

# Experimental Study of R32 as a Retrofit for R410A Refrigerant in a Residential Air Conditioner

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## ABSTRACT

This study evaluates the performance of a residential air conditioner (A/C) using R32 as a retrofit for R410A. One of the biggest challenges in the retrofitting is to determine the ideal mass of refrigerant, which eventually lead to optimum performance of the system. The theoretical mass of refrigerant charging in this retrofitting analysis was determined using the density ratio of alternative (R32) to the existing (R410A) refrigerants. To achieve the optimum performance, the mass of refrigerant charging was varied between 90, 95, 100 and 105% from the theoretical mass of refrigerant charging. The experiments were carried out using a 2.5 kW split type A/C. The results show that the replacement of R410A with R32 decreases the COP at all refrigerants charging. The highest COP of A/C with R32 was achieved during mass of refrigerant charging of 95%. In this condition, the COP only decreased by 5.1%. The decrement in COP is caused by an increase in input power of the A/C. Consequently, it is not recommended replacing R410A with R32 in the A/Cs that originally is designed for R410A.

**Keywords:** Air conditioning, retrofit, performance, refrigerant R410A, R32

## 1. INTRODUCTION

The most important issues related to vapor compression refrigeration system are the ozone layer depletion and global warming [1-3]. In order to protect the environment, the regulations on the refrigerants have become stricter. Nowadays, refrigerant from the group of hydro-chlorofluorocarbon (HCFC), which is R22 is widely used in Indonesia. However, since 2015, the use of R22 is prohibited in a new residential air conditioner [2], and must have been replaced by hydro-fluorocarbons (HFCs) type of refrigerant, such as R410A and R32. According to Montreal Protocol, the developed countries will phase out the HCFC refrigerants, whereas in the developing countries, the phased out of those refrigerants is scheduled in 2030 [1,4-5].

As current alternative refrigerant to R22, R410A also has zero ozone depletion potential (ODP = 0), but it has high global warming potential (GWP = 1725) [2,6-8]. In contrast to R22 and R410A, the R32 has lower global

warming potential (GWP = 675) [2,9]. As a result to meet dual environmental demands of the zero ODP and low GWP, R32 is expected to be an alternative refrigerant for residential A/Cs in the future.

Table 1 shows the properties of four refrigerants: R22, R410A, R134a and R32. It shows that the GWP of R410A (GWP = 1430) is approximately 112% higher than compared to R32 (GWP = 675). It indicates that the use of R32 will significantly reduce the negative impact of this refrigerant to the environment.

In order to investigate the performance of R32 in a domestic refrigerator, Bolaji [10] replaced the existing refrigerant (R134a) with R32. The experimental study reported that the replacement of R134a with R32 in a domestic refrigerator decreased the COP by 8.5%. Despite the decrease in performance, the use of R32 reduces the negative impact to the environment by more than a half, due to low GWP of R32 (GWP = 675), as compared to R134a (GWP = 1430). Based on the study,

they concluded that the replacement of R410A with R32 in a domestic refrigerator decreased the system performance.

**Table 1.** Refrigerant properties [1,2]

Refrigerant	Composition	Normal Boiling Point (°C)	Critical Temperature (°C)	GWP (100-year)
R22	Pure fluid	-40.8	96.2	1700
R410A	R32(50%): R125(50%)	-51.5	72.5	1725
R134a	Pure fluid	-26.1	101.1	1430
R32	Pure fluid	-48.3	78.1	675

Different results obtained by Xu et al. [11]. They reported that the use of R32 in a vapor-injected heat pump increased the cooling capacity and the COP by 10% and 9% compared to R410A. Their study also concluded that to enhance the system performance, the R32 can be utilized as a refrigerant alternative to replace R410A on the heat pump.

In spite of R32 has a low GWP, however scientific papers that discuss R32 as a retrofit for R410A in residential A/Cs are still limited. Therefore, it is the aim of the study to obtain the ideal mass of refrigerant charging of R32, when it is used as a retrofit for R410A on the split-type A/C.

**2. METHODOLOGY**

Experimental study was carried out on a split type air conditioner with the cooling capacity of 2.4 kW, which originally was designed for R410A. The first test was carried out in the A/C with 750 grams of R410A. Then, the refrigerant of R410A was evacuated and replaced by R32 for four different mass of refrigerant charging. Four parameters will be measured during this experimental study, i.e., temperature, pressure, electric voltage and electric current.

Densities of R32 and R410A at temperature of 5°C on the saturated vapor are 25.769 and 34.843 kg/m<sup>3</sup>, respectively. As a result, the density ratio R32 to R410A is 0.743. It means that when the R410A is replaced with R32, the mass of refrigerant charging is 750 g × 0.743 = 557.3 g. The mass of refrigerant of 557.3 gram in this study is defined as 100% of refrigerant charging or theoretical refrigerant charging. Furthermore, the next three masses of refrigerant charging of R32 with 90, 95 and 105% from theoretical value are calculated at 501.6, 529.4 and 585.2 grams, respectively.

