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The Effect of Cooling Load Variations on Basic Refrigerator Simulation Performance

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Abstract: The working principle of the cooling machine is to transfer heat from a place / material with a low temperature to another place / material with a higher temperature. Refrigeration technology is very closely related to modern life, and also the convenience of life. Currently, refrigeration machine innovation is very rapid development, one of which is a basic refrigerator simulation machine. For testing carried out for 1.5 hours with data collection for 5 minutes using variations in lamp loads, so that the data obtained from the test process in the basic refrigerator simulation with two evaporators include: Temperature, pressure, electric current, voltage, Cos φ and the length of the test process, the COP (Coefficient of Performance) and input power needed can be calculated. The resulting temperature in box 1 (freezer) is -5.5°C in the 14th minute and in box 2 (chiller) is 8°C. The relationship between the cooling load and the COP of the system forms a parabolic curve, where the largest COP position is found at a load between 50 watts to 75 watts, and then the COP of the system decreases. The decrease in temperature of evaporator box 2 (chiller) is longer than the temperature of box 1 (freezer), this is because on the exit side of evaporator box 2 (chiller) installed EPR valve (evaporator pressure regulator) where this valve functions to hold the temperature of the evaporator.

Keywords: Basic Refrigerator Simulation Machine, Evaporator, EPR Valve, COP

1. Introduction

A cooling machine is a device used to take heat from a low-temperature place and dispose of the heat to a high-temperature place. At this time cooling machines have been very widely used by the community, especially in urban areas, cooling machines can be found in almost every shop, office building and household. The cooling machine itself can be refrigerator, freezer, chiller and AC (air conditioning). AC itself functions as a cooler or air conditioner in the room which usually uses control [1, 2].

In the industrial world, the most common use of refrigeration machines is for production processes such as room conditioning and preservation of food or beverage ingredients. At ordinary temperature (room temperature) food will quickly rot because at ordinary temperature bacteria will develop quickly. While at the usual temperature to cool food is at 4.4°C or 40 °F [3, 4]. Refrigeration machines will be very easy to find in various stores that sell daily necessities at this time, because the refrigeration machine will minimize the growth of micro-organisms [5-7]. In addition, refrigeration machines are needed to prevent chemical or biological reactions that can damage the condition of a product [8, 9].

Apart from being a preservative for foodstuffs, refrigeration machines can be applied directly as a supporting component of a tool or machine, for example in vehicles that use air conditioning so that the temperature in the vehicle becomes cool [10, 11]. Cooling machine applications can also be developed in many other equipment and machinery, one of which is on simulation tools basic refrigerator. Therefore, this study was conducted to determine the results of reconditioning in simulations basic refrigerator with two evaporators using lamp loads with different lamp power, so the effect of cooling load variations on simulation performance basic refrigerator by using an EPR valve application (Evaporator Pressure Regulator) which functions as a regulating valve on the evaporator can be known. The valve in the cooling system with two evaporators can also maintain the temperature or pressure of each evaporator [12, 13]. Inside the two evaporators can be used to cool two types of products between box 2 (Chiller) and box 1 (Freezer).

This basic refrigeration simulator machine with two evaporators has previously been tested before by testing the cooling rate of honey on a basic refrigeration simulator machine with two evaporators getting a COP value from the evaporator. The resulting temperature in box 1 (Freezer) is -5.5 °C at 17.5 minutes and at the box (chiller) is 8°C at 10 minutes and the COP value for box 1 (Freezer) is 3.68, while the COP value for box 2 (Chiller) is 3.81 and the power obtained is 461.8 watts.

Research on the effects of cooling load has also been carried out by other researchers using R22 refrigerant but using hydrocarbons with the result of increasing COP [14, 15]. Similar research was also carried out using injector performance [16, 17]. Therefore, it is also necessary to conduct research on The Effect of Cooling Load Variations on Basic Refrigerator Simulation Performance. The objectives of this study are: (a) to determine the comparison of performance on a basic refrigerator simulation machine with 2 evaporators using variations in lamp load power, and (b) to determine testing on a simulated basic refrigerator with 2 evaporators using R-22.

2. Research Method

2.1. Research Design

Research was conducted on a modified and improved basic refrigerator simulation machine, namely in the form of reconditioning the basic refrigerator simulation with two evaporators to determine the capabilities of the machine, so that it can produce the desired temperature. In the basic refrigerator simulation machine of these two evaporators there is an EPR application (evaporator pressure regulator) which functions as a refrigerant pressure regulator to the evaporator which will cause a temperature difference between the two evaporators.

