Investigation of reducing electricity consumption in the refrigerator by using domestic refrigerant MC-22

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Abstract. A household refrigerator was machine that operates continuously throughout the day to keep food fresh. So that a little savings in electricity consumption was very beneficial. The purpose of this study was to obtain savings in refrigerator electricity consumption by replacing R-134a working fluid with Musicool-22 (MC-22) as natural refrigerant. Furthermore, to reducing global warming potential of the earth's surface due to HFCs refrigerants. The study was designed experimentally with the retrofit refrigerant drop in substitute method on refrigerator. The test was started by measuring the performance of refrigerators using R-134a working fluid. Then the working fluid R-134a was retrofitted with MC-22 with a mass of 15%, 20%, 25%, 35%, 45%, and 65% of the mass of R-134a. Finally, the performance of the refrigerator that has been retrofitted using the MC-22 was measured as a measurement of the performance of the refrigerator using the R-134a. The test results showed that, when the refrigerator was retrofitted using MC-22 with a mass of refrigerant 25% mass of R-134a refrigerant, the performance of the refrigerator increases. Electricity consumption was more efficient with a marked decrease in electrical power requirements to 12.2%. In addition, the freezer room temperature is lower at 6.9 °C compared to when operating with R-134a working fluid.

1. Introduction
Refrigerator is a type of electrical equipment that is commonly used in homes [1]. This machine is used to store food or raw materials to be more durable and stay fresh even if stored for days. The benefits are large enough to make the refrigerator as a primary need for some people [2]. But the refrigerator must continue to operate to maintain the quality of food ingredients stored in it. So cumulatively, it requires a large amount of electrical energy each month to operate [3,4]. For this reason, an experiment is needed to obtain electrical energy savings. Because the slightest saving in electricity consumption will be very beneficial for a refrigerator that works continuously throughout the day.

In general, household refrigerators use a vapour compression system. The refrigerant used as a working fluid in the piping system was R-134a. This type of refrigerant was an HFC group that has a zero-ozone deflection potential (ODP) value, but still has a high Global Warming Potential (GWP) value, so it is included as a substance controlled under the Kyoto Protocol [5-7]. Because it can result in higher surface temperatures of the earth. For that we need new environmentally friendly refrigerants that can replace old refrigerants. The new refrigerant must be able to maintain the performance of refrigerators that use the original refrigerant or even better.

Research to see the performance of a small heat pump by using several types of hydrocarbon refrigerant including type R-600a has been carried out by Bjorn Palm. The performance of heat pumps...
using hydrocarbons compared to heat pumps that use R-134a refrigerant. The test results show that COP (Coefficient Of Performance) heat pump uses hydrocarbons equal or greater than using R-134a [8]. In other studies, experiments had been carried out to replace R-134a refrigerant with environmentally friendly HFO1234YF refrigerant in a domestic refrigerator. The experiment was designed by drop in substitute the working fluid R-134a with refrigerant HFO1234YF without changing the components of the domestic refrigerator. The test results show that drop in substitute working fluid can still maintain the refrigerator compartment temperature according to the manufacturer’s design and electricity consumption was 3% more efficient compared to refrigerators that use R-134a [9]. Other researchers conducted an experiment drop in substitute R-134a refrigerant with R-430A in a domestic refrigerator. The R-430A has a lower GWP value than the R-134a. The experiment began with a leak test using 8 bar of pressurized nitrogen. After checking the leakage piping system is vacuumed. Then the refrigerator is filled with R-134a (100 g) according to the manufacturer’s recommendations. And then the performance of the refrigerator using R-134a was measured. After that the R-134a refrigerant is removed from the refrigerator and replaced with R-430A with a mass (40 g, 50 g, and 60 g). Then the performance of the refrigerator using R-430A was measured as the performance of the refrigerator using R-134a. The test results showed that the consumption of refrigerator electrical energy using R-430A is 3.9% lower and the time of freezer temperature reduction is reduced to 3.4% when compared to R-134a. So it can be concluded that R-430A can substitute directly R-134a without replacing the refrigerator component [10].

