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Technical Training on Replacement of R410a with R290 in Split Air Conditioners as an Effort to Reduce Global Warming for BLK Instructors in Karawang Regency

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ABSTRACT

Earth's surface temperature continues to rise due to the emission of gases that have a very high GWP (Global Warming Potential). One gas that has a very high GWP is R410A refrigerant, which is 2088. This refrigerant is still widely used in split air conditioners (A/Cs). Therefore, the use of R410A must be immediately reduced and replaced with a more environmentally friendly refrigerant, R290, which only has a GWP value of 3. One of the initial efforts to socialize the use of R290 as a substitute for R410A in split A/Cs was to provide socialization in theory and practice to instructors at the Karawang Regency Vocational Training Centre. A good understanding of environmentally friendly refrigerants by the instructors is expected to be transmitted to the job seekers who are trained and will later be in the business of installing and servicing split A/Cs. Based on direct interviews with the instructors who participated in this socialization and technical guidance, they felt enlightened and motivated to help the government program to reduce emissions of gases that cause global warming. The replacement of R410A refrigerant in split air conditioners with R290 reduced the total global warming impact, i.e. the TEWI (Total Equivalent Warming Impact) value decreased by 31.91%.

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INTRODUCTION

R410A was initially adopted to replace R22 because R22 still had ozone-depleting effects (R Llopis et al., 2012; Petersen & Kujak, 2022; Yu et al., 2021). Although R410A does not have ozone-depleting properties, it still has a very high global warming potential (GWP) of 2088 (Heredia-Aricapa et al., 2020; Tian et al., 2015). Currently, many split air conditioners (ACs) still use R410A, and thus the potential threat of global warming from the refrigeration sector remains significant. One effort to reduce the global warming effect from the refrigeration sector is to replace R410A in split ACs with R290. Replacing R410A with R290 does not require modifications to the installed split ACs; it is sufficient to vacuum the system and then directly replace it with R290. However, because R290 is slightly flammable, its replacement procedure must follow the correct methods. The flammability of R290 occurs at concentrations of approximately 2% to 10% (Li et al., 2020; Ning et al., 2022; Tang et al., 2019). This means that if the concentration of R290 is outside this range, the potential for R290 to catch fire will not occur.

The sales of split AC units in Indonesia in 2023 amounted to approximately 5 million units per year (Detik.com, 2024), with the majority being used in the residential sector. It is estimated that domestic production accounted for 1.2 million units (out of a production capacity of 2.7 million units), with the remaining 3.8 million units being imported (CNBC-Indonesia, 2024). To protect domestic production, the government will limit the import of electronic products, including AC units (CNBC-Indonesia, 2024; Portal-Informasi-Indonesia, 2024).

As for the quantity of split AC units in Karawang Regency, there is no specific data available. However, if we assume that split AC units are used by around 20% of households, then the number of split AC units in use would be approximately 162,000, given that the number of households in Karawang Regency in 2021 was 840,670 (BPS-Kab-Karawang, 2024). If we further assume that each year these split AC units experience leaks, with a refrigerant mass of about 500 grams per unit, then the total mass of refrigerant released into the atmosphere in Karawang Regency would be around 84 tons per year.

Global warming sources from the refrigeration sector originate both directly and indirectly (Cabello et al., 2015; IIR, 2019). Direct contributions come from refrigerant leaks, accounting for 37%, while indirect contributions stem from the input power used by refrigeration machines, accounting for 63% (Cabello et al., 2015; IIR, 2019). Direct contribution reduction can be addressed by replacing refrigerants with more environmentally friendly options, while indirect contribution reduction can be achieved by improving the performance of refrigeration machines, thereby reducing their power input.

This article will provide technical training on replacing R410A with R290 in split AC units for the instructors at the Vocational Training Center (BLK) in Karawang Regency. After replacing R410A with R290, performance testing on the split AC units will be conducted to observe any changes in performance. Based on the replacement and testing of refrigerant R410A with R290, the total impact on global warming from these AC units can be calculated, both directly and indirectly, using the Total Equivalent Warming Impact (TEWI) equation (Cabello et al., 2015; IIR, 2019; Shikalgar & Sapali, 2019).

METHOD

The technical training on the replacement of refrigerant R410A with R290 in split AC units was conducted at the Vocational Training Center (BLK) of the Department of Manpower and Transmigration in Karawang Regency. The participants of this technical training were several instructors working at the BLK. Before the practical session on replacing refrigerant R410A with R290, the participants were provided with theoretical materials about the characteristics of refrigerants R410A and R290. A similar activity has been conducted by Muliawan et al. (2022) at a vocational high school in Tasikmalaya, West Java.

