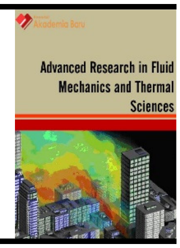
Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879



Effect of Cooling Load on the Performance of R22 Residential Split Air Conditioner when Retrofitted with Hydrocarbon Refrigerant (HCR22)

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ARTICLE INFO

Article history:
Received 3 January 2018
Received in revised form 13 April 2018
Accepted 5 July 2018
Available online 12 August 2018

Keywords:
Split air conditioner, hydrocarbon refrigerant, HCR22, COP, cooling load

ABSTRACT

An experimental study to evaluate the effect of cooling load on the performance of residential split air conditioner (RSAC) by replacing R22 refrigerant when retrofitted with hydrocarbon refrigerant (HCR22) had been carried out. The cooling load is varied from 0 W, 1000 W, 2000W and 3000 W like featuring on actual condition of cooling load in the residential. The research objective was the performance investigation of the cooling load influence on the performance of HCR22 refrigerant as a substitute for R22 refrigerant in standard vapour compression cycle of refrigeration system. The results show that the COP of RSAC increase with the increasing of cooling load (0 W, 1000 W, 2000 W and 3000 W), where the COP with HCR22 increase 16.10%, 12.66%, 16.56% and 19.99% higher than R22 respectively, and the compressor power consumption were reduced with HCR22 lower than R22 by 18.27%, 20.01%, 16.26% and 22.56% respectively, while the cooling capacity and heat rejection capacity were relatively similar. The experimental results show that HCR22 had better performance compared to R22, and indicating that HCR22 could be used for retrofitting existing RSAC with R22.

1. Introduction

R22 is the most widely used refrigerant in Residential Split Air Conditioner (RSAC) in Indonesia, because its excellent thermodynamics performance in compression refrigeration system but due to its ozone depleting effect (ODP) and global warming potential (GWP), Montreal Protocol and its amendments have set the phase out deadlines on R22 in different countries and areas [1]. The R22 refrigerant has an ODP of 0.055 and a GWP of 1780 as negative impact to environment [2]. Because of understanding the consequences caused by the ODP and GWP, many countries and areas have accelerated the will thoroughly ban the use of R22 by 2020 [1]. According to the Montreal Protocol, Indonesia, as a developing country, will stop R22 consumption for new equipment of RAC at its level

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in 2015, and will ban the use of R22 in A/C industry from 2040 and on [1]. However, due to the issue of environmental damage, causes experts try to use environmental friendly refrigerant, one of them is hydrocarbon refrigerant. Several studies have shown the results of the use of hydrocarbon refrigerants could increase the coefficient of performance (COP) of the air conditioning system [3-12].

The advantages of the thermodynamics properties of the hydrocarbon refrigerant are ODP equal to zero, low of GWP, high power mixed with oil, and non-toxic. The weakness of its hydrocarbon refrigerant is flammable, it was the prominent reason to weaken use of hydrocarbon refrigerants in compression refrigeration system. Nasution et al [13] reported retrofitting of R22 split type air conditioning with hydrocarbon (HCR22). The final results of the study shows an overall better energy consumption of the HCR22 compared with the R22. Bolaji [14] presented the performance of a R22 split-air-conditioner when retrofitted with ozone friendly refrigerants (R410A and R417A). The study shows that with R417A the system consistently had the best performance in comparison to both R22 and R410A, indicating that R417A would be a better choice for retrofitting an existing split-air-conditioners originally designed to use R22 as working fluid.

In this study, experimental research is aimed to evaluate the effect of cooling load on the performance of R22 refrigerant in residential split air conditioning (RSAC) when retrofitted with HCR22 refrigerant. The RSAC performance evaluation includes cooling capacity, compressor power, heat rejection capacity, room temperature as the testing parameter, and COP.

