Experimental study of small wall room air conditioner for R-22 retrofitted with R290 95.5%

by Berkah Fajar T.k

Experimental Study of Small Wall Room Air Conditioner For R-22 Retrofitted with R290 95.5%

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INTRODUCTION

The vapor compression cycle cooling machine is the most widely used type of cooling machine today generally, the medium used as a working fluid that removes heat from a product cooled to its environment is a synthetic refrigerant. the use of synthetic refrigerant is causing problems to the environment, a refrigerant that was originally considered ideal and perfect is now considered dangerous so it needs to be removed from its use.

In order to reduce the ODS (Ozone Depleting Substances) impact program, to the ozone layer in 1992 Indonesia has signed the Montreal protocol and at the same time Indonesia has launched the "Indonesian Country for the Phase Out of Ozone Depleting Substances (ODS) under the Montreal Protocol "So that from early 2020 to 2030 the HCFC refrigerant type will be removed and discontinued. Alternatives done by the researchers to overcome this, one of them is the use of hydrocarbon refrigerant mixture of propane and isobutane as a substitute for CFC-12, while the substitute HCFC 22 is propane or R 290, actually the use of hydrocarbons as refrigerant has been known to the public since 1920 at the beginning of refrigeration technology began to be developed alongside other natural working fluids such as ammonia, and carbon dioxide [1].

Since found in 1930 CFC refrigerant (Chloro-Fluor-Carbon) and HCFC plays an important role in refrigeration and air conditioning systems, this is because the refrigerant has good physical and thermal properties, stable, non-flammable, non-toxic and compatible against most of the component materials in the refrigeration system [2].

In refrigerant vapor compression refrigeration system is a medium for moving heat, plays a very important role and to this day is still widely used refrigerant materials on various refrigeration machines, one of which is HCFC 22 or generally synthetic refrigerant. This refrigerant has the value of ODP (ozone depletion potential) and GWP (global warming potential) is quite high. ODP is a relative measure of the rate of ozone destruction of a material against the level of ozone destruction by R-11.

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TABLE 1. ODP and GWP Refrigerant [2]

Refrigerant	ODP	GWP	NBP (°C)
CFC 11	1.00	4600	23.8
CFC 12	0.86	4000	-29.8
R134a	0.00	1300	-26.2
HCFC 22	0.06	1700	-40.7
HC 600	0.00	2.7	-0.5
HC 290	0.00	1.1	-42.1

GWP is the relative size of greenhouse-generating potentials to potential greenhouse effect due to CO2, ODP and GWP values of some refrigerants can be seen in table 1. One alternative refrigerant replacement for synthetic refrigerant HCFC 22 is propane hydrocarbon type refrigerant (HC-290) because it has ODP 0 and GWP 1.1 Research on hydrocarbon refrigerant as an environmentally friendly material has been started long enough and continues to be developed to obtain the most optimum results[3] research of butane, isobutane and mixtures thereof as an alternative R134a in the local refrigerator. The results show that the compressor consumes 3% and 2% less energy than HFC-134a at 28 ° C (ambient temperature). [4] reported that the propane/isobutane/butane mixture with propane 60% was the best substitute for R134a in the local refrigerator. [5] Comparing the performance of vapor compression refrigeration systems using a variety of non-azeotropic mixed refrigerants. It shows that HC290 / HC600a (40/60% mass) and HC290 / HC1270 (20/80 percent mass) are good alternatives to replace R12 and R22.

In the use of three types of refrigerant on the steam compression refrigerant engine, the results show that the coefficient of performance of R 290 is similar to HCFC 22 with lower power consumption R 290, the performance of the system is strongly influenced directly by the weight of the refrigerant itself. The lightweight molecules will have a low mass flow rate and have a high latent calorie. R32 compression ratio greater 25% and R 290 14% when compared to using refrigerant R-32 [6]