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The aim of this technical training for the instructors at BLK is to enable them to impart the knowledge provided by the lecturers from the Department of Refrigeration and Air Conditioning, Politeknik Negeri Bandung, to job seekers who routinely undergo job training at the BLK each year before they work in a company, industry, or become self-employed. The stages of the training is presented in the flowchart of Figure 1.

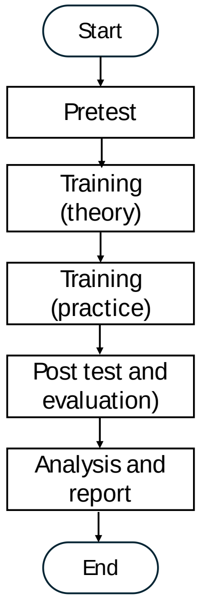

FIGURE 1. Flow chart of training process.

Figure 2 shows the instructors during the practical session of replacing refrigerant R410A with R290. Before the refrigerant replacement, the training participants collected data on various temperatures and working pressures of the split AC while it was using R410A. The purpose of this data collection was to quantitatively assess the performance of the split AC when using R410A. After obtaining the necessary data to evaluate the performance of the split AC with R410A, the next step was to remove the R410A refrigerant from the split AC and replace it with R290.

FIGURE 2. BLK Instructors in Karawang Regency are preparing for the practical session on replacing refrigerant from R410A with R290 in split AC units.

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Once the R290 was properly charged following the correct procedures, the same tests were conducted as when the split AC used R410A. This included measuring temperatures and working pressures at the same points used for the R410A measurements.

Based on the data collected from the split AC units while using R410A and R290, the instructors were taught how to compare the performance of each split AC. The performance metrics calculated in this activity include the refrigeration effect, compressor work, and COP (coefficient of performance). The refrigeration effect, compression power, and COP are calculated using equations (1), (2), and (3) (Sumeru et al., 2022, 2023). The enthalpy values in equations (1), (2), and (3) are obtained using a Ph (pressure vs. enthalpy) diagram, as shown in Figure 3.

Refrigeration Effect (Q_e): This is calculated using the equation:

$$Q_e = (h_1 - h_3) \tag{1}$$

Compressor Work (W_C): This is calculated using the equation:

$$W_c = (h_2 - h_1) \tag{2}$$

Coefficient of Performance (COP): This is calculated using the equation:

$$COP = \frac{Q_e}{W_c} = \frac{(h_1 - h_3)}{(h_2 - h_1)} \tag{3}$$

where

Q_e : Refrigeration effect (kJ/kg)
W_c : Work of compression (kJ/kg)
COP : Coefficient of Performance
h_1 : Enthalpy of refrigerant at point 1 (kJ/kg)
h_2 : Enthalpy of refrigerant at point 2 (kJ/kg)
h_3 : Enthalpy of refrigerant at point 3 (kJ/kg)

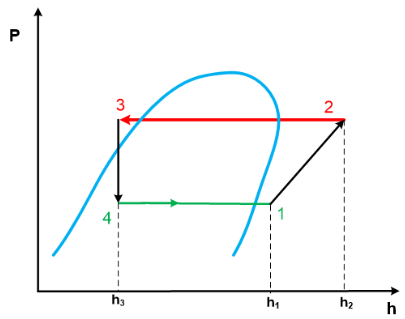

FIGURE 3. Refrigeration cycle in Ph diagram.

The Ph diagram (pressure vs. enthalpy diagram) is utilized to find the specific enthalpy values at various points in the refrigeration cycle. This enables the accurate calculation of the refrigeration effect, compressor work, and COP for both refrigerants, providing a clear comparison of their performance.

The replacement of refrigerant R410A with R290 will reduce the impact on global warming both directly and indirectly. To calculate this impact on global warming, the Total Equivalent Warming Impact (TEWI) equation is used (Cabello et al., 2015; IIR, 2019; Shikalgar & Sapali, 2019), which is:

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$$TEWI = TEWI_{dir} + TEWI_{ind} = (GWP.M.L.n) + GWP.M.(1-\alpha)) + (E_{el}.\beta.n) \quad (4)$$

where

M : Refrigerant charging (kg)
L : Leak rate per year (kg)
n : operational lifespan of refrigeration machines (year)
α : Recovery factor
E_{el} : Electrical energy consumption per year (kWh)
β : Indirect emission factor