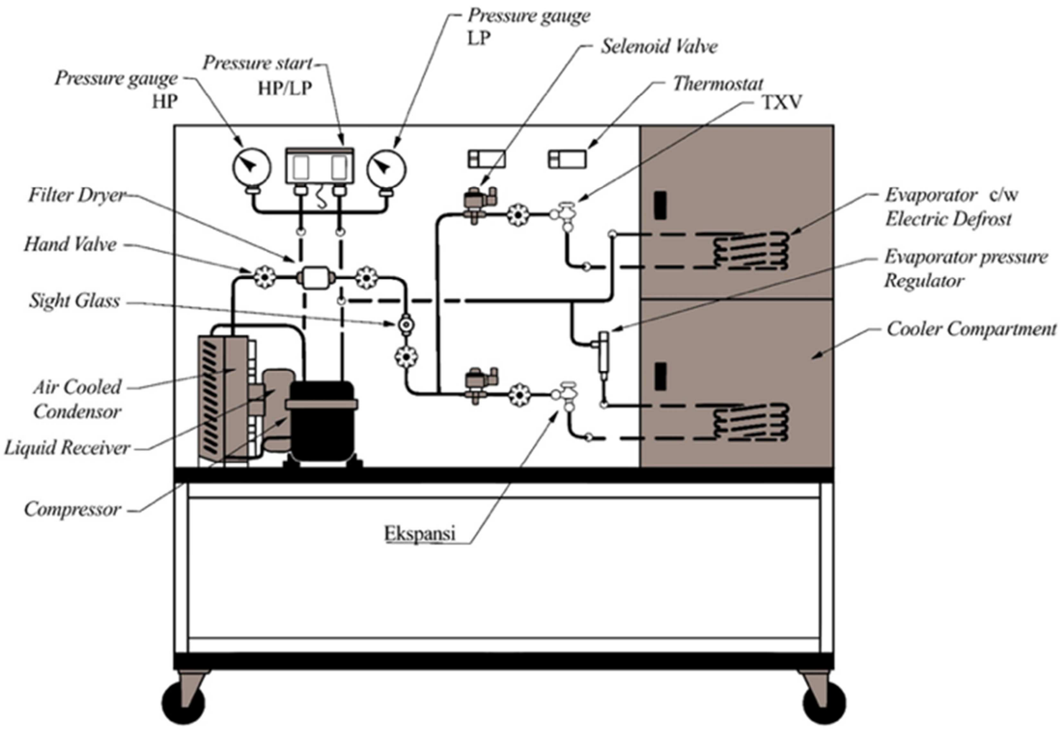

Figure 1. *Basic refrigerator simulation.*

The measured data are pressure, temperature, voltage and electric current that enter the simulation system in this study. All these data are needed to be able to determine the performance and temperature difference that occurs between the two evaporators box 2 (chiller) and box 1 (freezer).

2.2. Determination of Data Source

The source of data from the recondition of the basic refrigerator machine is the data needed to be taken after being reconditioned using experimental methods, by testing directly on the basic refrigerator simulation system with two evaporators. The data taken during testing after being reconditioned are as follows:

a. Current (I)

The current is measured with the aim of knowing how much power is used by the basic refrigerator simulation system with two evaporators. The tool used is a power analyzer with ampere units.

b. Pressure (P)

The pressure taken is the pressure at a predetermined point and corresponds to the basic refrigerator simulation system unit with two evaporators to be reconditioned. The tool used is a pressure gauge with psi units.

c. Temperature (T)

The temperature or temperature taken is the temperature at a predetermined point, and in accordance with the basic refrigerator simulation system unit with two evaporators to be reconditioned. The tools used are data scan loggers and thermocouple cables with units °C.

The data taken was carried out in the basic refrigerator simulation system unit with two evaporators at the Refrigeration and Air Conditioning Laboratory, Bali Polytechnic. At this stage, it will be explained the location of the measurement point placement in the basic refrigerator simulation system with two evaporators using R-22. Can be seen in Figure 2.