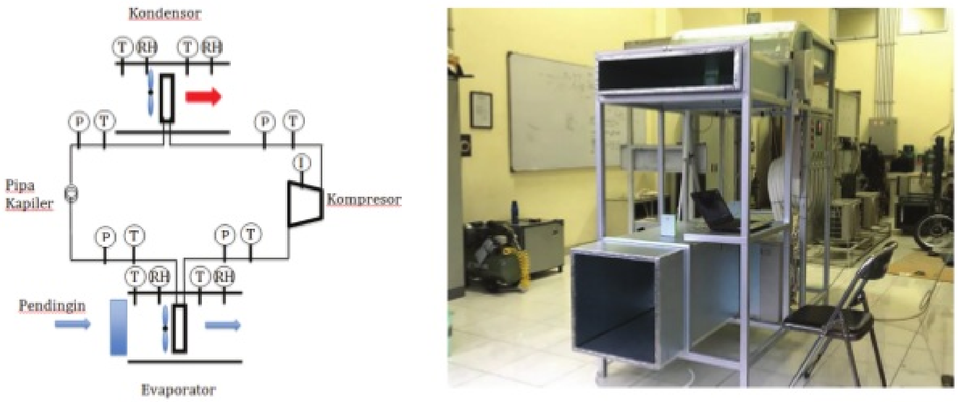
Split type air performance using HCFC22 and R 290 results showed that the mass flow rate for R 290 was only 44% and 47% compared to HCFC 22, this was possible due to different mass density factors. For cooling capacity, the system using HC is lower 4.7% s / d, 7% and input power 12.1 s / d 12.3% compared to HCFC22, but EER of R 290 obtains 8.5% higher than HCFC 22, this shows one of the advantages of using R 290 [7]

Air conditioners of the window type use a propane hydrocarbon refrigerant (R 290) and HCFC 22 refrigerant tested in a calorimeter chamber. it was found that the system with HC290 had a lower cooling capacity of 6.6% under low operating conditions and 9.7% under high operating conditions compared to using R22, while the performance coefficient for R 290 was 7.9% and 2.8% more high on low and high system operation. The energy consumption used for R 290 is lower in the range of 12.4 to 13.5% compared to the HCFC 22 refrigerant [8].

EXPERIMENTAL SETUP AND PROCEDURE

Experiment Setup

The set-up equipment consists of a compressor, condenser, evaporator and capillary pipe. The compressor, condenser, evaporator and expansion valve to be used are taken from a 1 PK split AC unit. This main component will be separated from its original configuration (AC split) to obtain performance data of compressor, condenser, and evaporator. Then Component is connected with refrigerant piping. Each component will be measured temperature and pressure to determine the level of refrigerant. The mass flow rate of the refrigerant will be measured by the refrigerant out of the compressor. In addition to pressure and temperature, the electric current required by the compressor is also measured. Condenser and evaporator will be placed in the chimney. The temperature and relative humidity of the inlet and outflow of the condenser will be measured. This measurement is intended to determine the actual heat transfer that occurs in the condenser and evaporator. Figure 1 (a) shows the test equipment that has been fitted with the measuring equipment. And Figure 1 (b) shows the equipment setup.



(a) (b)

FIGURE 1. a). The Schematic Diagram and (b) Setup equipment

MATERIAL AND PROCEDURE

Material

In this research, the refrigerant used is R-22 and R290 with Propane content of the lowest limit of 95%. The following is the data content of propane 97.74% obtained from the test results.

TABLE 2. Composition test results of propane 95%

Parametric	unit	Limit	result	Methods
Specific gravity	-	Reported		ASTM D1657
Cooper corrosion 1hr/100^0F	-	ASTM No.1	0.5076	ASTM D1838
Vapor Pressure at 100^0F	%WT	Maks.20	1A	ASTM D1267
Weathering test at 36^0 F	% Vol	Min 95	174,3	ASTM1837
Water content	-	No free water	No free water	Visual
Composition by GC				
-C2 (Ethane)			0,53	
-C3 (Propane)		95	97,74	
-I-C4 (Iso Butane)			1,49	ASTM D2163
-N-C4 (Normal Butane)	% Vol		0,23	
-C5+ (& C% Heavier)		2,5	NIL	

Procedure

Fig 1(b). shows the set-up image of the equipment. The set-up equipment consists of a compressor, condenser, evaporator and capillary pipe. The compressor, condenser, evaporator and expansion valve to be used are taken from a 1 PK Split AC unit. This main component will be separated from its original configuration (AC split) to obtain performance data on compressor, condenser, and evaporator. Then component is connected with refrigerant piping. Each component will be measured temperature and pressure to determine the level of refrigerant. The mass flow rate of the refrigerant will be measured by the refrigerant out of the compressor. In addition to pressure and temperature, the electric current required by the compressor is also measured.

