Vol. 5, No. 1, April 2024, page 134-143
JTTM: Jurnal Terapan Teknik Mesin
p ISSN 2721-5377| e ISSN 2721-7825
http://jurnal.sttmcileungsi.ac.id/index.php/jttm

The effect of refrigerant filling pressure on split AC performance with variations in refrigerant R22, R134A, and R290

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Submitted: 10/06/2023 Revised: 04/08/2023 Accepted: 10/11/2023

Abstract: R-22 refrigerant has been recognized as a major cause of climate change and ozone layer depletion, leading to increased interest in finding more environmentally friendly alternatives. Two alternatives being considered are R-134a and R-290. The main objective of this research is to compare the Coefficient of Performance (CoP) performance of split ACs using three types of refrigerants, namely R-22, R-134a, and R-290, taking into account the environmental impact and operational efficiency. The research method involved retrofitting a 1 PK split AC which initially used R-22 with three different types of refrigerant as an experiment. The research process includes test equipment design, equipment installation, and feasibility testing before carrying out experimental testing. Tests were carried out with variations in refrigerant charging pressure of 70 psi, 75 psi, 80 psi, 85 psi, and 90 psi. The research results showed that the largest COP was found in the R-290 refrigerant, reaching a value of 0.86 at a filling pressure of 90 Psi. The largest COP value for R-22 was also found at a filling pressure of 90 psi, namely 0.66. Meanwhile, R-134a achieved the highest COP value at a filling pressure of 90 psi, with a value of 0.57 at a variation of refrigerant filling pressure of 90 Psi. In conclusion, this study provides better insight into the efficiency and environmental impact of the three types of refrigerants discussed. It also provides a useful information basis for the selection of suitable refrigerants in split air conditioning systems, with the aim of environmental conservation and achieving optimal performance.

Keywords: Split AC; refrigerants; COP

1. INTRODUCTION

In the context of using an AC system, refrigerant charging pressure has an important role that can significantly influence AC performance. Some of the impacts of variations in refrigerant charging pressure in AC include the AC's ability to lower the temperature or cool the room in the car cabin [1], the influence on AC system performance which is greater with greater suction pressure, as well as the relationship between lower refrigerant pressure and reduced cooling results [2][3][4]. In addition, inappropriate refrigerant pressure, either too high or too low, can have a serious impact on the optimal performance of the AC, causing the compressor to work hard, and damaging AC system components such as the evaporator, condenser, and hoses [5]. Therefore, in the process of filling refrigerant in the AC, it is important to ensure that the pressure matches the specifications of the car or AC system being used, to achieve optimal performance and maintain the integrity of other components in the AC system [6].

The development of air conditioning systems has developed rapidly because humans need comfortable indoor air conditions. This is proven by the fact that many industries, offices, housing, and vehicles are equipped with air conditioners (AC) which aim to condition and freshen the room air. A cooling machine is equipment used in the process of cooling a fluid so that it reaches the desired temperature and humidity, by absorbing heat from a cold reservoir and giving it to a hot reservoir [7]. The main components of a refrigeration system are the compressor, condenser, expansion device, and evaporator.

The implementation of increasingly advanced developments in air conditioning systems encourages refrigerants to use environmentally friendly and energy-efficient materials. From the refrigerant side, the HCFC type was changed to a more environmentally friendly type, including Propane and R-407C [8]. Meanwhile, in terms of devices, to save electricity usage, inverter types have developed, most of which use R-22 refrigerant [9]. Charging the refrigerant at the right pressure is very important to achieve optimal efficiency and performance from the split AC system. Under- or overcharging pressure can cause a reduction in overall system performance, including cooling efficiency and coefficient of performance (COP). The use of air conditioning (AC) systems has become an important part of modern life, providing comfort and convenience in various sectors starting from households [10], commercial, to industrial. Split AC systems are a popular choice because of their ability to cool rooms efficiently and create a comfortable environment. The performance of a split AC system is greatly influenced by the type of refrigerant used in the cooling cycle [11].