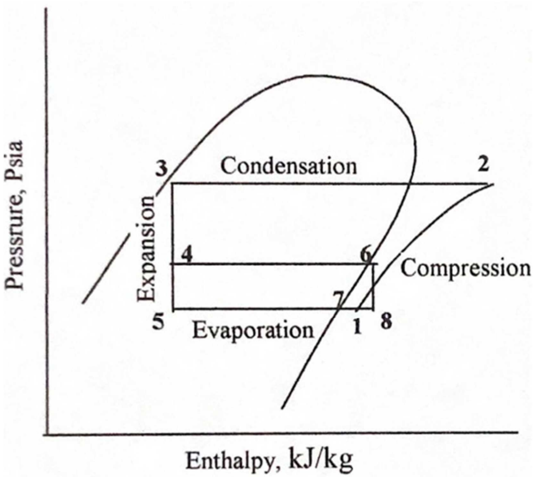

Figure 2. *Measurement points.*

Description of temperature point:
T1 = Compressor inlet temperature
T2 = Compressor exit temperature
T3 = Condenser exit temperature
T4 = Evaporator inlet temperature Chiller
T5 = Freezer evaporator inlet temperature
T6 = Temperature exit evaporator Chiller
T7 = Temperature exit evaporator Freezer
T8 = EPR valve outlet temperature
Description of pressure point:
P1 = Compressor inlet pressure
P2 = Pressure out of the compass
P3 = Condenser exit pressure
P4 = Chiller evaporator inlet pressure
P5 = The inlet pressure of the freezer evaporator
P6 = Chiller evaporator exit pressure
P7 = Pressure out evaporator freezer
P8 = EPR valve exit pressure

3. Results and Discussion

3.1. Reconditioning Basic Refrigerator Simulation Machine

Reconditioning is carried out on the basic refrigerator simulator machine in order to improve engine performance and be able to reach the desired temperature point. The process of testing refrigeration machines that have been reconditioned uses several load variations to determine the performance of a basic refrigerator simulation machine with two evaporators. The results of the reconditioning of the basic refrigerator simulation machine can be seen in Figure 3 below.

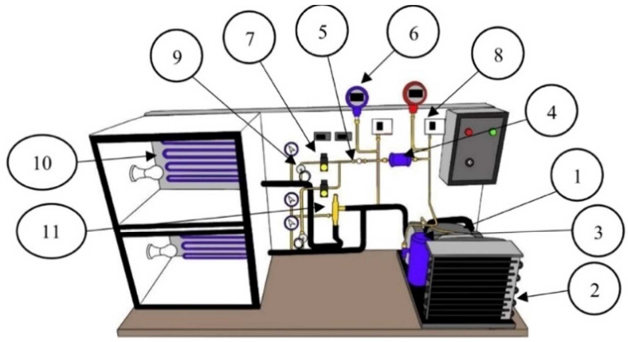

Figure 3. *Basic refrigerator simulation machine with two evaporators in 3D.*

Image caption:
1: Compressor
2: Condenser
3: Filter dryer
4: Liquid receiver
5: Sight glass
6: Pressure gauge
7: Solenoid valve
8: Pressure switch
9: Expansion valve
10: Evaporator
11: EPR

3.2. Basic Refrigerator Simulation Machine Testing

The testing process was carried out for 1.5 hours with data collection every 5 minutes. This test is carried out to find out data for performance calculation needs in the system. The data taken includes temperature, pressure, current, and voltage. The testing process can be seen in Figure 4.

Figure 4. *Basic refrigerator simulation machine testing process with two evaporators.*

From the test results that have been obtained, namely temperature and pressure, the data is entered into the P-h R22 diagram. Test result data can be seen in the appendix page section. Before being entered, the data for pressure (P) is first converted into P absolute with the following formula [18-20].

$$P\ absolute = P\ gauge + P\ atmosphere \quad (1)$$

Because the pressure gauge used has a Psi unit, the Psi unit is changed first to the Bar unit. For the value of 1 atmosphere has a value of 1.01 Bar, the formula for P absolute used is [18-20]:

$$P\ absolute = P\ gauge + 1.01\ bar \quad (2)$$

For pressure and temperature data entered at P-h R-22 according to the points used. After the pressure data and temperature data are entered on the P-h diagram, it can determine the enthalpy value to determine the COP value on the basic refrigerator simulation machine with two evaporators.

3.3. Calculation of Basic Refrigerator Simulation Performance with Two Evaporators (No Load)

From the Ph R-22 diagram above by entering temperature (T) in °C and pressure (P) in absolute bars, the magnitude of enthalpy of each point is as follows:

h1 = 402 kj/kg
h2 = 443 kj/kg
h3 = 238 kj/kg
h4 = 238 kj/kg
h5 = 238 kj/kg
h6 = 402 kj/kg
h7 = 400 kj/kg
h8 = 400 kj/kg

After the enthalpy value is obtained, a calculation is carried out to find the performance value using a formula that is in accordance with the Refrigeration Effect formula as follows [21, 22].

