Experimental Study Performance R-22 AC Split Retrofitted With Propane

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Abstract. Refrigerant 22 or called R-22 is still the most widely used for air conditioners. However, since it has a relatively high global warming properties, the use of R-22 should be stopped. Refrigerant 290 briefed as R-290 (propane) is the type of refrigerant recommended by many experts for R-22 replacements because the global warming properties of R290 are much lower than R-22. Therefore, in this study the cooling capacity, flow rate mass, power consumed and COP will be evaluated. The air conditioner engine used in this research has 1 PK capacity which is redesigned by adding separator / ducting on various main components of AC. From the result of the study, there are several conclusions revealed: on the same compressor capacity, R-22 cooling capacity is still greater than R290. Meanwhile, the flow rate of R290 is lower than R-22. For power consumption from R-290, it is smaller than R-22. For the value of COP R-290, the value shows greater ie at R-290 on the variation of Incoming Temperature In Evaporator 20°C = 6.23, 23°C = 6.36, 25°C = 6.86, 29°C = 6.20. While at R-22, it shows 20°C = 5.36, 23°C = 6.02, 25°C = 5.76, 29°C = 6.335

1 Introduction

The vapor compression refrigeration cycle machine is the most widely used between other types of cooling machine today. Generally, the medium used as the working fluid that removes heat from a cooling product to its environment is called a synthetic refrigerant. When it was first discovered around 1930 to mid-1970, the impact of using synthetic refrigerants such as chlorofluorocarbon refrigerants (CFCs) and hydrochlorofluorocarbons (HCFCs) had not made environmental problems. However, this does not mean that the use of those refrigerants had no negative impact to the environment, but rather it was because the limited knowledge and awareness of the environment at that time. With the increase of knowledge and environmental awareness, people now realize that the use of synthetic refrigerant causes problems to the environment; the refrigerant that was originally considered ideal and perfect, is now considered dangerous, and it needs to be removed from its use [1,2].

Later on, that fact encouraged the countries around the world including Indonesia to then jointly carry out prevention and reparation by making an agreement which became known as

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the Wina Convention in 1985 followed by the Montreal Agreement in 1987. In order to reduce the impact of ODS (Ozone Depleting Substances) program to the ozone layer, in 1992 Indonesia has signed the protocol of Montreal. At the same time, Indonesia has launched the "Indonesian Country for the Phase Out of Ozone Depleting Substances (ODS) under the Montreal Protocol" program so that from 2020 to 2030 the dangerous type of refrigerant such as HCFC would be removed and discontinued [2,7]. Further development in 2007, the countries incorporated in this convention decided to expedite the process of removing all materials that damaged the environment.

There are some alternatives found by the researchers to overcome this phenomenon; one of them is the use of hydrocarbon refrigerant mixed with propane and isobutene as substitutes for CFC-12, while the substitute of HCFC-22 is propane or R-290. Although actually the use of hydrocarbons as refrigerant has been known to the public since 1920 at the beginning of refrigeration technology development alongside with other natural working fluids such as ammonia, and carbon dioxide [2]. Since it was found in 1930, CFC (Chlorofluorocarbon) refrigerant and HCFC played an important role in refrigeration and air conditioning system. This is because the refrigerant has good physical and thermal properties, stable, non-flammable, non-toxic and compatible against most of the material components in the refrigeration system [3,4,7].

As it has been explained from the beginning, the refrigerant vapor compression refrigeration system is a medium for transferring heat. It plays a very important role and it is still widely used for refrigerant materials on various refrigeration machines. One of them is HCFC-22 or generally called as synthetic refrigerant. This refrigerant has high ODP value (ozone depletion potential) and GWP (global warming potential). ODP is a relative measure of the ozone destruction rate from a material against the level of ozone destruction by R-11.

Table 1. ODP and GWP Refrigerant [3]

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 a relative measure of greenhouse gazette potential to greenhouse effect due to CO2, while ODP and GWP values of some refrigerants can be seen in table 1.1. One of the alternative refrigerants replacement of synthetic refrigerant HCFC-22 is propane hydrocarbon refrigerant (HC-290). It is because HC-290 has 0 ODP 1.1 GWP, so it can be ignored. Research on hydrocarbon refrigerant as an environmental friendly material has been started long enough, and it still continues to be developed to obtain the most optimum results [3,7].

The usage of R-290 as R-22 replacement has also been performed by some experts: Lorentzen, Devotta, Xiao et al, and Zhou and Zhang. Based on the studies on thermodynamic properties of R-22 and R290, Lorentzen recommends replacement of R-22 with R-290.

Devotta [4] performed an experimental study in AC windows that originally used R-22 and then it was retrofitted with R-290. The experimental study results reported that there was a 6.6% reduction in cooling capacity. However, COP of R-290 was higher than R-22 which is 7.9%. The COP is a ratio of cooling capacity to the power of the compressor input, that is why the increase in COP is greater than the cooling capacity reduction in the AC window. That concludes retrofitting R-22 with R290 will reduce the compressor input power.