Refrigerant acts as a working medium in the cooling process, absorbing and releasing heat to enable heat transfer and room cooling [12]. However, in recent years, environmental regulations and increased awareness regarding global environmental issues have driven changes in refrigerant selection. Some refrigerants, such as R22, which were once commonly used, have been identified as substances that damage the ozone layer and contribute to global warming [13]. As a result, selecting an environmentally friendly refrigerant becomes very important in designing and operating a sustainable AC system [9]. This research aims to investigate the effect of refrigerant filling pressure on the performance of a split AC system by varying the use of three types of refrigerant, namely R22, R134a, and R290. These three refrigerants were chosen because they each have different characteristics and thermal properties, allowing a comprehensive comparison of the cooling efficiency and overall performance of each split AC system [7]. This research will use an experimental approach by testing various refrigerant charging pressures in the same split AC system for each type of refrigerant. Data will be collected and analyzed to compare the cooling efficiency, power consumption, and overall performance of each system.

The research was carried to know the performance of using refrigerants R-22, R-134a, and R-290 as a comparison material in efforts to save energy and save the environment in the future [14]. This research discusses the comparative performance analysis of 1 PK capacity cooling machines (air conditioners) using refrigerant types R-22, R-134a, and R-290 with different refrigerant filling pressure variations [15]. It is hoped that the results of this research will provide a deeper understanding of how refrigerant charging pressure affects the performance of split AC systems with variations of R22, R134a, and R290. Apart from that, this research can also provide valuable information for industry, manufacturers, and AC users in choosing the optimal refrigerant to optimize the performance, and efficiency of the cooling system, while still paying attention to aspects of sustainability and environmental protection.

2. METHOD

This research uses an experimental design with the independent variable in the form of variations in refrigerant charging pressure and the dependent variable in the form of split AC performance. The research sample consisted of several type 1 PK split AC units with similar capacities, taken from various brands and models commonly used on the market. Research variables include the type of refrigerant used (R22, R134A, and R290) and different refrigerant filling pressures, namely 70 psi, 75 psi, 80 psi, 85 psi, and 90 psi. Split AC performance data was collected by measuring cooling efficiency, electrical power consumption, and the air temperature produced by the split AC under standard test conditions. Data analysis was carried out experimentally by comparing test results for each pressure variation and type of refrigerant. The experimental results will show the effect of refrigerant charging pressure on split AC performance as well as a comparison of split AC performance with three different types of refrigerant. Determining the design and then installing the installation according to the scheme in Figure *1*. T1, T2, T3, T4 are refrigerant temperature measurements, while P1, P2, P3, P4 are refrigerant pressure gauges.

From Figure 1, it can be seen that P1 is the pressure of the refrigerant leaving the evaporator or entering the compressor and T1 is the temperature of the refrigerant leaving the evaporator or entering the compressor.

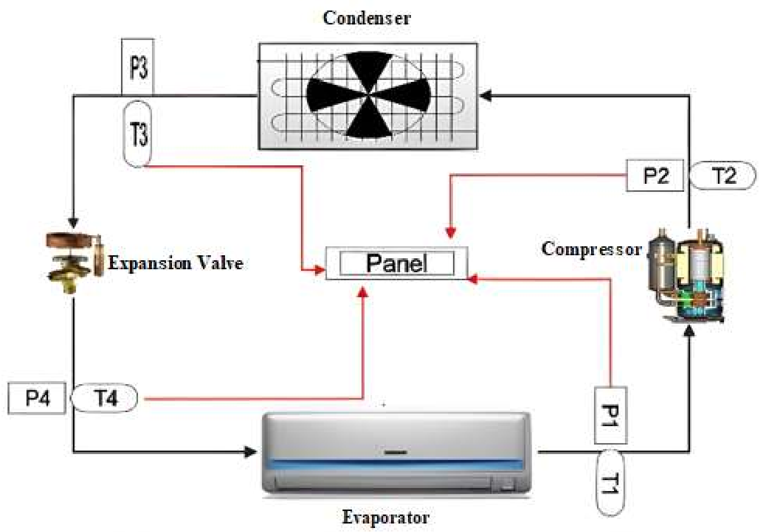

Figure 1. Schematic of the test equipment circuit

P2 is the refrigerant pressure from the compressor or condenser input and T2 is the refrigerant temperature from the compressor or condenser input. P3 is the output refrigerant pressure from the condenser and T3 is the condenser output temperature or expansion valve input. P4 is the output refrigerant pressure from the expansion valve and T4 is the expansion outlet temperature. Split AC performance is measured using COP (coefficient of performance) with the equation:

$$\text{COP} = \frac{q_e}{W} = \frac{h_1 - h_4}{h_2 - h_1} \quad (1)$$

In this research, the performance of a split AC is measured using the Coefficient of Performance (COP) which is calculated based on equation 1, where he is the heat absorbed by the evaporator (in units of kJ/kg), and W is the compression work by the compressor (in units of kJ/kg). kg). To calculate COP, it is necessary to know the enthalpy of the refrigerant at several important points in the split AC working cycle. These points include the enthalpy of the refrigerant leaving the evaporator (h^1), the enthalpy of the refrigerant entering the evaporator (h^4), and the enthalpy of the refrigerant leaving the compressor (h^2).