2. Methodology

2.1 Design of Experiment

The experimental method was used by replacement of the R22 refrigerant in RSAC systems with HCR22 refrigerant as a drop in substitute (without changes in the components of the system) at different cooling load. This RSAC originally use R22 refrigerant as the working fluid, with the compressor power 0.680 kW. The objective of the experimental study was to compare the effect of cooling load on the performance of the refrigerant HCR22 to R22, to show the difference in compressors power consumption, cooling capacity, heat rejection capacity and COP. Figure 1 shows the schematic diagram of the RSAC experimental device that use in this study. This device made by modified of RSAC with the addition of a dummy condenser trombone coil type as the machine of air conditioning and water heater, also is called Residential Split Air Conditioner Water Heater (RSACWH) that has been used in another research [15-17].

This apparatus test are equipped with 3 pieces valves (valve 2, 2a and 2b), so that the apparatus can function as standard RSAC or as RSAC Water Heater (RSACWH). The simulation test room as shown in Figure 2 have dimension of 2.26 m x 1.75 m x 2 m (length x width x height). It was fabricated with 30 pieces of 100 Watt incandescent bulb lamp, given the cooling load variation of 0 W, 1000 W, 2000 W, and 3000 W to the evaporator (indoor unit) as featuring of actual cooling load condition.

2.2 Experimental Procedure

Experiment was started with testing as standard RSAC by opening valve 2 and closing valves 2a and 2b. First test was conducted with refrigerant R22 (500 gram of refrigerant mass), and in the second test, the R22 refrigerant was replace by HCR22 refrigerant (300 gram of refrigerant mass). Each test is performed during 120 minutes, where data is recorded every 5 minutes. The thermodynamics calculation was carried out by ideal vapor compression cycle assumptions and using

REFPROP 6, where the enthalpy is calculated based on the high pressure and low pressure of refrigerant [18].

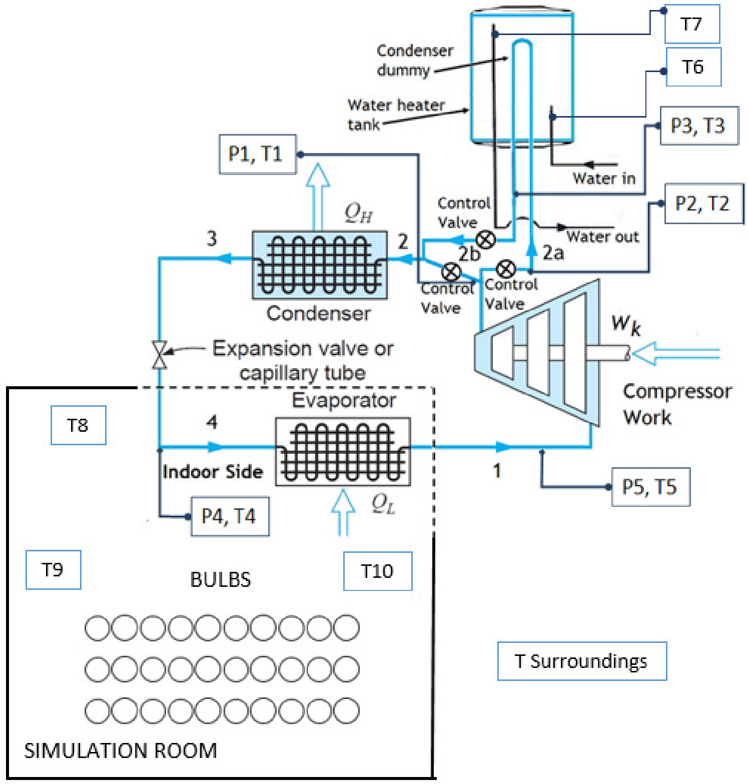

Fig. 1. Schematic diagram of experimental apparatus [15] with RSAC (standard Air Conditioning/AC) in dash line