In this study research team tested the replacement of R-134a refrigerator working fluids in our laboratory with MC-22 hydrocarbon refrigerants that produced by domestic companies in Indonesia. Testing was done by drop in substitute method (without replacing the main components of the refrigerator).

2. Materials and experimental method

The tools used in this study include a refrigerator as a test component, a refrigerant recovery machine to assist the retrofit process, a manifold gauge to measure low pressure and high pressure refrigerant in the piping of cooling machine, an electronic charging meter to measure the mass of refrigerant, a stopwatch to calculate data retrieval time, thermometer to measure the temperature in the evaporator cabin, ampere clamp to measure electric current, and AVO meter to measure electrical voltage. Furthermore, materials needed for research include natural MC-22 refrigerant and R-134a refrigerant as working fluid of refrigerator, Nitrogen for pressure testing of the cooling system piping leakage system, and refrigerant empty tubes to accommodate the retrofitted refrigerator.

This research was conducted experimentally using a refrigerator with refrigerants R-134a as original working fluid. Retrofitting / replacement of refrigerants is carried out by the drop in substitute method by replacing the original refrigerant without changing the components of the refrigerator. Hydrocarbon refrigerants used to substitute R-134a are MC-22 as refrigerant domestic which environmentally friendly. The test was carried out in two stages to measure the performance of the refrigerator before and after retrofitting/replacement of refrigerants. In the first stage using R-134a refrigerant and in the second stage using MC-22 refrigerant. Furthermore, the performance of the refrigerator is compared to observing a decrease in temperature and the use of electric current every interval of one to two minutes for 31 minutes. The electric power consumption of the refrigerator cooler is calculated using equation (1).

\[ P = V \times I \] (1)

\( P \) = Electrical power (Watt)
\( V \) = Electrical voltage (Volt)
\( I \) = Electrical current (Ampere)

Furthermore, the increase/decrease in electric power consumption is calculated by equations (2) and (3).

\[ \text{Increase/Decrease} = \frac{P_{\text{new}} - P_{\text{old}}}{P_{\text{old}}} \times 100\% \] (2)
In the first stage, the test begins with a leak test of a refrigerator piping system. Furthermore, the cooling machine is vacuumed for 20 minutes. Then the refrigerator is filled with 100 grams of R-134a refrigerant in accordance with the capacity of the cooling machine. Data parameters taken include pressure suction and discharge compressor, evaporator cabin temperature, electric current, and electric voltage. Furthermore, the performance of the refrigerator is analysed to determine the performance of the cooling machine when using R-134a refrigerant.

After the first stage of testing is completed, the refrigerator is retrofitted using MC-22 type hydrocarbon refrigerant as shown in Figure 1. The MC-22 refrigerant is entered into the cooling machine for six variations of the refrigerant mass. The ratio of the mass of MC-22 to refrigerant R-134a is 15% to 65% of mass R-134a. The amount of mass of refrigerant R-134a put into the refrigerator refrigeration machine is 100 g. While the amount of MC-22 refrigerant mass put into the refrigerator cooling machine is 15 g, 20 g, 25 g, 35 g, 45 g, and 65 g. Furthermore, the performance of a refrigerator that has been retrofitted using MC-22 is measured as a measurement of the performance of the refrigerator using the original refrigerant. Schematic of refrigerant retrofit and refrigerator performance test with MC-22 can be seen in Figure 1.

![Figure 1. Refrigerator performance test scheme.](image)

### 3. Results and discussion

Refrigerant replacement experiments from R-134a to MC-22 natural refrigerants on refrigerator practices have been carried out. Refrigerator performance data was taken under the same operating conditions and cooling loads for each refrigerant mass variation. Data on changes in freezer temperature, electric power, and increase / decrease in electric power consumption at intervals of the 1st minute to the 31st minute are displayed in the figure 2 to 5.
3.1. Freezer temperature
The freezer is the part of the room closest to the evaporator. This section is usually used to store food with temperatures below zero degrees. Freezer temperature is one indicator of refrigerator performance. The lower the temperature, indicates good engine performance. In addition, the less time needed by the engine to reach the lowest temperature is also a good benchmark of engine performance. Figure 2 shows a graph of the freezer temperature with respect to time for all types of refrigerants with various mass variations that were tested on the refrigerator.