$$P_{\text{Atm}} = 76 \text{ cmHg} - \frac{h}{100} \quad (2)$$

$$P\_Abs = P\_gauge + P\_Atm. \quad (3)$$

This research method involves analyzing data from split AC tests that use various refrigerant variations. First, atmospheric pressure is determined based on the altitude value of the Wahid Hasyim University Laboratory (Unwahas), which is obtained from Altitude on Google Maps, with a height value of around 19 meters above sea level. Then, atmospheric pressure (P_Atm) is calculated using Equation 2. Next, the amount of enthalpy is calculated using Coolpack software by entering test data, such as pressure and temperature at points P1 and T1, P2 and T2, and P4 and T4. These data are used to create an enthalpy curve and plot it to obtain a Coefficient of Performance (COP) value which reflects the performance of the split AC in testing. The higher the COP value, the more efficient the split AC's performance is in cooling the room by utilizing energy optimally. Thus, the COP value results become an indicator of split AC performance in testing, which can help in evaluating its operational efficiency. The amount of enthalpy is obtained from calculations in Coolpack by entering data obtained during testing, such as pressure and temperature at P1 and T1, P2 and T2, and P4 and T4, and these results are used to produce the enthalpy curve and plot needed for COP calculations.

3. RESULTS AND DISCUSSION

After obtaining data from the split AC test, data analysis will then be carried out to determine the performance of the split AC with a variety of refrigerants.

3.1 R-22 Testing

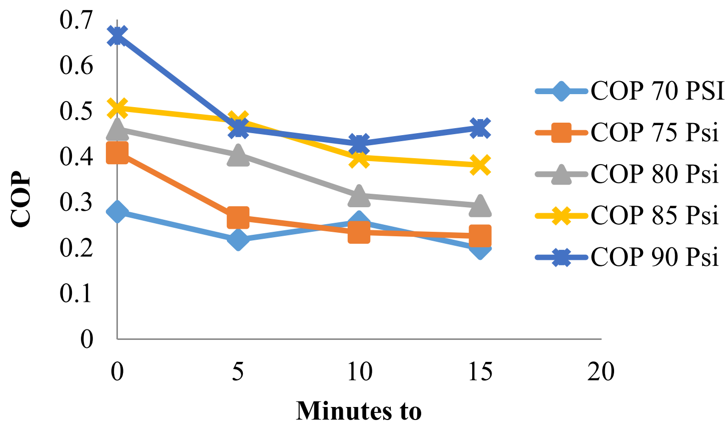

Figure 2. COP image of R-22 refrigerant charging pressure variations

Figure *2* shows the test results using R-22 refrigerant at varying refrigerant filling pressure. Based on this figure, it can be observed that the coefficient of performance (COP) value of the split AC system changes significantly with changes in refrigerant charging pressure. At a filling pressure of 90 psi, the COP value reached the highest value, namely 0.66 at 0 minutes. This shows that at this pressure, a split AC system using R-22 can achieve relatively high efficiency in cooling. However, it should be noted that the COP value decreases as the refrigerant charging pressure decreases. At a filling pressure of 70 psi, the COP value reached the lowest value, namely 0.19 at the 15th minute. This decrease in COP value can be caused by several factors such as decreased compressor efficiency, changes in refrigerant flow performance, or non-optimal system conditions. The results of this analysis show that setting the refrigerant charging pressure affects the overall performance of the split AC system. Therefore, it is important to pay attention to and optimize the refrigerant charging pressure so that the split AC system can operate with better and consistent efficiency.

