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Performance analysis of retrofit R410a refrigerant with R32 refrigerant on a split air conditioner

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Abstract
Split air conditioning (AC) is the most widely used in the community for both commercial and domestic utilities. At the present refrigerant which used in Split AC is mostly common group of HFCs, such as R410a. R410a is a zeotropic refrigerant and if there is a leak in the system, it cannot be added this refrigerant. This will increase the cost of maintenance. The aims of this research is to investigate the retrofit of R410a with R32 on the Split AC system. The R32 is chosen because it has higher latent evaporation heat at the same temperature and has less effect on global warming. The refrigeration effect, the power consumption and the system performance are the main three quantities that want to be examined in this research which are observed before and after retrofit. Experimental investigation conducted during this research, including design and manufacture of experimental equipment, calibration and tools installment, collecting the experimental data and analysis by quantitative description method before and after retrofit. The results informed that cooling effect increased during the research, but the COP system has a slight decrease about 4%. R32 refrigerant is quite feasible as a retrofit refrigerant to R410a refrigerant.

Keywords: Retrofit, refrigeration effect and COP

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1. Introduction

Refrigerants that used in split ac are very varied, for example old model that use R22 refrigerant and new model that use R410a, R32, R290 refrigerant. Every models have same purpose to have more efficiency system and eco-friendly. For system R410a refrigerant use mixture of two refrigerants, they are R32 and R125. This refrigerant mixture has zeotropic character which is the mixture cannot produce a new substance, but character of each substance are still in mixture. R410 refrigerant is classified as eco-friendly refrigerant, although it still has a fairly global warming effect [1,2].

The AC system with R410 refrigerant has some obstacles in charging proses to the system. For example, it is not justified to add refrigerant if half of refrigerant systems are leak out because there is a change in composition and so its characteristics also change. To fill the system, the remaining refrigerant in the system must be removed or completely discharged and then refilled again. So it makes the cost will be more expensive if the system is carried out maintenance and repairs.

In this problem, some technicians asked "Can R32 refrigerant replace R410a refrigerant without doing a change in system?". To answer that question, it is deemed necessary to test so that it can be known the effect of refrigerant replacement (retrofit) from R410a to R32 refrigerant. As it is known that R32 refrigerant is eco-friendlier and it is cheaper than R410a refrigerant for this reason, this research will investigate retrofit of R410a refrigerant with R32 refrigerant in split AC.

Based on simulation result comparison of potential refrigerant as retrofit refrigerant by using CoolPack program, it was found that R32 refrigerant has potential as a retrofit refrigerant in system that use R410a refrigerant, because R32 refrigerant has greater performance almost equal working pressure condition and it is eco-friendlier [1,3]. Hadya [4] has also done performance comparison simulation for 3 refrigerants in AC system. The result was R32 refrigerant has greater performance than R410a refrigerant at various evaporator temperatures. So does the compressor energy consumption for R32 refrigerant is less than R410a refrigerant. Performance evaluation on the heat pump and chiller systems using R410a refrigerant and R32 refrigerant has also been carried out [5,6]. It was reported that both experimentally and in simulation results, the performance for R32 refrigerant was greater than R410a refrigerant, but discharge the temperatures for R32 refrigerant was higher.

The applications of three refrigerants which are R22, R410a and R32 refrigerant in AC systems has also investigated [7,8,9,10,2]. The result was performance and energy efficiency ratio for R32 refrigerant was the biggest than the others. From the result of several investigations carried out both theoretically and experimentally it can be said that R32 refrigerant was very suitable as a refrigerant replacement(retrofit) of R410a refrigerant

2. Methods and Materials

This research was carried out in stages, which included: preparation, study of literature, design of experimental equipment, retrieval of experimental data, data processing and analysis of test results. The research equipment uses a series such as AC Split which is placed on a stand (buffer frame) with a capacity of 1460 Watt made by Daikin Industries LTD. Sketch the arrangement of the test equipment as shown in Figure 1