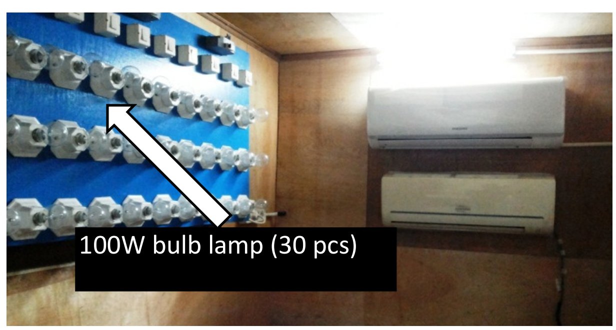

Fig. 2. The simulation test room with bulb lamp as cooling load and indoor of RSAC

The measuring instrument used in this research are omega TC-08 data logger with K type thermocouple (accuracy 0.2 percent ± 0.5°C and has a resolution of better than 0.1°C), digital thermometer (accuracy ±0,1°C), pressure gauges with accuracy ±5 psi (high pressure refrigerant in condenser side) and 1 psi (low pressure refrigerant in evaporator side), ampere-meter (accuracy ± 2.0 percent) and voltmeter (accuracy ± 1.0 percent).

3. Results and Discussion

Figure 3 shows the discharge of compressor pressure between HCR22 and R22 with various cooling load (0 W, 1000 W, 2000 W and 3000 W) as featuring of actual condition of the internal cooling load in the residential. The experimental study at standard RSAC system with HCR22 refrigerant as the working fluid, the pressure on the discharge side of the compressor are 189 psig, 189 psig, 191 psig and 196 psig for cooling load 0 W, 1000 W, 2000 W and 3000 W, respectively. The evaluation of performance parameters in this study are the average values of test data that obtained during 2 hours at steady state condition where data are recorded every 5 minutes. Figure 4 shows small discrepancies difference in pressure on the discharge side of the compressor between HCR22 and R22, where the pressure of R22 are higher than HCR22 at the ranges between 201-208 psig for various cooling load. The compressor discharge pressure of RSAC tends increase with the increasing of internal cooling load for HCR22 in small value. While for RSAC with R22 the compressor discharge pressure is the same for the internal cooling load 1000 W and 3000 W, but the discharge pressure tends to increase in small value for internal cooling load 0 W and 2000 W, as shown in Figure 3.

The similar condition also appears in discharge temperature of the compressor as shown in Figure 4, because of the proportional relationship between pressure and temperature, when the pressure of compressor increase the temperature of compressor increasing too [16]. There is no significant pressure change occurred in the compressor (suction side or discharge side) so that the increasing of cooling load does not give significant effect to the compressor pressure, because of small difference of pressure.

From the relation thermodynamics properties of Figure 3, Figure 4 and Figure 5, when the pressure and temperature of compressor increase, the compressor power electrical consumption increasing too. So that the average of compressor power consumption using HCR22 are lower than R22 as shown in Figure 5, where the HCR22 compressor power consumption are 0.559 kW, 0.554 kW, 0.583 kW and 0.543 kW for internal cooling loads 0 W, 1000 W, 2000 W and 3000 W, respectively. And R22 compressor power consumption are 0.685 kW, 0.693 kW, 0.696 kW and 0.701 kW for internal cooling loads 0 W, 1000 W, 2000 W and 3000 W, respectively. This result made the present study give good agreement with the work reported by Nasution *et al.*, [13]. Compressor power consumption tends to similar value by the increasing of internal cooling loads.

