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Analysis of the Effect of R1270 Refrigerant Pressure on a 12,000 Btuh Capacity Split Air Conditioning on the Performance of the Refrigeration System as an Alternative to R32

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Abstract. Synthetic refrigerant R32 is quite widely used in Split AC cooling machines because it does not contain ozone-depleting materials, but still contains quite high fluoro elements. Fluoro in R32 causes global warming, this is a special concern for developed and developing countries including Indonesia. The fluoro content in R32 is 675 equivalents to 675 kg of CO_2. While R1270 is a natural refrigerant, does not contain chloro and fluoro elements, excellent thermodynamic properties, but has flammable properties at a threshold of 2% -10%. This study used a Split AC with a capacity of 12,000 Btuh using R32 refrigerant. This test equipment is equipped with temperature and pressure measuring devices on the suction and discharge sides at the inlet and outlet of the compressor and in a room with a temperature of ±32°C, air humidity of ±80%, for the condenser placed outside the room with a temperature of ±35°C. Testing was conducted by varying the suction pressure of R1270 from 80, 90, and 100 psig, while R32 was at the manufacturer's standard pressure of 115 psig. Data collection was conducted after the AC unit had operated stably and recorded for 60 minutes. Pressure, temperature, and electrical power data were recorded using a data logger for each type of refrigerant, R32 and R1270. The results of air testing on the evaporator side average R32/R1270: 19.8/19.9 °C, condenser outlet air temperature: 35.5/31.7°C, refrigeration effect: 265/314.8 kJ/kg, compression work: 45/60.4 kJ/kg, heat wasted in the condenser: 31/371.9 kJ/kg 14.9% greater than R32, COP R32 is 14.6% greater than R1270, electricity consumption saves 28.6% higher than R1270: 3.5/2.5W. The R32 evaporator air temperature is 0.5°C cooler than R1270. The cooling effect of R1270 is 12.8% higher than R32. The compression work of R1270 is 34.2% higher compared to R32. The R1270 refrigerant in this Split AC can save electricity consumption and reduce the GWP value from 675 to 3. From the results of the tests and calculations carried out, R1270 can be used as an alternative to R32 in the future. The use of hydrocarbon refrigerants in general requires guidelines and charging procedures according to standards so that the resulting performance is better and safer for the environment.

Keywords: hydrocarbon refrigerant; GWP; COP; R32; R1270

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1. Introduction

Refrigerant R32 as a synthetic coolant that is widely used in split type Air Conditioning. R32 is included in the synthetic refrigerant group replacing the R22 and R410A generations that were previously used in Split type AC. R32 has the lowest GWP value of 675 compared to R22 and R410A(1). Policies related to the Global Warming Potential (GWP) value of each refrigerant include R134A, R410A and R404A used in air conditioning refrigeration systems against the GWP value limit(2). The use of CO2 as an environmentally friendly alternative refrigerant for use in cascade cooling machines fueled by HFC (hydro fluoro carbon) which has an impact on global warming in

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addition to being able to reduce discharge temperature and electricity consumption by 4.3% COP 2.1% (3).

The use of a zeotropic mixture as a working fluid to achieve non-isothermal phase changes through the evaporator and condenser results in a higher coefficient of performance (COP) compared to other heat pump technologies operating within the same temperature rise and capacity range. Research results show that the COP increase reaches up to 30%(4). The restriction on GWP values by European Union policy No. 2024/573 on Fluorinated Greenhouse Gases, known as the F-Gas policy, was announced on February 20, 2024, and came into effect in European Union countries on March 11, 2024(5). The use of refrigerant R1270 as a CO2 (R744) mixture resulted in an average COP decrease of ±20% compared to R32 with a 19% mixture, but the mixture with R1270 had an increase in cooling capacity of ±21.5%. The hydrocarbon refrigerant R1270 has the potential as a replacement mixture refrigerant for R744(6).

When a mixture of R744-R134a and R744-R1270 was applied to a heat transfer device, the overall performance results were 2.2% higher than the COP of the R134a mixture, but the energy content of R1270 was approximately 50% higher, impacting cooling capacity. The discharge temperature increased by 2-7°C compared to R134a. R1270 has a higher pressure than R290 and can reduce CO2 emissions (7). Comparison of evaporation analysis of R600a and R1270 in a very small pipe. From the test results using a 5mm outer diameter pipe with an inner diameter of 1.51 and 2.63 at a vapor temperature of 5.10 and 20°C, R1270 has a lower pressure drop than R600a (8). The effect of energy on the internal heat exchanger on the R1270/R134a mixed refrigerant generally has higher thermodynamic properties and heat effectiveness increasing by 4.8% and 2.6% COP for COP is positive but still better than the synthetic refrigerant mixture compared to the R290 and R600a mixture (9).