Condenser and evaporator will be placed in the chimney. The temperature and relative humidity of the inlet and outflow of the condenser will be measured. This measurement is intended to determine the actual heat transfer.

Test procedure:

1. The test is done for R22 and R290 95%
2. Testing I: Split AC machine filled R22 as much as 490g (100%) by varying air temperature entering the evaporator at 20°C, 23°C, 25°C and 29°C.
3. Testing II: Split AC machine filled R290 95% by varying the refrigerant mass by 30%, 40%, 50% and 60%. For each mass, air temperatures entering the evaporator are varied at 20°C, 23°C, 25°C and 29°C. The quantity obtained by the data is shown in table 3.

TABLE 3. The quantities to be measured in the test

No	Measurement	Unit
1	Temperature out evaporator TDB/TWB	K
2	Temperature out condenser TDB/TWB	K
3	Temperature in. Evaporator TDB/TWB	K
4	Temperature In. condenser TDB/TWB	K
5	Temperature in. expansion valve	K
6	Temperature out expansion valve	K
7	Temperature In. compressor	K
8	Temperature out compressor	K
9	Pressure In. compressor	Pa
10	Pressure out compressor	Pa
11	Pressure in. expansion	Pa
12	Pressure out expansion	Pa
13	The ambient temperature	K
14	Current	A
15	Voltage	V
16	Air Speed out Evaporator	m/s

Data analysis techniques

After finishing the testing, the research stages were continued with data processing. With the used of Refprop software, then the results were compared between systems using HCFC 22 refrigerants with Propane 95% at various temperature variations so that the performance of the system can be determined.

Equation

The Refrigeration Effect can be calculated using equation 1:

$$Q_{ref} = (h_1 - h_4) \qquad (1)$$

While the cooling capacity can be calculated using equation 2

$$\dot{Q}_{ref} = \dot{m}_{ref}(h_1 - h_4) \quad (2)$$

Compressor power is calculated using equation 3.

$$\dot{W}_k = V.I.\cos\emptyset \quad (3)$$

Then the refrigerant flow rate can be calculated using equation 4

$$\dot{m}_{ref} = \frac{\dot{W}_k .\mu}{(h_2 - h_1)} \quad (4)$$

Air cooling capacity can be calculated using equation 5.

$$\dot{Q} = \dot{m}_{air}(h_1^* - h_2^*) (5)$$

Air mass flow rate can be calculated using equation 6.

$$\dot{m}_{air} = \rho.V.A \quad (6)$$

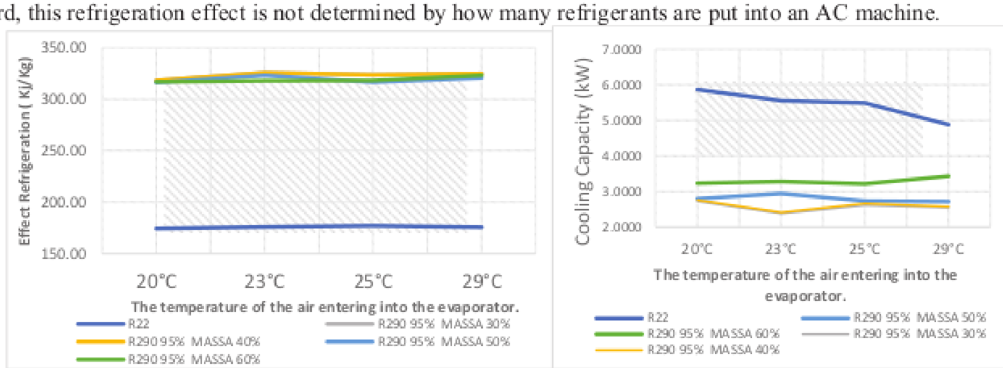
The coefficient of Performance (COP) can be calculated using an equation

$$COP = \frac{\dot{Q}_{air}}{\dot{W}_k} \quad (7)$$

RESULTS AND DISCUSSION.

Analysis of Refrigeration Effect on Testing R22 and Propane 95%.

The refrigeration effect is the result of the reduction between enthalpy after-evaporator and when entering evaporator (h1-h4). From Figure 2 (a) it can be seen that hydrocarbons have a refrigeration effect that almost doubles the effect of R22 refrigeration. This refrigeration effect is solely determined by the thermodynamic properties of a substance; therefore, the hydrocarbon is very good for a refrigerant for an AC machine. For the record, this refrigeration effect is not determined by how many refrigerants are put into an AC machine.