3.2 R-134a Testing

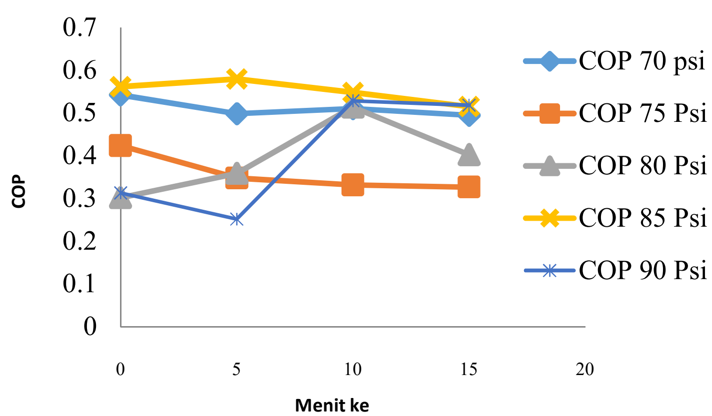

Figure 3. COP image of variations in filling pressure of R-134a refrigerant

Figure *3* shows the test results using R-134a refrigerant at varying refrigerant filling pressure. From this figure, it can be seen that the coefficient of performance (COP) value of the split AC system changes significantly with changes in refrigerant charging pressure. At a filling pressure of 85 psi, the

COP value reached the highest value, namely 0.58 in the 5th minute. This shows that at this pressure, the split AC system using R-134a achieves relatively high efficiency in cooling. However, it should be noted that at a filling pressure of 90 psi, the COP value decreased and reached the lowest value of 0.25 at the 5th minute. A decrease in the COP value at this pressure can be caused by various factors, such as changes in component performance, sub-optimal refrigerant distribution, or other problems in the system. The results of this analysis show that setting the refrigerant charging pressure affects the overall performance of the split AC system using R-134a. It is important to pay attention to and optimize the refrigerant charging pressure so that the split AC system can operate with better efficiency and stability at a certain pressure. Apart from that, it should also be noted that the highest and lowest COP values occur at different filling pressures, which shows that there is a more optimal pressure to achieve the highest efficiency in using R-134a in this split AC system.

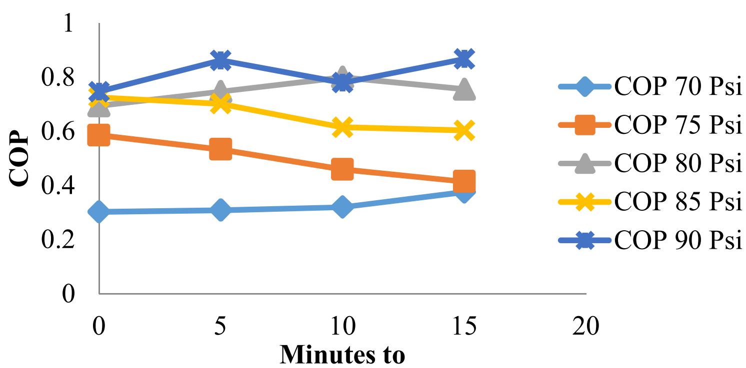

Figure 4. COP variations in R-290 refrigerant filling pressure

In Figure *4*, the R-290 test for the COP value of variations in refrigerant filling pressure, the largest value at a filling pressure of 90 psi, namely 0.86 in the 15th minute, and the lowest value at a refrigerant filling pressure of 70 psi, namely 0.30 in the 15th minute. 0.

3.3 COP value with variations in refrigerant charging pressure

Data from COP calculation results at a refrigerant filling pressure of 70 psi, refrigerant types including R-22, R-134a, and R-290 are shown in Table 1.

Table 1. Relationship between refrigerant type and COP of variations in refrigerant charging pressures of 70 psi

3rd minute	R-22	R-134a	R-290
0	0,27	0,42	0,30
5	0,21	0,34	0,30
10	0,25	0,33	0,32
15	0,19	0,32	0,37

The data in Table *1* shows an interesting relationship between the type of refrigerant (R-22, R-134a, and R-290) with the Coefficient of Performance (COP) at varying refrigerant charging pressure of 70 psi at four different time points (0.5, 10, and 15 minutes). Initially, R-134a had the highest COP, but as testing progressed, R-290 showed efficiency, eventually becoming the refrigerant with the highest COP. This shows that refrigerant efficiency can vary over time. Selection of the right refrigerant in a split AC system can play an important role in achieving optimal performance and energy efficiency. In addition, refrigerant replacement can also have a significant impact on air conditioning performance, which must be carefully considered in the maintenance and retrofitting of the cooling system.