Comparison of energy values in the combination of CO2 with synthetic and hydrocarbon refrigerants in cases in the refrigeration system. Refrigerant R290 and R1270 have a greater cooling capacity than the combination with R134a and R1234zeE. While for the combination of synthetic refrigerants is more efficient at cooling temperatures of 20° and 30°C. For COP refrigerants R1270 and R290 is higher than synthetic (10). Replacing R22 with R290 and R1270 in Air conditioning capacity of 2.4 kW experienced an increase in cooling performance of 2.4% and no need for replacement of the type of cooling oil in the compressor as well as an increase in the efficiency of the energy ratio of 13.9-17.6% (11). Exergy and energy analysis in the R410A vapor compression system replaced with hydrocarbon refrigerant R290. R290 has several advantages, including reducing electricity consumption, condenser pressure, and the amount of refrigerant mass used. The COP of R290 is higher than that of R410A at a mass charge of 50% of the R410A mass. The exergy destruction in the R410A evaporator is 30%-50% greater than that of R290 (12).

The use of mixed refrigerant R290/R32 as an alternative to R410A provides a positive performance impact, especially on the refrigeration effect in the evaporation area, more efficient electricity consumption and reduces the impact of global warming because R290 has a GWP value of only 3 compared to R410A (13). The potential of refrigerant R290, R1270, R600A to replace R22 and R32 and refrigerants containing fluoro is quite high. R1270 has a higher working pressure than R290 (14). Mixed refrigerant groups A3, A2 Low and low GWP below 150, are then mixed to reduce the high GWP value, for which a synthetic refrigerant mixture is required. Only hydrocarbon refrigerants will be mixed with A2 and A2L refrigerants, with a mass limit of 500-1200 grams when charging(15). Several studies have yielded nearly identical results: R1270 has the potential to be used as a refrigerant for blending with several synthetic refrigerants, has a very low GWP value, has a relatively high enthalpy, and, in some studies, can increase COP and energy savings. Therefore, this study aims to complement previous research, particularly on R1270 for use in split-air conditioners as an alternative to R32.

2. Methodology

To ensure the performance of this type of Split AC cooling machine, a method is required through testing and data collection from each main component of the refrigeration system. Before testing, the Split AC unit is first assembled and equipped with the addition of a temperature testing room in the condenser (outdoor unit) and evaporator (indoor unit). The condenser and evaporator temperatures are maintained stable at 35°C and 27°C. Pressure measurements are taken from four points: suction pressure, discharge on the compressor and inlet and outlet expansion pressure using a manual pressure gauge. A detailed tool testing diagram is explained in Figure 1.