During experiments, the indoor and outdoor temperatures are kept constant, which is 5°C and 34°C, respectively. The data are recorded at steady state

condition that is the indoor temperature does not change 0.3°C for 15 minutes.

The cooling capacity and the input power are calculated using equation:

$$Q = \dot{m} (h_2 - h_1) \tag{1}$$

$$W = V \cdot I \tag{2}$$

where,

$Q$  = cooling capacity, Kw

$\dot{m}$  = mass flow rate of indoor air, kg/s

$h_1$  = specific enthalpy of indoor air, kJ/kg

$h_2$  = specific enthalpy of leaving air on the cooling coil, kJ/kg

$W$  = input power, kW

$V$  = electric voltage, V

$I$  = electric current, A

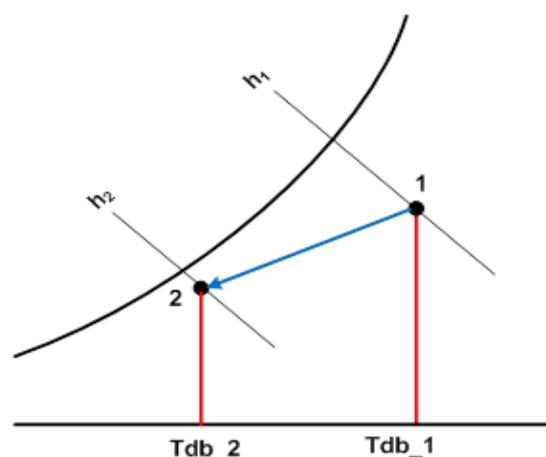
Furthermore, the coefficient of performance (COP) is calculated using equation,

$$COP = \frac{Q}{W} \tag{3}$$

The COP reduction due to drop-in replacement from R410A to R32 is calculated using equation,

$$COP_{red} = \frac{COP_{R410A} - COP_{R32}}{COP_{R410A}} \tag{4}$$

The values of  $h_1$  and  $h_2$  are obtained using psychrometric chart as shown in Figure 1. Where, Tdb\_1 and Tdb\_2 are dry bulb temperatures of leaving air on the cooling coil and indoor air, respectively.

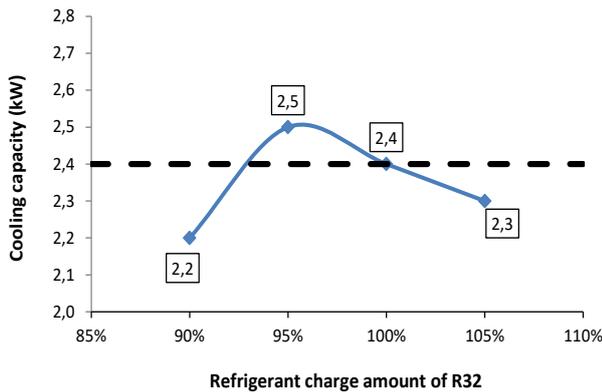


**Figure 1** Air process in the psychrometric chart to determine the cooling capacity

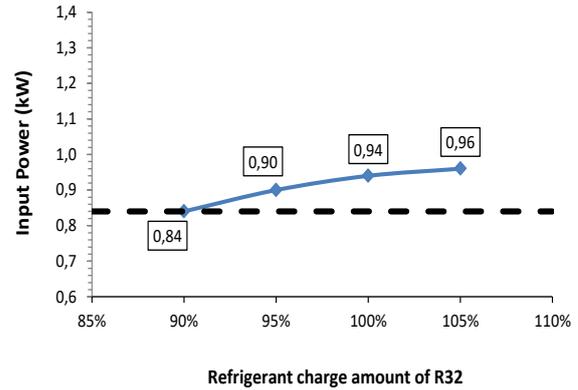
### 3. RESULTS AND DISCUSSION

Figure 2 illustrates the correlation between cooling capacities and four different refrigerants charging of R32, i.e., 90, 95, 100 and 105%. As described above, the refrigerant charging of 100% is 557.3 g of R32. The figure shows that when the A/C is filled with 90% (501.6 g) of R32, the cooling capacity is 2.2 kW. It is lower than that of the cooling capacity of A/C when using R410A as refrigerant (standard system), which is 2.4 kW (shown by dash line). When the mass charging of R32 is increased to 95% (529.4 g), the cooling capacity increases 2.5 kW, or 0.1 kW is higher than that of the standard system. At 100% (557.3 g) of R32 is charged to the A/C, the cooling capacity decreases compared to the previous filling (95%), and the cooling capacity is the same with the standard system, which is 2.4 kW. The cooling capacity continues decreasing when the mass refrigerant charging is increased. Based on the figure indicates that to obtain the highest cooling capacity, the mass of refrigerant charging is 95% of the density ratio R32 to R410A.

Figure 3 depicts the correlation between input powers and four different refrigerants charging of R32, i.e., 90, 95, 100 and 105%. The figure shows that the trend of the line in the figure is different from the previous figure (Figure 2). In Figure 3, the input power enhances when the mass of refrigerant charging increases. The increase in the input power with increasing mass of refrigerant charging is caused by increasing mass flow rate of refrigerant in the system. In terms of energy saving, the lower the input power, the better the system. However, as explained above, at mass of refrigerant charging of 90%, the A/C only generated the cooling capacity of 2.2 kW, lower than that of the standard system. As a result, the line trend in the Figure 3 cannot be used as a reference.