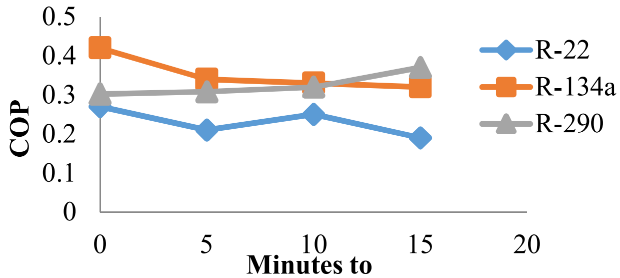

Figure 5. Refrigerant relationship with COP varying filling pressure of 70 psi

In Figure 6, the relationship between the refrigerant and COP for the refrigerant filling pressure at a variation of 70 psi shows that the highest value is 0.42 at the 0th minute for the R-134a type refrigerant and the lowest COP value is 0.19 at the 15th minute for the R-134a type refrigerant. 22. Of the three types of refrigerant used from the 0th minute to the 15th minute, the COP value decreased further.

Data from COP calculations at a refrigerant filling pressure of 75 psi, refrigerant types include R-22, R-134a, and R-290 are shown in Table 2.

Table 2. Relationship between refrigerant type and COP of variations in refrigerant charging pressure of 75 psi

3rd minute	R-22	R-134a	R-290
0	0.40	0.42	0.58
5	0.26	0.34	0.53
10	0.23	0.33	0.45
15	0.22	0.32	0.41

Table 2 reveals various aspects that need to be considered in selecting and using the type of refrigerant in a split AC system at a charging pressure of 75 psi. Initially, R-290 showed highly efficient performance with the highest COP (0.58), outperforming R-22 (0.40) and R-134a (0.42). However, an in-depth analysis of the data revealed that R-290 experienced a significant decrease in efficiency over time, with the lowest COP (0.41) at 15 minutes. Meanwhile, R-134a remained stable (0.32) and R-22 experienced a moderate decrease (0.22). This highlights the influence of time on refrigerant efficiency and shows that refrigerant performance may change significantly over a short period, which needs to be taken into account in the selection of a refrigerant for a particular application. In selecting a refrigerant, apart from looking at the initial COP, it is also necessary to consider the stability of performance under various operational conditions and the desired period of use. Thus, an in-depth understanding of refrigerant characteristics is important in achieving optimal performance and consistent energy efficiency in split AC systems.

Figure 7, the relationship between the refrigerant and COP for the refrigerant filling pressure at a variation of 75 psi shows that the highest value is 0.58 at the 0th minute for R-290 type refrigerant and the lowest COP value is 0.22 at the 15th minute for R-type refrigerant. -22.

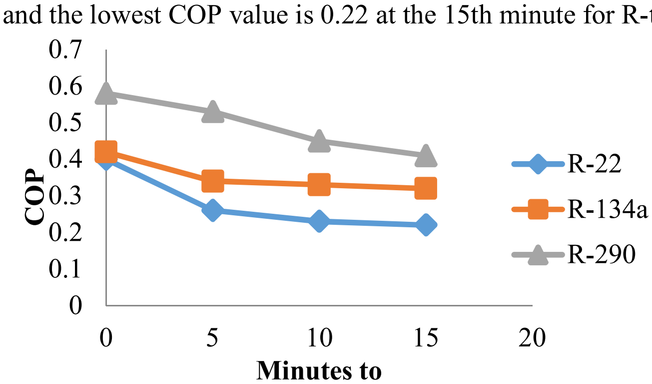

Figure 6. Refrigerant relationship with COP varying filling pressure of 75 psi

The three types of refrigerant used from the 0th minute to the 15th minute, the average COP value decreased further. Data from COP calculation results at a refrigerant filling pressure of 80 psi, refrigerant types include R-22, R-134a, and R-290 are shown in Table 3.