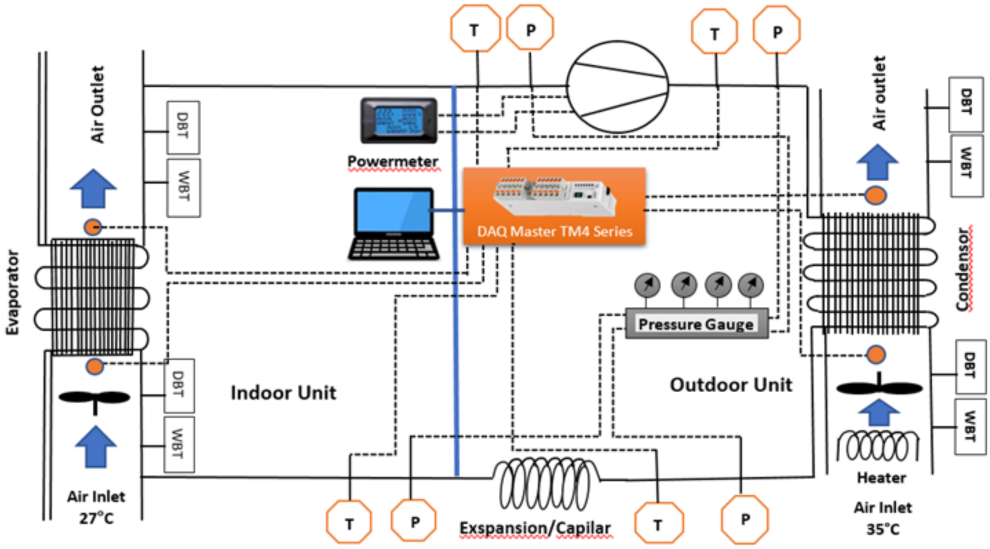


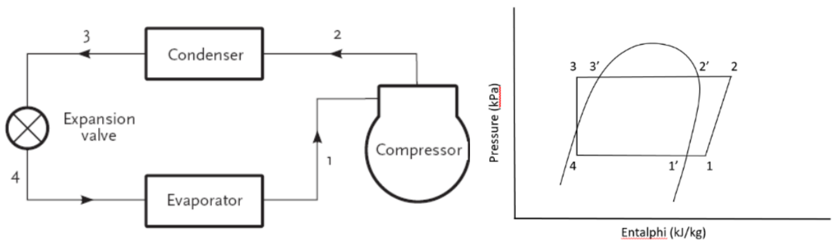
Figure 1. Equipment testing diagram

Room temperature and electrical power test data were collected using an Arduino data logger, while working pressure was measured using a manual pressure valve. Data collection was performed after the split-AC unit had been operating stably and data collection was carried out for 60 minutes. The thermodynamic properties of the refrigerant have a significant influence on the performance of each main component of the vapor compression system. In general, the properties of the refrigerant are described in Table 1.

Table 1. Properties of the refrigerant

Thermodynamic Properties	R32	R290	R1270
Molecular weight (g mol^{-1})	52.0	44.0	42.1
Normal boiling point (°C)	-51.6	-42.1	-47.7
Critical temperature (°C)	78.1	96.9	92.6
Critical pressure (kPa)	5782.0	4251.2	4664.6
Density (kg/m^3)	1037.0	440.48	421.01
GWP	675	3	2

The vapor compression refrigeration system consists of four main components: a compressor, a condenser, an expansion valve, and an evaporator. The vapor compression diagram and P-H diagram are shown in Figure 2a and Figure 2b.



(a) (b)

Figure 2. (**a**) Vapor compression cycle (**b**) P-H diagram

3. Equations

To determine the performance of each main component in a system, use the following formula:

1. Isentropic compression in compressor (Process 1-2)

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

2. Isobaric heat rejection in condenser (Process 2-3)
$$Q_c = (h_2 - h_3) \quad (2)$$
3. Isentropic throttling in capillary tube (Process 3-4)
$$h_3 = h_4 \quad (3)$$
4. Isobaric heat addition in evaporator (Process 1-4)
$$Q_e = (h_1 - h_4) \quad (4)$$

5. Coefficient of performance
$$COP = \frac{heat\ absorbed\ by\ evaporator}{work\ compressor} \quad (5)$$
6. Power of Compressor
$$P = V \times I \times PF \quad (6)$$

4. Results and Discussions

The data from the air temperature test results on the evaporator of the two refrigerants R32 and R1270 have similarities to R1270 when approaching the last minutes there is a temperature decrease of only 0.1°C. This is reinforced by several previous researches which are caused by the thermodynamic properties of the boiling point of R32 being lower than R1270. From the results of previous research that the temperature of the R1270 evaporator at a small compressor ratio, the temperature is lower than R32 (16). The evaporator temperature profile of the two refrigerants is shown in Figure 3.

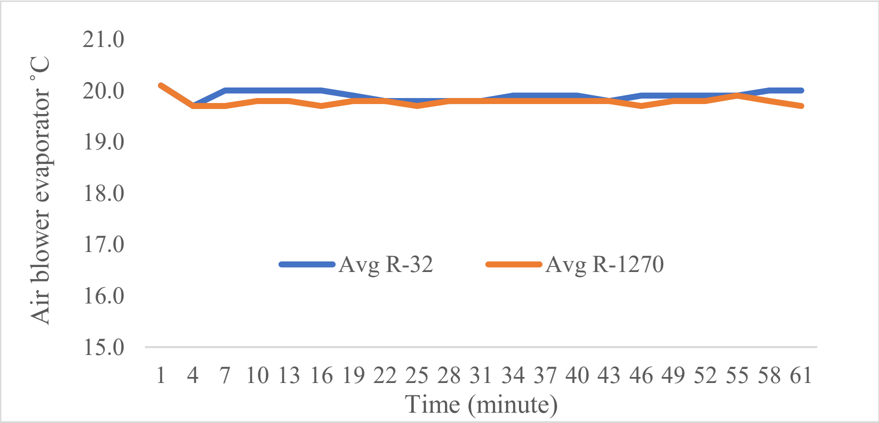


Figure 3. Comparison evaporator air blower temperature

The condenser air temperature of R1270 is lower than that of R32, this condition can affect the decrease in compression ratio and increase COP. In previous research, the COP of R1270 was 2% different from R32 due to the short compression work distance with large cooling capacity (17). R1270 has a more stable temperature compared to R32 as shown in Figure 4.