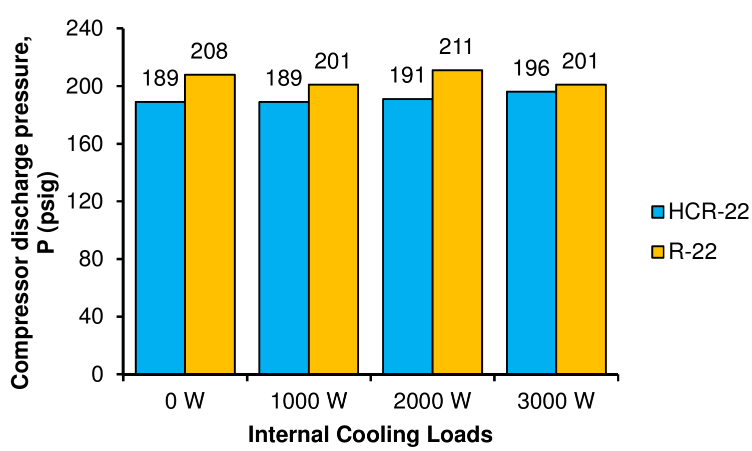

Fig. 3. Compressor discharge pressure at various cooling loads on RSAC standard

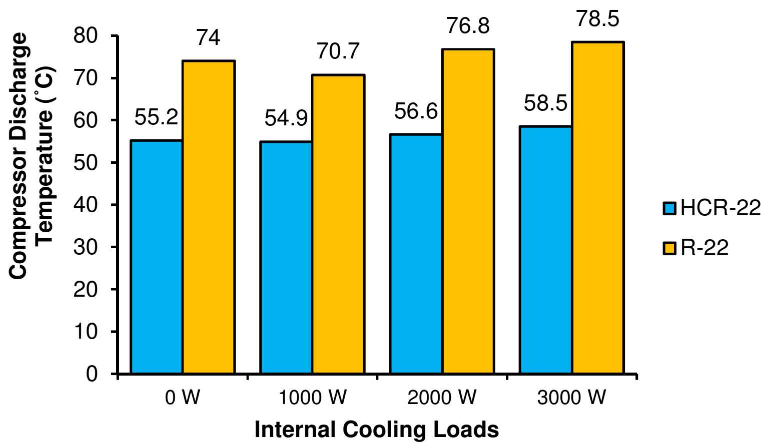

Fig. 4. Compressor discharge temperature at various cooling loads on RSAC standard

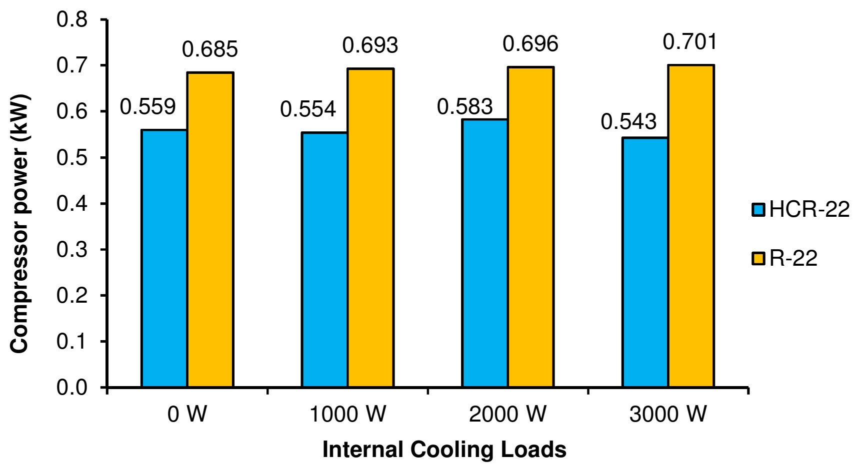

Fig. 5. Compressor power consumption at various cooling loads on RSAC standard

Compressor power consumption shows the electrical energy consumed by the air conditioning system, so it can be said that compressor power consumption reduction means savings of electrical energy usage. Figure 6 shows the percentage of electrical energy savings with the use of the HCR22 as the working fluid on RSAC standard. The electrical energy savings are 18.27 %, 20.01 %, 16.26 % and 22.56 % for internal cooling loads 0 W, 1000 W, 2000 W and 3000 W respectively, compared to R22.