Table 3. Relationship between refrigerant type and COP of variations in refrigerant filling pressure of 80 psi

3rd minute	R-22	R-134a	R-290
0	0.46	0.30	0.69
5	0.40	0.35	0.74
10	0.31	0.51	0.79
15	0.29	0.40	0.75

Table *3* illustrates an interesting relationship between the type of refrigerant (R-22, R-134a, and R-290) with the Coefficient of Performance (COP) at a refrigerant charging pressure of 80 psi at four different time points (0, 5, 10, and 15 minutes) on split AC systems. At the start of testing, R-290 demonstrated very high initial efficiency with the highest COP (0.69), outperforming R-22 (0.46) and R-134a (0.30). Even more interesting, R-290 can maintain its efficiency for a longer period compared to the other two refrigerants. Despite an increase in the COP of R-22 and R-134a during testing, R-290 still had the highest COP (0.75) at 15 minutes. These results highlight the importance of considering the stability of refrigerant performance in selection for split AC applications, especially at charging pressures of 80 psi. R-290, with its high initial efficiency and good stability of performance over a longer period, maybe a more favorable choice for applications that require consistent and efficient performance.

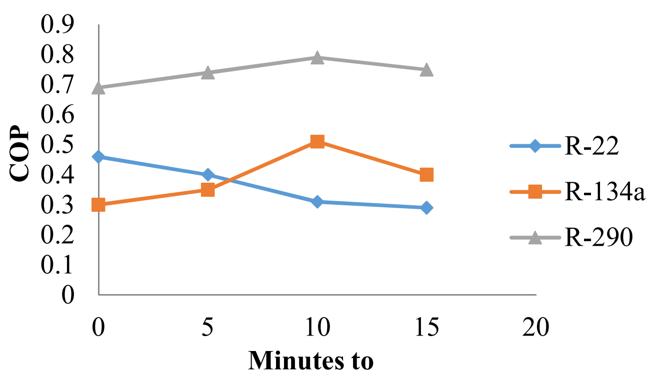

Figure 7. Refrigerant relationship with COP varying filling pressure of 80 psi

Figure 7, the relationship between the refrigerant and COP for the refrigerant filling pressure at 80 psi shows that the highest value is 0.79 at the 10th minute for the R-290 type refrigerant and the lowest COP value is 0.29 at the 15th minute for the R-22 type refrigerant. Of the three types of refrigerant used from the 0th minute to the 15th minute, the average COP value decreased further.

Data from COP calculation results at a refrigerant filling pressure of 85 psi, refrigerant types including R-22, R-134a, and R-290 are shown in table 4. From Table 4, it can be seen that at a variation of filling pressure of 85 psi, the R-290 refrigerant shows performance which is better in split AC systems compared to R-134a and R-22. At all test time intervals (0, 5, 10, and 15 minutes), R-290 had a higher coefficient of performance (COP) than the other two refrigerants. At minute 0, R-290 reached the highest COP value of 0.72, while R-134a and R-22 had COP values of 0.56 and 0.50, respectively. A decrease in COP values occurs over time, but R-290 still maintains higher efficiency. These findings confirm that the use of R-290 as a refrigerant in split AC systems has the potential to increase cooling efficiency and reduce environmental impact.

Table 4. Relationship between the refrigerant type and COP of variations in refrigerant filling pressure of 85 psi

3rd minute	R-22	R-134a	R-290
0	0.50	0.56	0.72
5	0.47	0.57	0.70
10	0.39	0.54	0.61
15	0.38	0.51	0.60

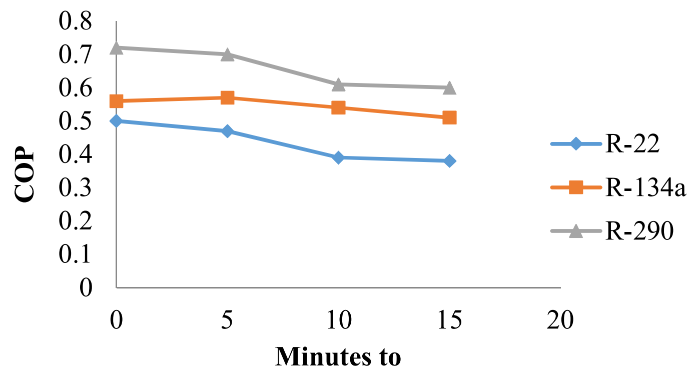

Figure 8. Refrigerant relationship with COP varying filling pressure of 85 psi

Figure 8, the relationship between the refrigerant and COP for the refrigerant filling pressure at 85 psi shows that the highest value is 0.72 at the 0th minute for the R-290 type refrigerant and the lowest COP value is 0.38 at the 15th minute for the R-290 type refrigerant. 22. The three types of refrigerant used from the 0th minute to the 15th minute, the average COP value decreased further.