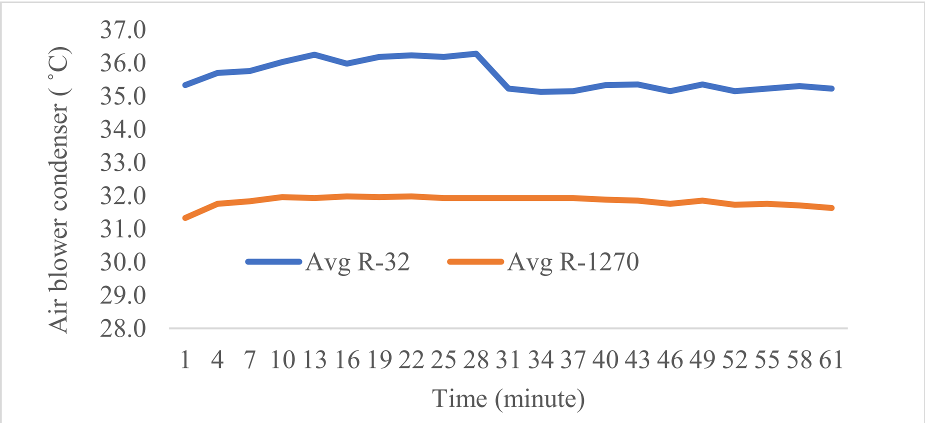


Figure 4. Comparation condenser air blower temperature

The discharge temperature of R32 is higher than that of R1270, due to the thermodynamic properties of R1270, which has a lower working pressure and a higher enthalpy value in both the liquid and gas phases. This is shown in Figure 5.

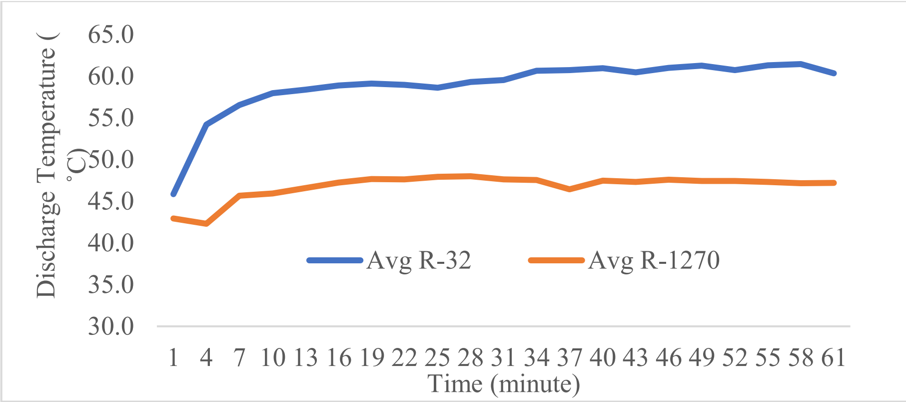


Figure 5. Comparation discharge temperature

The expansion temperature of R32 is higher than R1270, this condition is caused by the enthalpy value of R1270 being greater than R32 even though R32 has a boiling point 4°C lower than R1270. The temperature of R1270 is more stable than R32, the profile of R1270 can be seen in Figure 6.

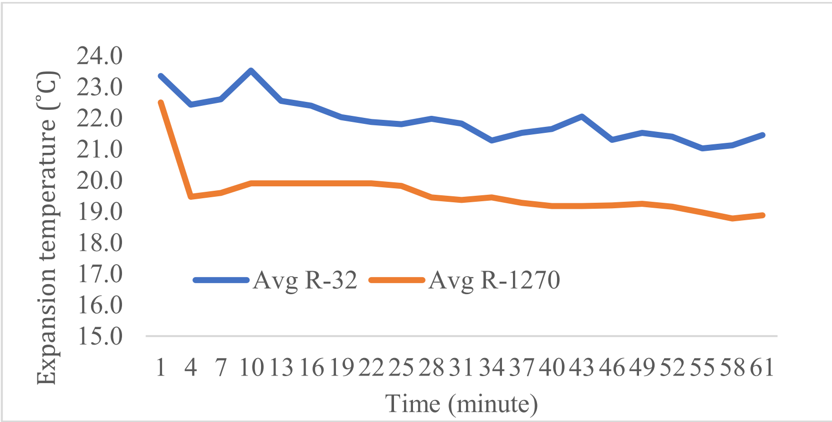


Figure 6. Comparation Expansion Temperature

From the results of the next test plotted on the P-H diagram (pressure and enthalpy) then using the reprof software, the plotting results are obtained in Figure 7. From the plotting results, it can be seen that there is a decrease in discharge pressure on the R1270 compressor which has a lower working pressure than R32. At suction pressure, there is a decrease in pressure compared to R32.