Refrigeration Effect (ER)

ER box2 = h6-h4

= 402 kj/kg - 238kj/kg = 164 kj/kg

ER box1 = h7-h5

= 400 kj/kg – 238 kj/kg = 162 kj/kg

1) Compression work (WC)

WC = h2 – h1

= 443 kj/kg – 402 kj/kg

= 41 kj/kg

2) Coefficient of Performance (COP)

$$\text{COP box2} = \frac{ER2}{WK} = 4.00\ \frac{h6-h4}{h2-h1} \frac{167\ kj/kg}{41\ kj/kg}$$

$$\text{COP box1}=3.95\ \frac{ER2}{WK} \frac{h6-h4}{h2-h1} \frac{162\ kj/kg}{41\ kj/kg}$$

3) Power input (Pi)

Pi = V x I x cosφ (3)

= 220 V x 2.31 x 0.85 = 431.9 watts

3.4. Performance Results of Simulating Basic Refrigerator with Two Evaporators

a. Effects of Refrigeration (ER) and Working Compression (WC)

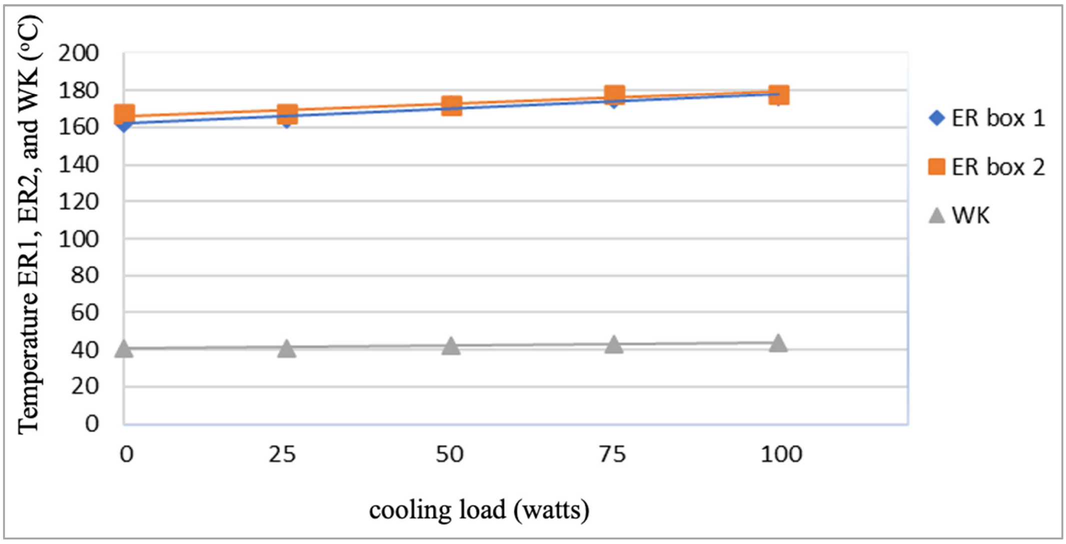

Figure 5. *Refrigeration effect and compression work.*

From Figure 5 shows a simulation of a basic refrigerator with two evaporators, it can be seen that there is an increase in compressor work (WC) and refrigeration effect (ER). From starting without load to 100 watts loads, there is a significant increase in refrigeration effects compared to the increase in compressor work.

b. Coefficient Of Performance (COP)