Data from COP calculation results at a refrigerant filling pressure of 90 psi, refrigerant types including R-22, R-134a, and R-290 are shown in Table 4. From Table 4, it can be seen that at a variation of filling pressure of 90 psi, the R-290 refrigerant shows performance which is superior in split AC systems compared to R-134a, and R-22. At all test minutes (0, 5, 10, and 15 minutes), R-290 had a higher and more stable coefficient of performance (COP) value, with the highest value reaching 0.86 at the 5th minute. Meanwhile, R-134a, and R-22 showed fluctuations in COP values with a more significant decrease. These findings confirm that R-290 is a more efficient and potentially more environmentally friendly refrigerant choice for use in split AC cooling systems at a charge pressure of 90 psi.

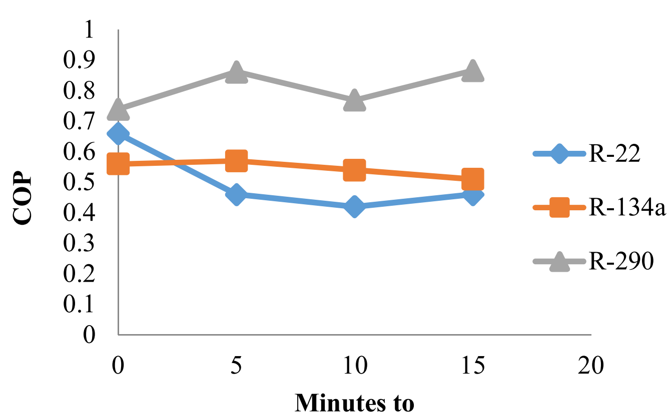

Figure 9. Refrigerant relationship with COP varying filling pressure of 90 psi

The analysis results in Figure 9 show the relationship between the type of refrigerant and the coefficient of performance (COP) value at varying refrigerant filling pressures of 90 psi. In the testing period from the 0th minute to the 15th minute, it can be seen that the average COP value of the split AC system continues to decrease. This indicates a decrease in system efficiency in producing cooling. In the 5th minute, it can be seen that the R-290 type refrigerant reaches the highest COP value of 0.86. R-290 is a natural refrigerant that has environmentally friendly characteristics and very low global warming potential. These results show that at a filling pressure of 90 psi, the use of R-290 can provide more efficient cooling performance compared to R-22 and R-134A. On the other hand, at 10 minutes, refrigerant R-22 showed the lowest COP value of 0.42. R-22 is a refrigerant that is hurt the ozone layer and has high global warming potential. These results indicate that at a filling pressure of 90 psi, the use of R-22 is not efficient in producing cooling when compared to R-290 and R-134A.

The decrease in the average COP value from the 0th minute to the 15th minute shows that the performance of the split AC system tends to decrease over time. Factors such as refrigerant leaks, component performance, and changes in environmental conditions can affect overall system efficiency. In this overall analysis, it can be concluded that at a filling pressure of 90 psi, refrigerant R-290 shows better performance with the highest COP value, while R-22 shows the worst performance with the lowest COP value. During the test period, the performance of the split AC system generally decreased, and this needs to be considered in maintenance and maintenance efforts to maintain optimal efficiency and performance of the system.

As the refrigerant filling pressure increases, the COP value will increase, the highest COP value is for R-290 refrigerant, namely 0.867 at a refrigerant filling pressure of 90 psi in the 15th minute, then R-22 with a COP of 0.66 at a refrigerant filling pressure of 90 psi in the 15th minute. -0 and the lowest COP value is for R-134a refrigerant with the same pressure of 90 psi, namely 0.52 at the 5th minute. The COP value of the three types of refrigerants is still very small, for the COP standard from SNI for air conditioning conservation in buildings, namely a minimum of 2.7 for split ACs above 1/5 PK, several factors are causing the low COP value, namely an AC testing unit that is not new, factory default compressor type for type R-22, and a large testing area so that the compressor works harder.

3 CONCLUSION

Based on this research, it can be concluded that R-290 refrigerant has better performance in split AC systems, with the highest Coefficient of Performance (COP) value compared to R-22 and R-134a. This shows that R-290 is a more efficient and environmentally friendly alternative in the context of environmental stewardship and operational efficiency. Therefore, this research has achieved its objective of comparing the performance of the three types of refrigerants and providing clearer recommendations on selecting appropriate refrigerants for split AC systems for optimal operational efficiency and better environmental impact

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