A decreasing (energy savings) in compressor power consumption using the HCR22 is not a big influence on the evaporator cooling capacity as shown in Figure 7. The ability of the system absorbs heat delivered by the internal cooling loads between the HCR22 and R22 is also similar. There was no significant effect in the value change of evaporator cooling capacity due to increasing of internal cooling load for RSAC with working fluid HCR22 or R22. It can also be seen through the room temperature achieved as shown in Figure 8.

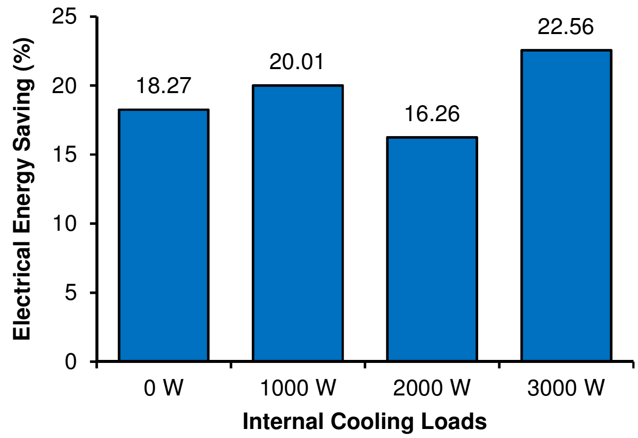

Fig. 6. Percentage of energy saving of HCR22 against R22 at various cooling loads on RSAC standard

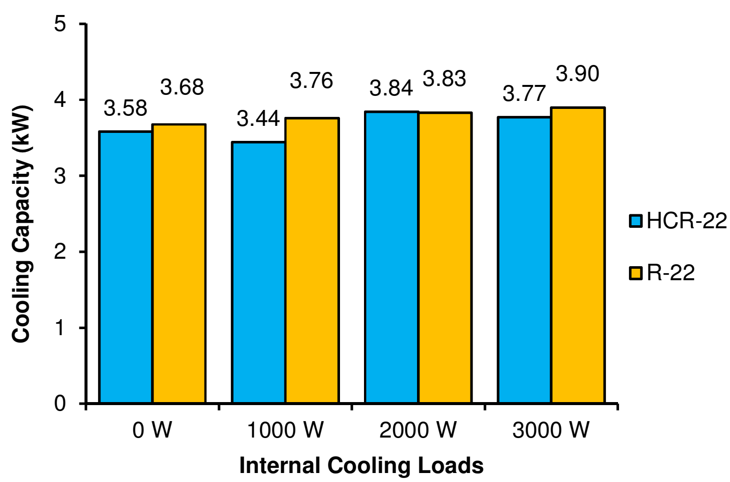

Fig. 7. Cooling capacity of evaporator at various cooling loads on RSAC standard

Figure 8 shows the inside room temperature of RSAC standard using HCR22 and R22. The inside room temperature average using HCR22 are 19.15°C, 19.33°C, 23.16°C and 27.43°C, increase with the increasing of internal cooling loads 0 W, 1000 W, 2000 W and 3000 W respectively. The same conditions are also obtained using R22 where inside room temperature are 20.09°C, 17.97°C, 22.52°C and 26.26°C, increase with the increasing of internal cooling loads 0 W, 1000 W, 2000 W and 3000 W respectively. The inside temperature tends to increase due to the increasing in the amount of heat absorbed in the evaporator from internal cooling loads, as shown in Figure 8.

The condenser heat rejection value to the surrounding with the HCR22 and R22 do not show significant differences, as shown in Figure 9. The heat rejection value of HCR22 are 4.14 kW, 4.00 kW, 4.43 kW and 4.31 kW increase in small discrepancies with the increasing of internal cooling loads 0 W, 1000 W, 2000 W and 3000 W respectively. The same condition also occurs in RSAC with R22 where the heat rejection value of R22 are 4.36 kW, 4.45 kW, 4.53 kW and 4.60 kW increase in small discrepancies with the increasing of internal cooling loads 0 W, 1000 W, 2000 W and 3000 W respectively.