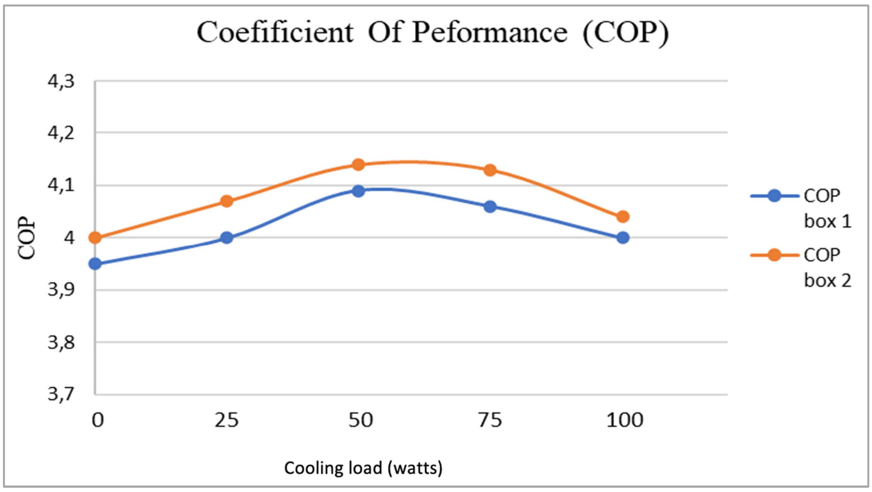

Figure 6. *Coefficient Of Performance (COP) value graph.*

From Figure 6. showing a simulation of a basic refrigerator with two evaporators, it can be seen that the relationship between the cooling load and the COP of the system forms a parabolic curve, where the largest COP position is at a load between 50 watts to 75 watts, and then the COP of the system decreases.

c. Temperature evaporator box 2 (*chiller*)

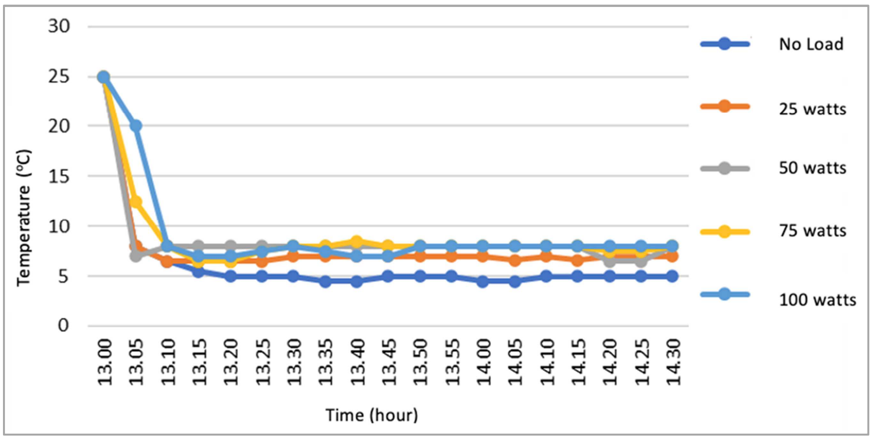

Figure 7. *Graph of temperature values of evaporator box 2 (chiller).*

Temperature evaporator box 1 (*freezer*)

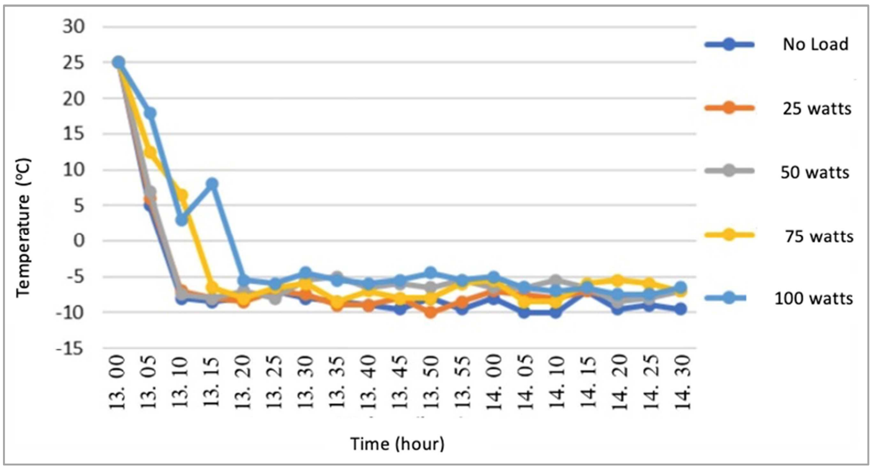

Figure 8. *Graph of temperature values of evaporator box 1 (freezer).*

From Figures 7 and 8. showing the graph above it can be concluded that the temperature drops of evaporator box 2 (chiller) is longer than the temperature of box 1 (freezer), this is because on the exit side of evaporator box 2 (chiller) installed EPR valve (evaporator pressure regulator) where this valve functions to hold the temperature of the evaporator.

d. Load temperature in box 1 (*freezer*)