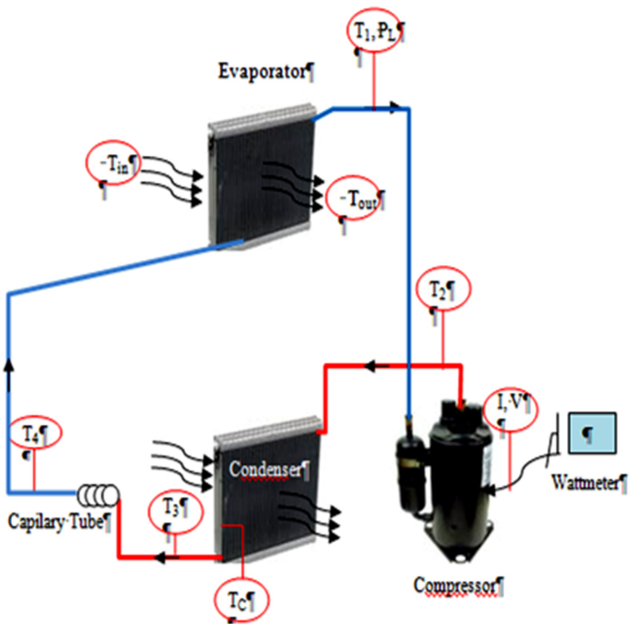

Figure 1. Sketch of the experimental design and position of the instrument equipment

Compressor power consumption measuring device uses a digital AC clamp power meter (Kyoritsu, with 1.5% accuracy). Evaporator output refrigerant pressure is measured with a bourdon tube type pressure gauge according to the refrigerant used with a precision level of 5 psi. Pressure drop on the condenser and evaporator in this study was ignored because the influence on the final result was not significant. Refrigerant temperature, and evaporator air circulation at predetermined measurement points are measured using a K type thermocouple. Test data are recorded every minute after the system is in a steady state.

Eqs. (1) - (4) are used to calculate the desired parameter. Equation (1) is used to calculate the compressor power consumption. The mass flow rate is calculated using Eq. (2). The cooling capacity is calculated using equation (3), while for system performance is calculated using Eqs. (4) [11,12].

$$Wp = V.I.\cos\varphi \tag{1}$$

$$\dot{m} = \frac{Wk}{h_1 - h_3} \tag{2}$$

$$Q_r = \dot{m}.(h_1^{'} - h_2) \tag{3}$$

$$COP = \frac{Q_r}{W_k} \tag{4}$$

In the equations above, subscripts (1), (2), (3) and (4) are used to express the output condition of the evaporator, compressor, condenser and capillary pipe output respectively.

3. Results and Discussion

The test was carried out in stages using R410a refrigerant and R32 refrigerant. The first test was carried out using R410a refrigerant. The second test was carried out using R32 at various working pressures including; (130, 140, 150, 160, 170, 180 and 190) psi. Testing for each condition was carried out at the same time on different days. Data was recorded after the steady state system, which was estimated after 10 minutes the system operates. Testing data was recorded every 5 minutes with 5 data per test. The test data obtained as an example as shown in Table 1.

Table 1. Data and Data Processing Results

Parameter	R410a	R32-P_{140}	R32-P_{150}	R32-P_{160}	R32-P_{170}	R32-P_{180}	R32-P_{190}
Compressor output refrigerant temperature (T_2) (°C)	60,8	88,0	87,0	83,0	81,0	78,6	45,0
Condenser output refrigerant temperature (T_3) (°C)	32,0	32,0	32,0	34,0	35,0	34,0	31,1
Evaporator output refrigerant temperature (T_1) (°C)	17,0	24,0	24,0	22,0	20,6	20,3	18,0
Condensation temperature (Tc) (°C)	41,3	42,2	42,9	42,0	40,0	40,5	41,0
Evaporator pressure (psig)	170	140	150	160	170	180	190
Evaporator entering air temperature (°C)	28,4	29,0	28,9	28,6	28,8	28,1	28,7
Evaporator exiting air temperature (°C)	19,6	23,1	22,9	22,5	21,6	19,7	19,7
Compressor electric current (A)	1,4	1,5	1,5	1,5	1,5	1,5	1,5
Electric voltage (Volt)	220	220	220	220	220	220	220
Superheat degree (K)	1,5	15,3	12,2	9,2	5,9	3,7	-0,4
Refrigeration effect (ER) (kJ/kg)	175	276	172	165	159	158	
COP	6,73	6,25	5,97	6,02	6,33	6,57	

R32-P_{140},... R32 refrigerant at 140 psig working pressure

Based on the data that has been obtained, then flipped into the P-h diagram with the help of the Mollier-Chart program will get an enthalpy magnitude at each measurement position which is then used to calculate; refrigeration effect, cooling capacity and system coefficient of performance (COP). Calculations are made for both types of refrigerant used. One of the results of plotting data with R410a refrigerant can be seen in Figure-2, and the results of the calculation of the effects of refrigeration and COP as shown in Table 1.