Xiao et al. [5] conducted a retrofit experiment from R-22 to R290 on a small-capacity AC with varieties of R-290 charging. The results of their research reported that the maximum increase in AC performance is achieved when the mass of R-290 is 50% of R-22. In this optimum charging, cooling capacity decreased 2.8% and enhanced EER (energy efficiency ratio) reaching to 12.6%.

Zhou and Zhang [6] conducted a retrofit experimental from R-22 to R290 on a split type air conditioner by varying the diameter of a capillary tube roll. In the experiments, R-290 refrigerant mass filling was 44% and 47% of the R-22 filling mass, and the diameter of the capillary tube rolls improved from 40mm to 120mm. They stated that an increase in the diameter of the capillary tube rolls reflected the changes in the mass flow rate in the system, yet it did not show significant changes in cooling capacity, compressor input power and COP in air conditioners. The results of their study reported that there was a decrease in cooling capacity of 4.7% to 6.7%, and compressor input power by 21.1% to 12.3%, while there was an increase in EER which reached to 8.5%.

2 Experiment Setup and Procedures

2.1 Setup Equipment

The set-up equipment consists of a compressor, condenser, evaporator and capillary pipe. The compressor, condenser, evaporator and expansion valve used are taken from a 1 PK split-AC unit. These main components are separated from its original configuration (split-AC) to obtain data performance on compressor, condenser and evaporator. Then the component is connected with the refrigerant piping. Each component measured the temperature and pressure to determine the level of refrigerant. The mass flow rate of the refrigerant is measured by the refrigerant out of the compressor. In addition to pressure and temperature, the electrical current required by the compressor is also measured. Condenser and evaporator is placed in the ducting. Also, the temperature and relative humidity of the inlet and outflow of the condenser is measured. This measurement is designed to determine the transfer of actual heat that occurs in the condenser and evaporator.

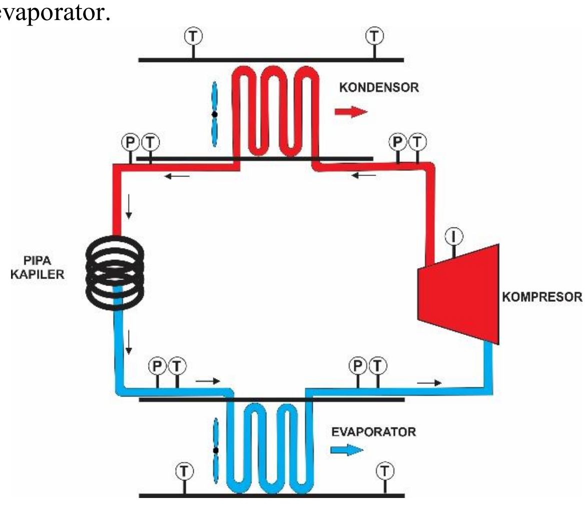

Fig. 1. The Schematic Diagram.

2.2 Recharging Refrigerant

After completion of the vacuum process, the recharging of R-22 as much as 490 grams from the data contains in the nameplate outdoor unit. After completion of data retrieval system using R-22 refrigerant, then it was re-vacuumed as it did before in the initial vacuum process. Furthermore, the system loaded R-290 refrigerant as much as 40% that is fixed as much as 196 grams.

2.3 Procedure

The procedures performed in this research are as follows:
- To test the cooling machine in the laboratory of energy conversion (Training Center) Diponegoro University of Semarang.
- To carry out the test system by using a variation of evaporator entrance temperature as the cooling load. Temperatures used were 20ºC, 23ºC, 25ºC, 29ºC, respectively.
- To charge a heavy (mass) charging refrigerant R-22 for 490 grams and R290 around 196 grams.
- To perform R-22 and R-290 test with the same cooling load.

3 Equation

A refrigerating effect is a difference of enthalpy on the outlet and inlet side of evaporator. The refrigerating effect can be calculated as below:

$$\frac{\dot{Q}_{in}}{\dot{m}} = h_1 - h_4 \tag{1}$$

While the work of the compressor can be calculated as follows:

$$\frac{\dot{W}_c}{\dot{m}} = h_2 - h_1 \tag{2}$$

Heat transfer rate per unit mass in condenser is the total heat that is rejected by the condenser onto the surrounding per unit mass of refrigerant flowing.

$$Qc = \dot{m}(h2 - h3) \tag{3}$$

Efficiency of an air conditioner can be stated by Coefficient of Performance (COP or β). It can be inferred as the ratio between refrigerating capacity and work of the compressor.

$$\beta = \frac{\dot{Q}_{in}/\dot{m}}{\dot{W}_c/\dot{m}} = \frac{h_1 - h_4}{h_2 - h_1} \tag{4}$$

4 Result and Discussion

This refrigerant replacement process from R-22 to R290 does not need replacement of the AC components system. It is because the character of pressure and temperature from HC refrigerant is similar to synthetic refrigerant. Thus, almost all kinds of compressor can accept hydrocarbon refrigerant. The cooling capacity is the output of the expected AC. The larger cooling capacity is, the faster the room temperature will reach to the desired temperature. In Figure 2, it is seen that a higher temperature of the evaporator enters the resulting cooling capacity. It also shows that the cooling capacity of R-22 is higher than R290 for all variations of the inlet temperature of the evaporator. This is one of the reasons why R-22 was still used for decades, given that R-22, in terms of thermodynamic properties is superior than R290. However though, since R-22 still has relatively high ODP and GWP properties, the use of R-22 as a refrigerant must be stopped immediately.