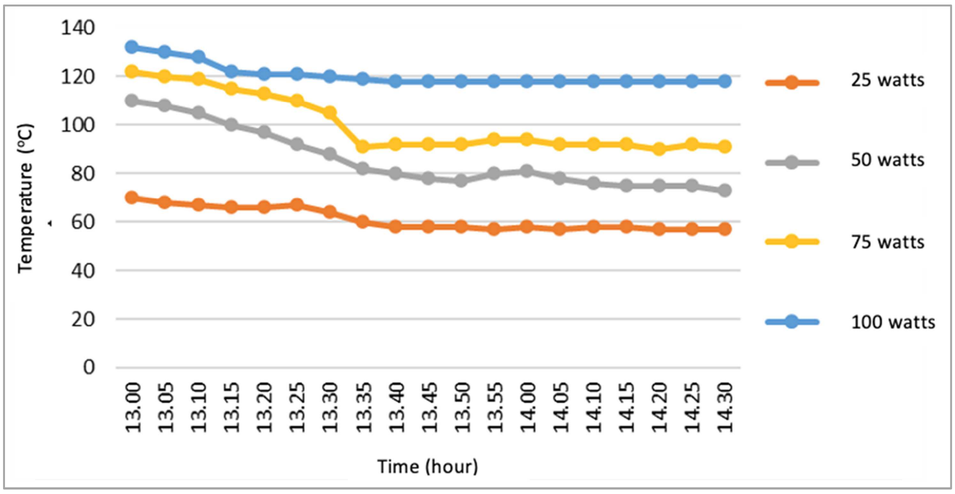

Figure 9. *Graph Temperature load on box 1 (freezer).*

e. Load temperature in box 2 (*chiller*)

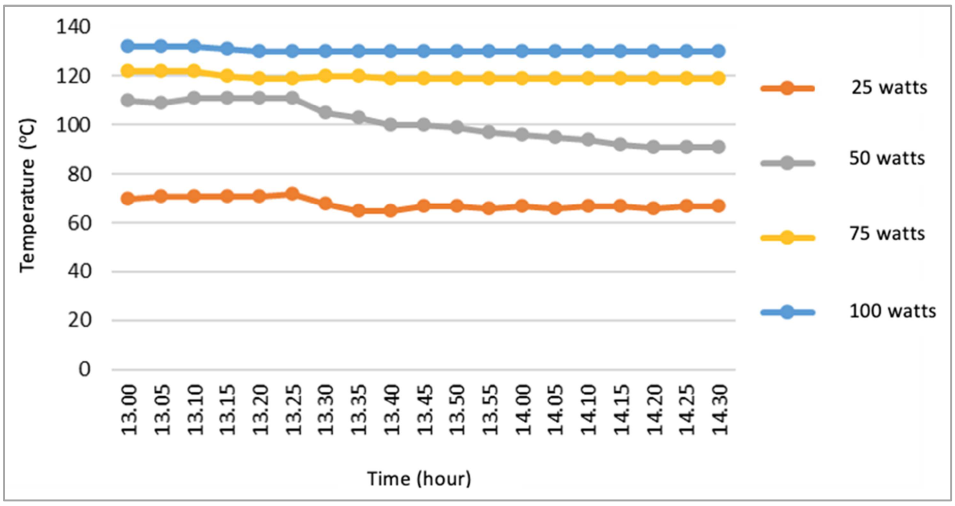

Figure 10. *Graph Load temperature on box 2 (chiller).*

From Figures 9 and 10 showing the graph above, it can be concluded that the load on box 1 (freezer) has decreased temperature. The temperature of all box 1 loads was initially the same, which was 25°C. After 1.5 hours of testing, with the thermostat to close the solenoid valve, the temperature of box 2 (chiller) is 8°C and the temperature in box 1 (freezer) is -5.5°C.

4. Conclusions

Based on the results and discussion above, the following can be concluded.

1) The relationship between the cooling load and the COP of the system forms a parabolic curve, where the largest COP position is found at a load between 50 watts to 75 watts, and then the COP of the system decreases.
2) The decrease in temperature of evaporator box 2 (chiller) is longer than the temperature of box 1 (freezer), this is because on the exit side of evaporator box 2 (chiller) installed EPR valve (evaporator pressure regulator) where this valve functions to hold the temperature of the evaporator.

The recommendation for the next research is to check for leaks in the installation because looking for thin leaks requires a lot of time and complexity which disrupts the coefficient of performance and work of the compressor.

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Abbreviations

COP: Coefficient of Performance
AC: Air Conditioning
EPR: Evaporator Pressure Regulator
P: Pressure
T: Temperature
ER: Effect of Refrigeration
WC: Working Compression
Pi: Power input
°C: Degrees Celsius

Conflicts of Interest

The authors declare no conflict of interest.

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