RESULTS AND DISCUSSION

Change in Refrigeration Effect

The instructors, after being equipped with theory regarding the working principles of refrigeration systems in split AC units and the method of replacing refrigerant from R410A to R290, are further instructed to conduct data collection. The primary objective of this data collection is to directly observe and understand the changes in various parameters of the split AC units following the refrigerant replacement. The instructors are also expected to illustrate the refrigerant process inside the split AC units on a Ph diagram. Through this Ph diagram, quantitative calculations can be made to determine the increase or decrease in the parameters of the split AC units due to the refrigerant replacement. Equipping the instructors with the theory of split AC unit operation principles and correct refrigerant replacement procedures will boost their confidence and provide them with teaching materials when instructing job seekers.

refrigeration effect. The refrigeration effect is the ability of the refrigerant inside the evaporator to absorb heat per unit mass present in the room. When the refrigeration effect increases, it means that the refrigerant in the evaporator is capable of absorbing more heat. Figure 4 illustrates the comparison of refrigeration effects between R410A and R290. It can be seen in the figure that the refrigeration effect of R290 is 292.1 kJ/kg, significantly higher than that of R410A, which is only 165.5 kJ/kg. This implies that for the same mass flow rate, the evaporator of an AC unit using R290 is capable of absorbing more heat compared to R410A. Therefore, the replacement of refrigerant from R410A to R290 in split AC units will not only reduce the impact on global warming but also increase the refrigeration effect of the AC units.

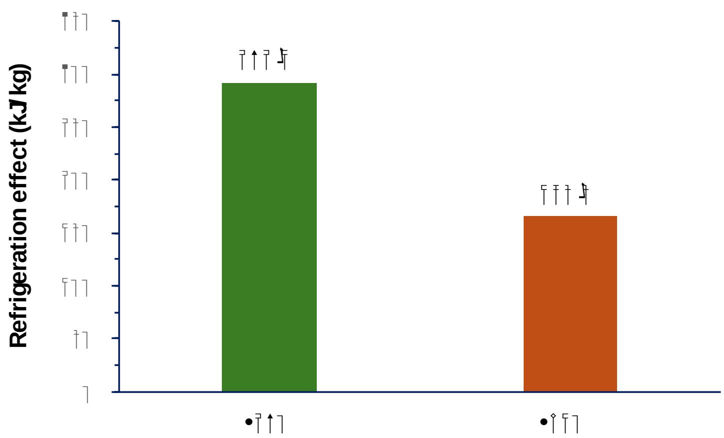

FIGURE 4. Refrigeration effect of system with R410A and R290.

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Changes in Compression Work

Another performance aspect of split AC units is compression work. Based on Figure 2, compression work is the work done by the compressor to compress the refrigerant. The calculation to determine compression work uses equation (2). The results of this calculation are shown in Figure 5. It can be seen in the figure that the compression work using R290 is 72.3 kJ/kg, which is higher than R410A, which is 44.5 kJ/kg. This means that for the same refrigerant filling mass, R290 requires a higher electrical power.

In refrigerant replacement in AC units, the reference used is the equation for the same refrigerant filling volume. This means that if the replacement refrigerant has a lower density than the refrigerant being replaced, then the filling mass is lower. The filling mass of the replacement refrigerant is the ratio of the density of the replacement refrigerant to the density of the replaced refrigerant. Since the density of R290 is approximately 0.77 of the density of R410A, the filling mass of R290 is also about 0.77 of the filling mass of R410A. This means that the electrical power required for AC units using R290 can be lower than when using R410A because the compression work is lower due to the lower filling mass of R290 compared to R410A.

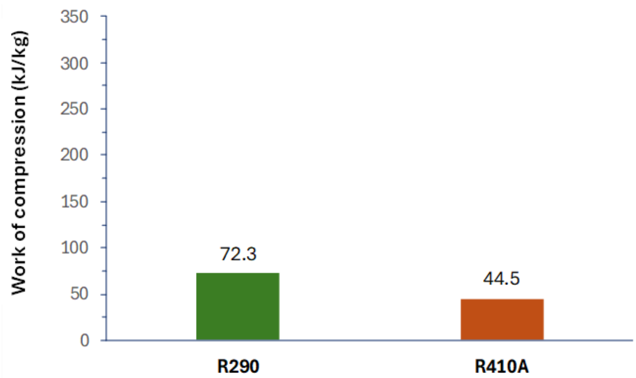

FIGURE 5. Work of compression of system with R410A and R290.