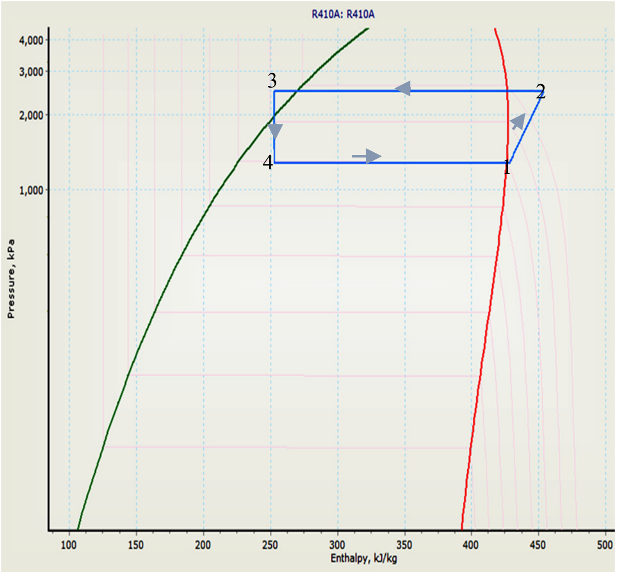

Figure 2. P-h diagram of system with R410a

In the retrofit process of an AC system using R410a refrigerant to R32 refrigerant without changing the system, it was found that the pressure limit for filling with R32 ranged from 165 ÷ 180 psig as shown in Figure 3. This charging takes into account the magnitude of the refrigerant superheat in the system which ranges between 3 ÷ 8 °C

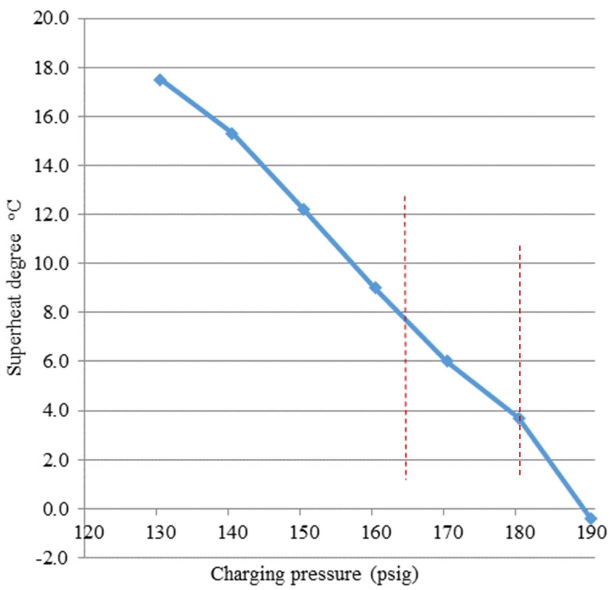

Figure 3. R32 superheat degree at various charging pressure

Based on the results of data processing carried out for both types of refrigerant used, it was found that R32 refrigerant instead of R410a had a greater refrigeration effect than R410a as shown in Figure-4. R32 refrigerant charging in the range of 165 ÷ 180 psig provides a nearly same refrigeration effect of 260 kJ/kg.

