4.52
16:00	4.32
17:00	4.32
18:00	4.32
19:00	4.32
20:00	4.32
21:00	4.37
22:00	4.47
23:00	4.27
0:00	4.32
1:00	4.22
2:00	4.23
3:00	4.40
4:00	4.39
5:00	4.40
6:00	4.43

Table 10. Temperature Recapitulation of Cooling Engine Components During Testing

Hari	Kaca (°C)		Kolektor (°C)				Kondensor (°C)				Evaporator (°C)				Air (°C)		Intensitas Matahari (W/m²)	
			Atas		Bawah		In		Out		Kiri		Kanan					
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
I	73,66	20,41	125,25	22,52	105,51	22,83	40,21	22,78	35,37	22,23	26,78	10,26	26,77	10,12	26,56	9,98	803,1	0,6
II	74,6	21,19	121,8	23,15	100,63	23,51	43,23	23,19	38,57	22,73	27,10	17,39	27,13	17,28	26,85	17,16	849,4	0,6
III	74,74	21,25	120,22	22,55	88,24	22,71	46,29	22,78	38,24	21,19	21,56	18,56	21,51	18,37	18,50	18,29	665,5	0,6

3.4. Data Processing

Research on solar adsorption cycle cooling machines has already been carried out in various countries and several people from the USU Department of Mechanical Engineering have also done it. Therefore, this study is also based on these studies and from the results of these studies several conclusions can be drawn such as: (1) The most commonly used collectors are flat plate and parabolic evacuated tubes, but among the two collectors the most frequently used is the flat plate type because it is more economical, easy to maintain and quite efficient. (2) The condenser used is an air cooled condenser so that the condensation process takes place due to natural convection. (3) The evaporator used is in direct contact with the cooled water (direct cooling). (4) The main component materials (collector/absorber, condenser and evaporator) commonly used are copper or stainless steel. (5) The activated carbon-methanol pair has been widely used in previous studies. Because the final temperature obtained is able to reach temperatures below 0oC. The resulting Coefficient of Performance (COP) is also high. (6) The optimum mass of activated carbon to be filled into the collector is 20 – 26 kg/m2. (7) The ratio of effective adsorption to methanol is only 0.26 kg/kg activated carbon. In other words, 1 kg of activated carbon is only able to absorb a

maximum of 26% of the mass of activated carbon used. Based on the conclusions above, it is used as the basis for this research which can be described as follows: (1) The collector used is a flat plate type. (2) The condenser used is an air-cooled condenser with the addition of fins in the form of a horizontal flat plate with the aim of accelerating the process of heat transfer from the condenser to the ambient air. (3) The evaporator used is in direct contact with the cooled water. Therefore, at the bottom of the evaporator there is an addition of fins (trapezoidal grooves) with the aim of increasing the surface area of contact of the evaporator wall with the cooled water so as to accelerate the process of absorption of heat/heat from the water. The mass of the evaporator used = 2.3 kg. (4) The main material of the component (collector/absorber, condenser and evaporator) used is stainless steel with consideration of lighter and cheaper although its conductivity is lower than copper but still optimally used in adsorption cycle refrigeration machines. (5) The adsorbent used is ordinary/technical activated carbon with consideration of a more affordable price, widely available and easy to obtain. While the adsorbate/refrigerant is pro-analyst methanol (purity 99.9%). The use of pro-analyst methanol due to its high purity is expected to be optimally adsorbed by activated carbon. (6) For a collector with an absorber surface area of 1m2, then: The optimum mass of activated carbon used is 20kg – 26kg. In the previous test, the mass of activated carbon used was 25kg. However, to increase absorption effectiveness, In this study, the collector thickness was reduced by half from the previous collector thickness by remaking the collector, so that the mass of activated carbon that can be filled in the collector is 18.5 kg. (7) For 18.5 kg of activated carbon, then: Maximum mass of methanol = 26% x 18.5 kg of activated carbon = 4.81 kg = 3.79 liters (□= 0.790 kg/liter) (8) Collector Tilt Angle 0o.
.

4. CONCLUSION

The conclusions obtained from this research are: (1) After testing, the lowest temperature of cooled water is 9.98 oC with a pressure of 0.08 bar, where the initial temperature of the test water is 26.01oC. (2) The volume of methanol adsorbed in the first test was 1.02 liters. In the second test the volume of desorbed methanol was 0.78 liters, during the adsorption process the volume of methanol adsorbed was 0.29 liters. In the third test the volume of desorbed methanol was 0.15 liters, at night the volume of methanol adsorbed was 0.09 liters. (3) The actual energy absorbed in the first test is 2,523 MJ. In the second test, the actual energy absorbed is 3.129 MJ. In the third test, the actual energy absorbed is 3.186 MJ.□□in the first test of 16,443 Watt, in the second test of 20,436 Watt, in the third test of 17.305 Watt. Efficiency of the evaporator for the first test of. 53.37%, on the second day it was 65.44%, and on the third day it was 51.51%.5. The actual COP value of the cooling machine in the first test was 0.1598, the second test was 0.0776, and in the third test it was 0.0237.