(a) (b)

FIGURE 2. (a) Effect of refrigeration versus temperature the air entering into the evaporator **(b)**The cooling capacity versus of the air entering into the evaporator

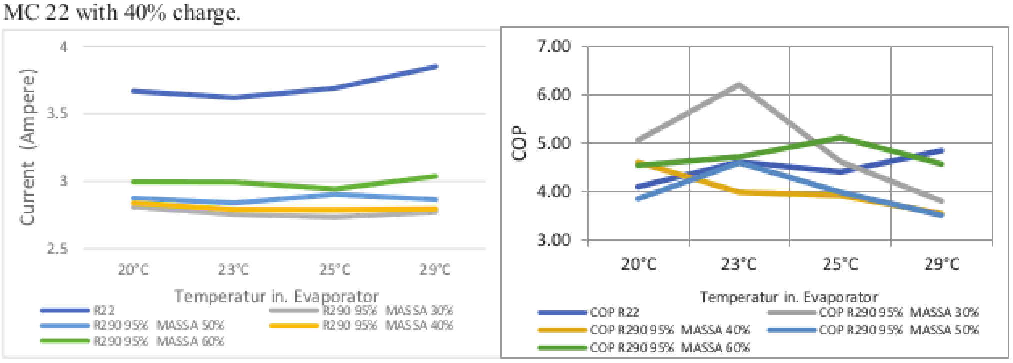
Analysis of Cooling Capacity at Propane 95%.

In this study the air-conditioning machine is filled by R22 100% mass of 490 g, while for propane 95% of mass incorporated into AC machines is varied from 30%, 40%, 50% and 60%. Varying the 95% propane mass is intended to find the best performance and can be near the performance of R22. As mentioned earlier, that as a baseline the air temperature enters the condenser 28^{0}C-29^{0}C and the air temperature entering the evaporator is varied as follows 20^{0}C, 23^{0}C, 25^{0}C and 29^{0}C for each variation of 95% propane mass.

From Figure 2 (b) it can be seen that the R22 cooling capacity is better than the 95% propane cooling capacity, this is due to the much higher R22 charging of hydrocarbon filling. The amount of refrigerant inserted in the AC machine determines the mass flow rate of the refrigerant.

Analysis of Electric Current on Propane Testing 95%

From Figure 3(a) can be seen the power or demand of the greatest electrical energy is R22, then followed by propane 95% by filling 60%, 50%, 40% and 30%. The need for electric power R22 is 1.5 times the need for electrical power for hydrocarbon refrigerant. What is interesting from Figure 3(a) is, the need for electrical energy at high cooling loads, the electrical energy requirement for propane 95% with 60% lower charging compared to the MC 22 with 40% charge.



(a) (b)

FIGURE 3. (a) The electric current is needed by the compressor functions the air temperature entering the evaporator **(b)** COP (Coefficient of Performance) functions the temperature of the air entering the evaporator

COP Analysis on Propane Testing 95%

The coefficient of Performance is the ratio between the capacity of an AC machine compared to the electrical energy needed by a compressor.

$$\dot{W} = \dot{Q}/\dot{W} \quad (8)$$

From Figure 3(b), we can see that COP MC 22 is the highest, followed by propane 95% by filling 60% and R22. Whereas propane 95% by filling 30%, 40% and 50% have a low COP.

CONCLUSION

1. R290 95% has a 200% latent heat of evaporation
2. Cooling capacity R22 is greater than the cooling capacity of R290 95%. The R290 95% cooling capacity is the biggest / highest for 60% chargy. Cooling capacity R22 compared to R290 95% is equal to 71%.
3. R290 95% cooling capacity increases with increasing evaporator inlet air temperature.
4. The average electric current of the compressor power R22 compared to R290 95% charging 60%, the electric current of the compressor power for R290 95% charging 60% is the highest compared to R290 95% charging 50%, 40%, 30%.
5. The highest COP was experienced by R290 95% charging 60% at 23°c which was 4.62. COP R290 95% charging 60% decreased at a temperature of 23°c.
6. The best performance of the R290 95% AC engine is the filled with R290 95% charging 60%.

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