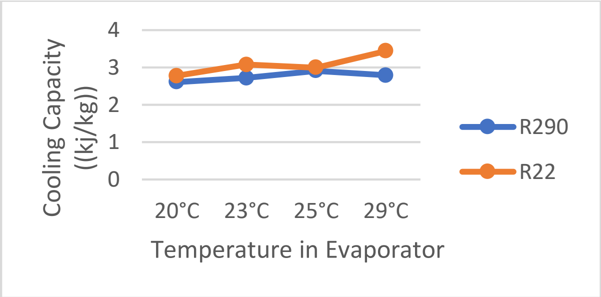

Fig. 2. Graphic Cooling Capacity and Temperature in Evaporator.

In figure 3, the mass flow rate of R290 is smaller than R-22. This shows that the required refrigerant is less than R-22. With a mild lifetime and a lower mass transfer rate than R-22, the compressor's work is not heavy.

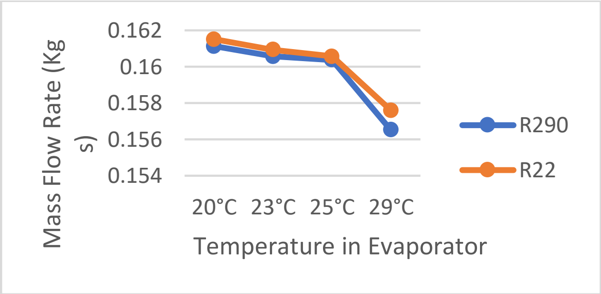

Fig. 3. Graphic Mass Flow Rate and Temperature in Evaporator.

As shown in Figure 4, it shows that the power consumed by the compressor at R290 is lower than R-22. This is due to the lighter compressor work, and because the mass flow rate of R290 is smaller.

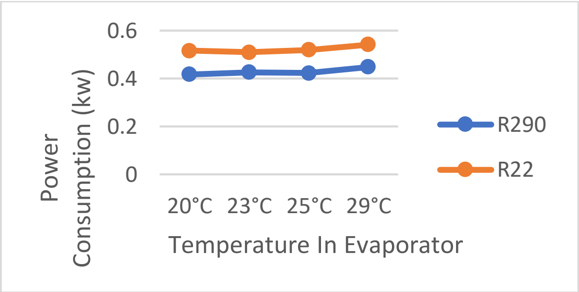

Fig. 4. Graphic Power Consumption and Temperature in Evaporator.

From Figure 5, it can be seen that COP R290 is larger than R-22. In the previous chart we know that the cooling capacity of R290 is smaller than that of R-22. In contrast, here is larger at 5 COP graph, this is because the R290 power consumption is also smaller than R-22, so it is increasing its COP value.

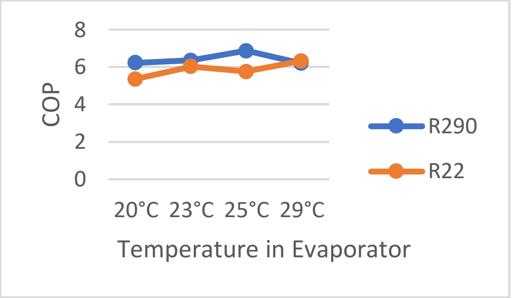

Fig. 5. Graphic Power Consumption and Temperature in Evaporator.

In the previous section, it has explained the advantages and disadvantages of R290 and R-22 from the side of the cooling capacity, thermodynamic properties and power consumption. Moreover, we can draw the conclusion that the performance of R290 is better than R-22, and its use needs to be developed for the better environmental impact. However, due to the flammable and explosive nature of the R290, it is necessary to set standards on how to utilize and socialize them to AC technicians.

5 Conclusions

Based on the above discussion, there are several conclusions made from this study:
• For the same compressor capacity, R-22 cooling capacity is still greater than R290.
• The flow rate of R290 is lower than R-22.
• Power consumption from R290 is less than R-22.
• For the value of COP, R290 value is higher than COP of R-22, R290 on the variation of Incoming Temperature In Evaporator 20 °C = 6.23, 23 °C = 6.36, 25 °C = 6.86, 29 °C = 6.20. While at R-22 the temperature is 20 °C = 5.36, 23 °C = 6.02, 25 °C = 5.76, 29 °C = 6.335.

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