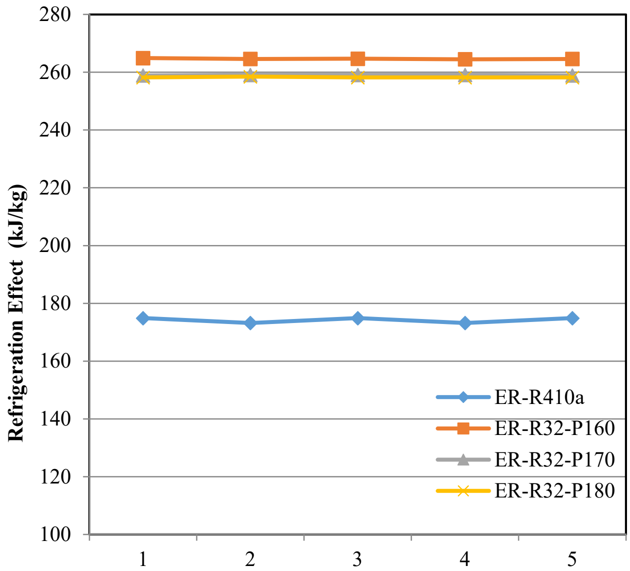

Figure 4. Refrigerant Effects of R410a and R32 Refrigerants

Figure 5 shows that the coefficient of performance (COP) of the system using R32 refrigerant is indeed slightly smaller than the system using R410a refrigerant of around 4%. Then the R32 refrigerant is quite feasible as a R410a refrigerant retrofit. Besides that, R32 refrigerant is more environmentally friendly and is a single refrigerant making it easier to add refrigerant to the system.

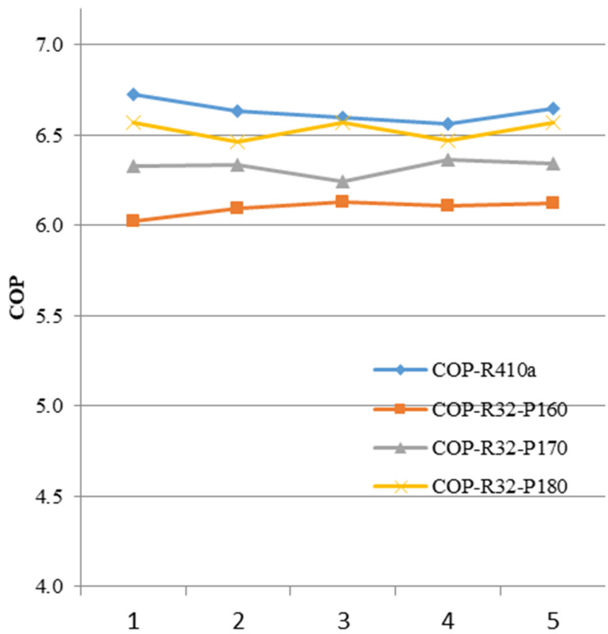

Figure 5. COP system with R410a and R32 refrigerants

Based on observations of the data, that the temperature of the cold air that exits the evaporator after being retrofitted with R32, occurs slightly higher when the charging pressures are 160 and 170 psig. But at a charging pressure of R32 of 180 psig, the evaporator outlet air temperature is the same as shown in Figure 6.

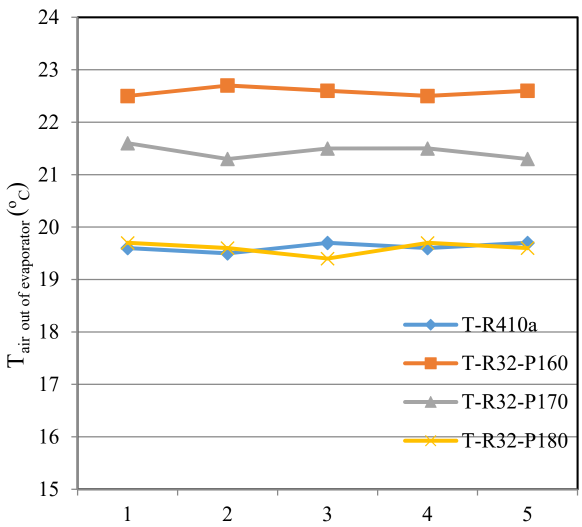

Figure 6. Temperature of air out evaporator

4. Conclusion

From the results of this study and the analysis that has been carried out it can be concluded that in the same system, R32 refrigerant is suitable as a retrofit refrigerant against R410a refrigerant with a greater refrigeration effect although there is a slight decrease in COP of around 4%. Besides that, R32 refrigerant is more environmentally friendly. The charging pressure for R32 refrigerant instead of R410a refrigerant is in the range of 170 - 180 psig. Evaporator outlet air temperature is slightly higher when using R32 refrigerant compared to using R410a refrigerant

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Nomenclature

AC	Air conditioning	P	pressure, psi
COP	Coefficient of performance	Wp	Horse power of compressor, watt
HFC	Hydro fluoro-carbon	$\dot{m}$	Mass flow rate, kg/s
R	Refrigerant	Qr	Heat rejection, watt
T	Temperature, °C	h	Specific enthalpy, kJ/kg
V	Voltage, Volt	Cosφ	Power factor
A	Current, Ampere	ER	Refrigeration effect, kJ/kg

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