Based on Figure 2, when the refrigerator uses its original refrigerant working fluid (R-134a, m = 100g), the freezer temperature drops rapidly from 23 °C to -17.1 °C in the 11th minute. Furthermore, the freezer temperature drops slowly with the lowest temperature that can be reached is -19.1 °C for 31 minutes. Then, after the refrigerator was retrofitted using MC-22 natural refrigerant working fluid with a mass variation from 15% to 65% mass of R-134a, the refrigerator showed different performance. When the refrigerator uses MC-22 with a mass of 15 grams, the freezer temperature drops slowly from the 1st minute to the 31st minute. The lowest temperature that can be reached for 31 minutes is only up to 12 °C. Then when the refrigerator uses MC-22 with a mass of 20 grams, the freezer temperature drops quite fast until the 11th minute with a temperature of -9.9 °C. Then the freezer temperature drops more slowly until the 31st minute with the lowest temperature that can be reached is -19.9 °C.

Furthermore, in the operating conditions and cooling load the same as R-134a refrigerator, m = 100 g. When the refrigerator uses MC-22 with a mass of 25 grams, the freezer temperature drops faster. In the 11th minute the freezer temperature had reached -17.4 °C. A decrease in temperature rapidly occurs until the 17th minute with a temperature of -25 °C. Furthermore, from the 17th minute to the 31st minute the freezer temperature only drops to -26 °C. Then when the refrigerator cooling machine uses MC-22 working fluid with a mass of 35 grams, the freezer temperature drops even faster than before. In the 11th minute the freezer temperature had reached -21 °C (the lowest of all test results). In this mass variation, the temperature continues to drop quite rapidly until the 15th minute with a temperature of -25 °C. Furthermore, from the 15th minute to the 31st minute the freezer temperature only dropped by one degree. Both variations of the MC-22 refrigerant mass (m=25g and m=35g), showed the best refrigerator performance.

![Figure 2](image2.jpg) Graph of freezer temperature with respect to time.  
![Figure 3](image3.jpg) Frost on the suction line.

Furthermore, for variations in the mass of the MC-22 refrigerant (m = 45g) in the operating conditions and cooling load the same as R-134a refrigerator, m = 100 g, the freezer temperature at the 11th minute was -16.5 °C. The freezer temperature keeps dropping to the lowest temperature of -17.5 °C in the 17th minute. Then, from the 17th minute to the 31st minute the freezer temperature rises again. In the MC-22
mass variation of 45 grams, the performance of the cooling machine starts to decrease again compared
to when the cooling machine uses the MC-22 with a mass of 20 g, 25 g, and 35 g. In this variation of
mass refrigerant, seen in the suction line, there appear frosts until the compressor shown in Figure 3.
This indicates that the amount of refrigerant that was put into the cooling machine was too much.
Furthermore, the variation of MC-22 mass of 65 grams showed that the performance of the refrigerator
was decreasing again. In the 11th minute the freezer temperature was only up to -7 ⁰C or 9.5 ⁰C worse
than when using MC-22 (m=45g). This showed that refrigerator performance was getting worse for
variations of MC-22 mass above 35 grams. In this variation, more frost appears on the suction line up
to the bottom wall of the compressor.

3.2. Electrical power

Electrical power can be said as the amount of electrical energy consumption of an electrical equipment
every time unit. The greater the electrical power needed for a machine to operate, the greater the
consumption of electrical energy. While the less electrical power needed by an electrical equipment, the
less the amount of electrical energy or the more efficient. Figure 4 shows the test results of the amount
of electrical power required by the refrigerator cooling machine when using R-134a (m = 100g)
refrigerant and when using MC-22 natural refrigerant (m = 15g, m = 20g, m = 25g, m = 35g, m = 45g,
and m = 65g).