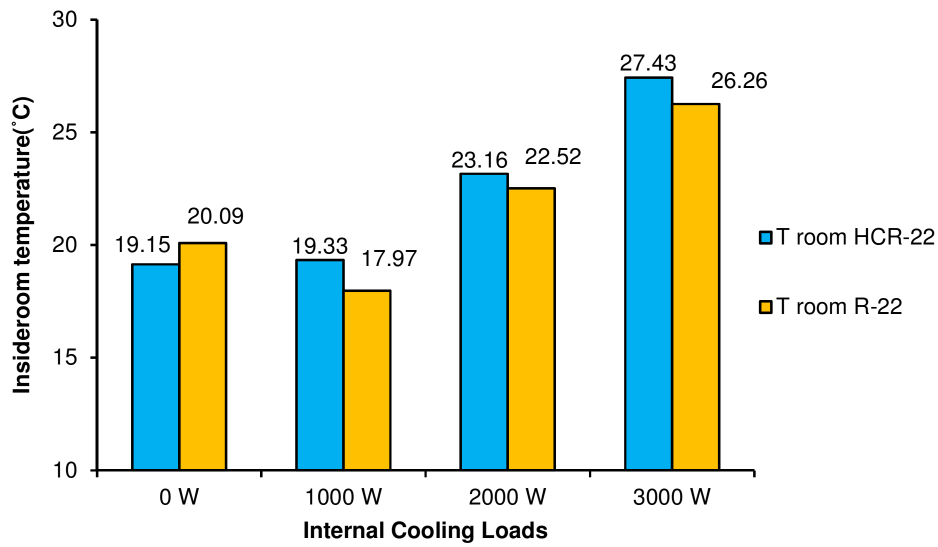

Fig. 8. Room temperature at various cooling loads on RSAC standard

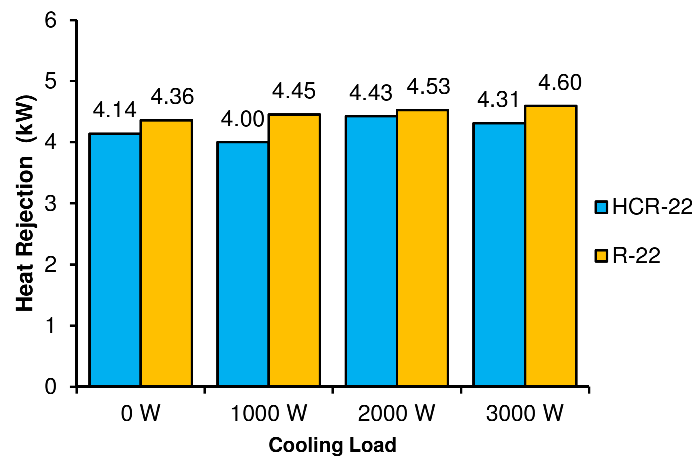

Fig. 9. Heat rejection of condenser at various cooling loads on RSAC standard

RSAC performance was indicated by the coefficient of performance (COP) where COP is the ratio from the cooling capacity to the compressor power consumption for running the system. COP of HCR22 and R22 at various cooling loads on RSAC standard are shown in Figure 10. The COP using HCR22 on RSAC standard are 6.40, 6.21, 6.59 and 6.95, increase in small value with the increasing of internal cooling loads 0 W, 1000 W, 2000 W and 3000 W respectively. On the other hand the COP using R22 on RSAC standard have the same condition compared to HCR22, where the COP increase with the increasing of internal cooling loads also in small value. Overall value of COP for HCR22 as shown in Figure 10 is higher than R22 refrigerant because the lower of compressor power consumption than R22 as shown in Figure 5. This result gives good agreement with Nasution et. al. [13], where the cooling capacity of HCR22 was higher than R22, due to the fact that the COP of R-22 lower than that of HCR-22.