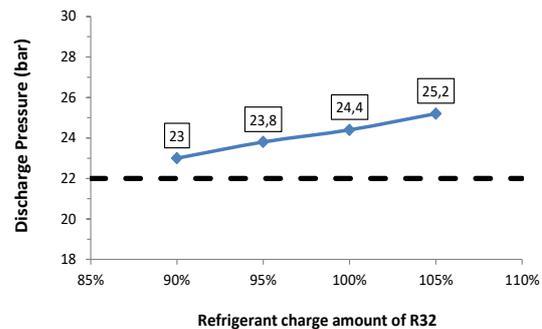
**Figure 2** The variation of cooling capacity for various mass of refrigerant charging of R32



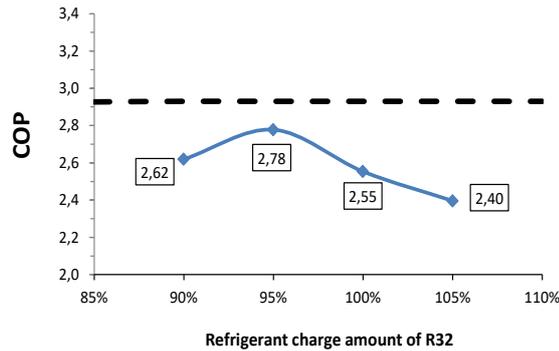
**Figure 3** The variation of input power for various mass of refrigerant charging of R32

The increase in mass flow rate leads to the increase in the discharge pressure, as shown in Figure 4. The increase in the discharge pressure causes electric current increment. As a result, the input power increases, as well. Because the input power is calculated using Eq. (2), the line trend on Figure 4 is similar to Figure 3 because during measurement the electric voltage is constant, whereas the values of the electric current follow the discharge pressure.

In terms of energy consumption of A/C, the COP can be applied to determine the performance of the system. Using Eq. (3), it indicates that the higher the COP the more efficient the system. Figure 5 illustrates the correlation between the COP and four different refrigerants charging of R32. The figure shows that the COPs of four mass of refrigerant charging are lower than that of standard system. It indicates that drop-in replacement of R410A with R32 in the A/C that originally is designed for R410A will not generate higher COP. As shown in Figure 5, the highest COP of the A/C using R32 occurs at mass of refrigerant charging of 95%. The refrigerants charging under and higher of 95% generate a lower COP. The results indicate that drop-in substitution of R410A with R32 reduces the COP due to increase in input power. Although in Figure 2 shows that at 95%, the cooling capacity of R32 is higher than that of R410A, but the increment of input power at this charging (95%) is higher than that of the increment of the cooling capacity. It causes a decrease in COP.

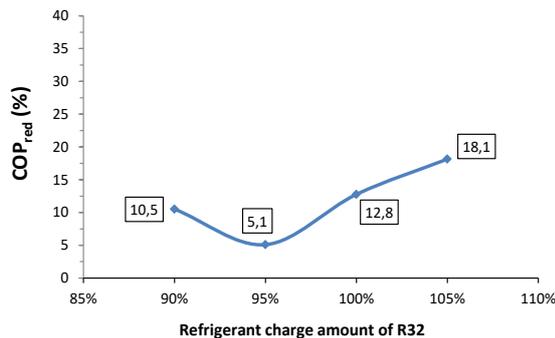


**Figure 4** The variation of discharge pressure for various mass of refrigerant charging of R32



**Figure 5** The variation of COP for various mass of refrigerant charging of R32

Using Eq. (4), the COP reduction for four different mass of refrigerant charging can be calculated. Fig. 6 shows that because there are no COP improvements due to drop-in replacement. The lowest COP reduction occurs at 95%, which is 5.1%. It indicates that the COPs of R32 for all drop-in are never higher than that of R410A. It means, in terms of energy saving, it is not recommended to drop-in replacement in A/Cs that originally is designed using R410A with R32. However, because R32 has much lower GWP than that of R410A, retrofitting from R410A to R32 on the residential A/C is possible to apply.



**Figure 6** The variation of COP reduction for various mass of refrigerant charging of R32

#### 4. CONCLUSION

Performance evaluation of a residential A/C using R410A replaced by R32 has been presented in this paper. In order to obtain optimum performance, the mass of refrigerant charging is varied from 90% to 105% of the density ratio R32 to R410A. Drop-in replacement of R410A to R32 resulted in a maximum cooling capacity when the mass of refrigerant is 95% (529.4 g). At this mass of refrigerant charging, the cooling capacity of R32 was higher than that of R410. For four masses of refrigerant charging, the COPs of R32 were always lower than that of R410A. As a result, in terms of energy saving, it is not recommended to drop-in replacement of R410A to R32 in residential A/C. However, in terms of environmental control, it is strongly recommended,

because the GWP of R32 is much lower than that of R410A.

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