Based on the graph of electrical power with respect to time, when the refrigerator operates with a
working fluid R-134a (m = 100g), it is seen that the electrical power needed ranges from 209 Watts to
233.2 Watts in an interval of 31 minutes. Furthermore, in the operating conditions and cooling load the
same, when the refrigerator operates using MC-22 refrigerant with six different mass variations, it
produces smaller electric power for mass variations of MC-22 (m = 15g, m = 20g, m = 25g, m = 35g)
and greater electrical power for the MC-22 mass variation (m = 45g, m = 65g), compared to a refrigerator
using R-134a refrigerant. The amount of electricity needed by the refrigerator when operating with the
MC-22 (m = 15g) ranges from 200.2 Watt to 204.6 Watt. Then, when the refrigerator operates with MC-
22 (m = 20g), the amount of electrical power needed ranges from 198 Watts to 211.2 Watts. The best
performance is obtained when the refrigerator operates with MC-22 (m = 25g), the amount of electrical
power needed ranges from 187 Watt to 206.8 Watt. Furthermore, when the refrigerator operates with
MC-22 (m = 35g), the amount of electrical power needed ranges from 191.4 Watt to 211.2 Watt. Then
when the refrigerator operates with MC-22 (m = 45g), the amount of electrical power needed ranges
from 215.6 Watt to 248.6 Watt. Then when the refrigerator cooling machine operates with MC-22 (m =
65g), the amount of electric power needed ranges from 242 Watts to 266.2 Watts. In this mass variation,
the performance of the refrigerator is very bad.

![Figure 4. Graph of electric power with respect to time.](image-url)
3.3. Increase / Decrease in electric power

Figure 5 shows a graph of increase or decrease in electric power of a refrigerator operating with MC-22 working fluid for mass variation \((m = 15g, m = 20g, m = 25g, m = 35g, m = 45g, \text{and } m = 65g)\) compared to a refrigerator which operates with a working fluid R-134a \((m = 100g)\). Experiments were carried out under the same operating conditions and cooling load. Based on this picture, at the time interval of the 15\(^{th}\) minute to the 31\(^{st}\) minute, the electrical power requirements of the refrigerator operating with the MC-22 working fluid \((m = 15g, m = 20g, m = 25g, m = 35g)\) go down and the refrigerator operating with MC-22 working fluid \((m = 45g, m = 65g)\) rises. The best reduction in electrical power requirements was obtained when the refrigerator uses MC-22 \((m = 25g)\) of 8.2% to 12.2%. Then followed by MC-22 \((m = 35g)\) with a decrease of 4.2% to 9.2%. The smallest reduction was obtained when using MC-22 \((m = 15g \text{ and } m = 20g)\) with a large decrease in power requirements ranging from 5.3% to 7.1% for MC-22 \((m = 20g)\) and 4.2% to 7.1% for MC-22 \((m = 15g)\).

And then, when the refrigerator uses MC-22 working fluid \((m = 45g \text{ and } m = 65g)\), the electricity demand actually increases compared to when operates with a working fluid R-134a \((m = 100g)\). The biggest increase in electricity demand occurred when the refrigerator used MC-22 \((m = 65g)\) with an increase in value of 12.2% to 18.9%. Whereas when the refrigerator uses MC-22 \((m = 45g)\) the increase in power needed by the refrigerator to operate is 1% to 6.3% compared to when operates with a working fluid R-134a.

![Figure 5. Graph of increase / decrease in electric power over time.](image)

4. Conclusion

Refrigerant replacement experiments in refrigerators with MC-22 natural refrigerant drop in substitute method have been carried out. The test results showed that the refrigerator can operate better when MC-22 was retrofitted with a mass of refrigerant 25% to 35% mass of R-134a refrigerant.

- Improved refrigerator performance is characterized by decreasing electrical power requirements ranging from 4.2% to 12.2% when using MC-22 \((m = 25g \text{ and } m = 35g)\). This indicates a more efficient consumption of electrical energy.
- The freezer temperature was lower at 6.9 \(^{\circ}\)C compared to when the refrigerator uses the original refrigerant (R-134a, m = 100g).
- The amount of mass of MC-22 refrigerant that was needed by the refrigerator to operate was only around 25% to 35% of the R-134a as original refrigerant.
The test showed good results, so that the MC-22 refrigerant can replace the R-134a refrigerant.

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