Figure 11 show the percentage of COP increasing of HCR22 against R22 at various cooling loads on RSAC standard the, where the increasing of the COP value is 16.10 %, 12.66 %, 16.56 %and 19.99 % at internal cooling loads 0 W, 1000 W, 2000 W and 3000 W respectively. The final results show that

HCR22 had better performance than R22, and indicate that the HCR22 could be used for retrofitting on existing R22 residential split air conditioner as drop in substitute without modified parts of RSAC system. It can be stated that the COP of RSAC standard with HCR22 better than R22, where the compressor power consumption using HCR22 lower than R22 and also gives higher electric power consumption saving. It means when the compressor power are lower, it will give the higher COP than R22.

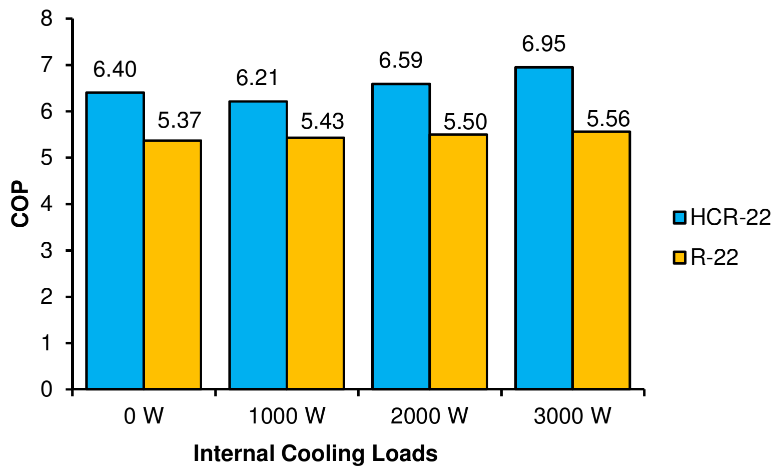

Fig. 10. COP of HCR22 and R22 at various cooling loads on RSAC standard

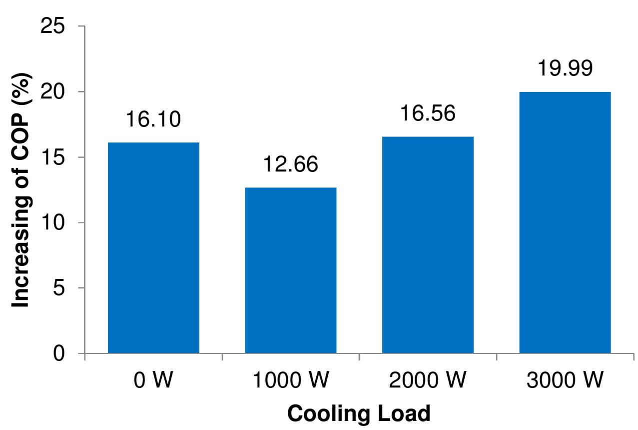

Fig. 11. Percentage of COP increasing of HCR22 against R22 at various cooling loads on RSAC standard

4. Conclusion

The effect of cooling load on the performance of R22 RSAC when retrofitting with HCR22 as the working fluid in the standard condition has been conducted. The results show that the COP of RSAC increase with the increasing of cooling load, where the COP with HCR22 increase 16.10%, 12.66%, 16.56% and 19.99% higher than R22 for cooling load 0 W, 1000 W, 2000 W and 3000W, respectively. The compressor power consumption were reduced with HCR22 lower than R22 by 18.27%, 20.01%, 16.26% and 22.56% for various cooling load (0 W, 1000 W, 2000 W and 3000W) while the cooling capacity and heat rejection capacity were almost equal to slightly lower when compared with R22. The experimental results show that HCR22 had better performance compared to R22, and indicating that HCR22 could be used for retrofitting existing RSAC with R22.

Acknowledgments
The present study was financially supported by Universitas Riau and Ministry of Research, Technology and Higher Education (Penelitian Unggulan Perguruan Tinggi, DRPM, Desentralisasi Research Grant 2017, contract no: 095/SP2H/LT/DRPM/IV/2017).

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