The suggestions given for further research are: (1) Further research uses a vacuum pump with greater power so that it can provide greater vacuum pressure and increase the COP of the cooling machine. (2) Research is conducted on months that get a large intensity of solar radiation so that the efficiency of the cooling engine is more optimal. (3) Then use a volume measuring tool that is better and more accurate to determine the reduction in the volume of methanol. (4) The HOBO Micro Station needs to be properly maintained and checked before testing whether all sensors are functioning properly.

ACKNOWLEDGEMENTS

We would like to thank all those who have contributed to this research, so that the research can be carried out properly.

REFERENCES

Bako, C. S. O. (2016). *PENGUJIAN PEMBANGKIT LISTRIK SOLAR CELL BERBAHAN TEMBAGA DENGAN PENUTUP KACA HITAM DAN KACA PUTIH*.

Damanik, J. (2016). *Pengujian Mesin Pendingin Adsorpsi Tenaga Surya dengan Karbon Aktif-Metanol sebagai Pasangan Adsorben-Adsorbat*.

Dewi, I. K. (2010). *Perpustakaan Umum Surakarta Sebagai Perwujudan Ruang Komunal Dengan Pengoptimalan Pengolahan Lansekap*.

Harjunowibowo, D., Wijayanto, D. S., & Rahayu, J. T. W. (2014). Model Eksperimen Konversi Energi Sistem Refrigerasi Dengan Metode Adsorpsi. *Jurnal Materi Dan Pembelajaran Fisika*, *4*(2).

JUNATA, M. R. I. D., & NOPEMBER, I. T. S. (n.d.). *DESIGN OF MARINE TRANSPORTATION SYSTEM TO SUPPORT POTENTIAL MARITIME TOURISM: CASE STUDY MARATUA ISLAND*.

Karyono, T. H. (2001). Wujud Kota Tropis di Indonesia: Suatu Pendekatan Iklim Lingkungan dan Energi. *DIMENSI: Journal of Architecture and Built Environment*, *29*(2).

Marwani, M., Kadir, M. Z., & Ellyanie, E. (2019). ANALISIS PERFORMANSI PEMANAS AIR SURYA RANGKAIAN SERI DAN PARALEL MENGGUNAKAN PIPA TEMBAGA DENGAN GLASS TUBE COLLECTOR. *Applicable Innovation of Engineering and Science Research (AVoER)*, 380–385.

Maysha, I., & Trisno, B. (2013). Pemanfaatan Tenaga Surya Menggunakan Rancangan Panel Surya Berbasis Transistor 2N3055 Dan Thermoelectric Cooler. *Electrans*, *12*(2), 89–96.

Mbolo, Y. (2011). *APLIKASI SMS UNTUK MONITORNG TAGIHAN LISTRIK DI CABANG KUPANG WILAYAH NTT BERBASIS SMS GATEWAY*. STMIK AKAKOM Yogyakarta.

Panjaitan, J. (2019). *PENGARUH LAMA PENGERINGAN ASAM GELUGUR SECARA HYBRID DENGAN ENERGY SURYA TERHADAP KANDUNGAN ASAM SITRAT*.

Pranoto, A., Nauri, I. M., & Sumarli, S. (2022). Pengaruh temperatur air yang didinginkan AC dan temperatur air radiator terhadap output daya thermoelectric generator. *Jurnal Teknik Otomotif: Kajian Keilmuan Dan Pengajaran*, *5*(2), 13–18.

Pratama, A. O., Rohdiana, A., & Saraswati, R. R. (2018). Potensi Electronic Tree Based On Solar Cell and Microalgae. *Risenologi*, *3*(2), 71–75.

Ratnasari, S. (2022). *ANALISIS AUDIT ENERGI PADA SISTEM TATA UDARA GEDUNG RUMAH SAKIT UMUM PRASETYA BUNDA KOTA TASIKMALAYA*. Universitas Siliwangi.

Sitorus, T. B. (2018). Kinerja Kolektor Tipe Plat Datar Pada Mesin Pendingin Adsorpsi Tenaga Surya Di Kota Medan. *Jurnal Teknosains*, *7*(2), 94–103.

Wibisono, A. (2020). Analisis Sistem Pengkondisian Udara Menggunakan Fotovoltaik Tenaga Surya Sebagai Sumber Energi Alternatif Ramah Lingkungan. *ABSTRACT OF UNDERGRADUATE RESEARCH, FACULTY OF INDUSTRIAL TECHNOLOGY, BUNG HATTA UNIVERSITY*, *16*(2), 4.

Widayana, G. (2012). Pemanfaatan energi surya. *Jurnal Pendidikan Teknologi Dan Kejuruan*, *9*(1).