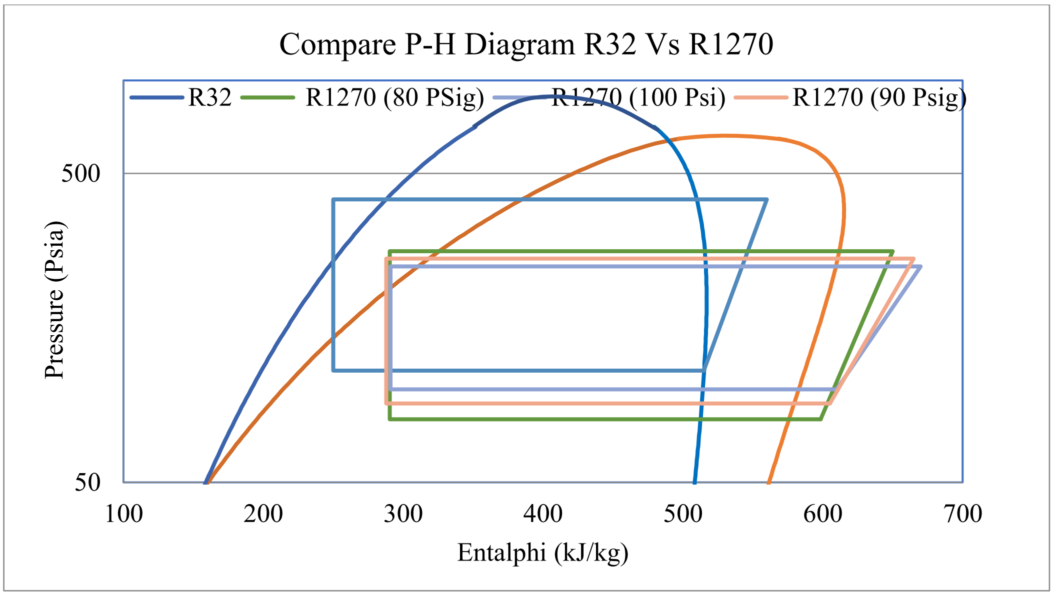


Figure 7. P-H Diagram R32 versus R1270

The results of the subsequent tests were calculated using empirical formulas and assisted by refprop software. R32 has slightly better performance seen in COP 5% higher than R1270, R1270 electric current is 14% lower than R32, R32 compression work is 21% lower than R1270, R1270 refrigeration effect is 15.8% greater than R32 and the heat released in the R32 condenser is 16.6% lower than R1270 in detail can be seen in Table 2.

Table 2. Performance result investigation report R32 and R1270

Description	Pressure (psig)			
	R32	R1270		
	115	80	90	100
COP	5,89	5,99	5,29	5,32
Current (Ampere)	3,52	2,65	2,55	2,4
Work of Compressor (kJ/kg)	45	51,44	60	60
Refrigeration Effect (kJ/kg)	265	308,16	317,1	319,05
Heat of Condenser (kJ/kg)	310	359,6	377,1	379,05

5. Conclusions

Calculations using refprop software and empirical formulas yield the following results:

a. The air temperature from the evaporator using R32 refrigerant is 0.1°C lower, due to R32's lower boiling point than R1270.
b. The cooling effect of R32: 265 kJ/kg and R1270: 319 kJ/kg, is 15.8% lower than that of R1270.
c. The compression work of R32: 45 kJ/kg and R1270: 57.1 kJ, is 12.1% lower than that of R1270.
d. The heat loss in the condenser of R32: 265 kJ/kg and R1270: 314.7 kJ/kg, is 15.8% lower than that of R1270.
e. The COP of R32 is 5.89 and R1270 is 5.53, 5% higher than R1270.
f. Overall, the performance of both refrigerants has its own advantages and disadvantages, but from an environmental perspective, R1270 has advantages due to its better thermodynamic properties, fluorosis, and reduced power consumption. Therefore, R1270 can be recommended as an alternative to R32, provided that greater caution is exercised in its use.

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