Changes in COP Value

The COP value is calculated using equation (3), which compares the refrigeration effect in the evaporator with the compression work used to drive the compressor in the split AC unit. The COP value is commonly used to indicate the performance of an AC unit, where a higher COP value indicates that the AC unit is more efficient than one with a lower COP value. The maximum value of efficiency is 1, while the COP value can be greater than 1. For AC units, the COP value typically ranges from 3 to 5. This means that a COP value of 3 indicates that if the power input of the AC unit is 1 kW, then the evaporator of the AC unit is capable of absorbing heat from the room at a rate of 3 kW.

A comparison of COP values for split AC units when using R410A and R290 can be seen in Figure 6. As shown in the figure, the COP value for R290 is 4.04, which is higher than R410A, which is 3.72. This means there is an increase in COP of 8.6% for the split AC unit when replacing R410A with R290. This implies that the monthly electricity cost for split AC units using R290 is 8.6% more economical compared to using R410A. The testing conducted in this activity has proven that, besides reducing the impact on global warming, replacing R410A with R290 in split AC units can also reduce monthly electricity consumption by 8.6%.

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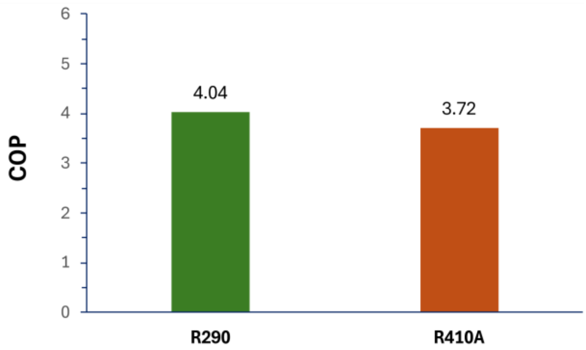

FIGURE 6. COP of system with R410A and R290.

Changes in TEWI Value

As previously mentioned, the primary objective of replacing R410A with R290 is to reduce the global warming impact due to refrigerant leakage in AC units. The GWP value of R410A, which is 2088, is significantly higher than R290, which is only 3. Therefore, it is reasonable to expect that replacing R410A with R290 will directly reduce the global warming impact. The global warming impact due to refrigerant leakage is referred to as direct impact. Meanwhile, the impact due to the decrease in electricity consumption is considered an indirect impact. The calculation of direct and indirect impacts on global warming from split AC units due to the replacement of R410A with R290 is calculated using equation (5). By using the testing data discussed above and data from several references (Rodrigo Llopis et al., 2020; Shikalgar & Sapali, 2019; Vaccaro et al., 2024), the direct, indirect, and total TEWI values are shown in Table 1. From the table, it can be seen that the GWP value of R410 is much higher than R290, i.e., 2088 compared to 3.

From Table 1, it is evident that the direct TEWI value due to the replacement of R410A with R290 decreases dramatically, from 7,929.38 to only 1.35, or a decrease of approximately 99.98%. Meanwhile, the decrease in indirect TEWI value is not as significant compared to direct TEWI. Indirect TEWI decreases by 8.20%, from 23,159.3 to 21,167.6. Meanwhile, the total TEWI value decreases by 31.61%, from 31,088.63 to 21,168.95. This means that although the difference in GWP values between R410A and R290 is significant, the total global warming impact decreases by only 31.91%. This is because the decrease in indirect TEWI value is not as significant, even though the decrease in direct TEWI value is very large.

TABLE 1. TEWI values

Parameter	R410A	R290
GWP	2088	3
L = Leak rate per year (kg)	0,245	0,0845
n = Operational lifespan of AC (year)	15	15
M = Refrigerant charging (kg)	0,49	0,169
α = Recovery factor	0,8	0,8
E_{el} = Energy consumption per year, kWh	3285	3022,2
β = Indirect emission factor	0,47	0,47
TEWI *Direct*	7.929,38	1,35
TEWI *Indirect*	23.159,3	21.167,6
TEWI Total	31.088,68	21.268,95

CONCLUSION

After participating in this technical training, the instructors understand the working principles of split AC units. In addition to understanding the principles of split operation, the instructors can also perform the refrigerant replacement procedure correctly and safely. The instructors are also able to assess the

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performance of split AC units by measuring temperature and pressure at specific points in the unit. Based on the measurement results, it is shown that replacing refrigerant R410A with R290 can increase the COP value by 7.6% and reduce the total global warming impact (TEWI) by 31.61%. The fact that the COP value increases and the total TEWI value decreases in split AC units due to the replacement of R410A with R290 obtained during the technical training for BLK instructors in Karawang Regency is expected to be transmitted to job seekers. Thus, the Karawang Regency BLK has contributed to efforts to reduce global warming in the air conditioning sector.

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