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Analysis of the Effect of Adding a Water Heater to the R290 Split Air Conditioning Instead of R22

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Abstract: The heat generated by split air conditioning (AC-Split) is sufficiently high to be utilized as a heat exchanger. The installation of a heat exchanger device, referred to as an Air Conditioning Water Heater (ACWH), is used to heat water in a tank by utilizing the waste heat from the condenser. In this study, refrigerant R290 will be used as a replacement for R22, with the aim of eliminating the Ozone Depleting Potential (ODP) and Global Warming Potential (GWP) associated with R22. Calculations are carried out to ensure the performance of the split AC by testing each refrigerant, R22 and R290, installed in the heat exchanger system. The test data is calculated and analyzed based on the performance on the vapor compression diagram. The results of the performance calculations of each R290/R22 refrigerant COP: 9.7/6.4, compression work: 28.7/25.72 kJ/kg, cooling effect, and electrical power: 881/976 Watts. The calculation results of R290 have better performance compared to R22, especially in electrical power. R290 is 10% lower than R22, COP is 34% higher, and it is ODP and GWP-free.

Keywords: R290, R22, COP, Power, ACWH.

Abstrak: *Panas yang dihasilkan oleh Air Conditioning jenis split (AC-Split) cukup tinggi untuk dapat dimanfaatkan sebagai alat penukar panas. Pemasangan alat penukar panas yang dinamai Air Conditioning Water Heater (ACWH) digunakan untuk memanaskan air di dalam tangki melalui pemanfaatan panas buang dari kondensor. Dalam penelitian ini akan dilakukan penggunaan refrigeran R290 sebagai pengganti R22 yang bertujuan untuk menghilangkan nilai Ozone Depleting Potential (ODP) dan Global Warming Potential (GWP) yang terkandung di refrigeran R22. Perhitungan dilakukan untuk memastikan kinerja AC split melalui pengujian pada masing-masing refrigeran R22 dan R290 yang terpasang pada alat penukar panas. Data hasil pengujian dihitung dan dianalisis berdasarkan kinerja pada diagram kompresi uap. Hasil perhitungan performa dari masing-masing refrigeran R290/R22 COP: 9.7/6.4, Kerja Kompresi: 28.7/25.72 kJ/kg, Efek pendinginan dan Daya Listrik: 881/976 Watt. Hasil perhitungan R290 memiliki kinerja lebih baik dibandingkan dengan R22, terutama pada daya listrik. R290 lebih rendah 10% dibanding R22, COP lebih tinggi 34%, dan bebas ODP dan GWP.*

Kata kunci: *R290, R22, COP, Daya Listrik, ACWH.*

INTRODUCTION

HCFC-22 (R22) refrigerant is a refrigerant that damages the ozone layer and causes global warming because it still contains ODP = 0.055 and GWP: 1810. The potential of R290 to replace R22 is quite high, because R22 does not contain Ozone Depleting Potential (ODP), Global Warming Potential (GWP) and has characteristics of physical and thermodynamic properties close to R22. Air Conditioner Water Heater (ACWH) is a conventional Air Conditioning device combined with a water heating system, by utilizing the heat of the fluid coming out of the compressor to the condenser. Usually this heat is only exhaled with a fan in the condenser to the surrounding environment but this time to increase the efficiency of the power or energy wasted to be utilized as a tool to heat water [1], [2]. The Indonesian government through the Minister of Industry Regulation No. 41 / M-Ind / 5 / 2014 has banned the use of R22 for all uses in commercial, industrial and household air conditioner.

The refrigeration system processes all work by using refrigerant as the working fluid. The main function of the refrigerant is to absorb heat and dissipate the heat [3]. The process of absorbing heat occurs in the indoor air conditioning unit or evaporator while the heat dissipation process occurs in the outdoor unit or condenser [4], [5]. Refrigerant has many types that can be used in refrigeration systems and each refrigerant has different characteristics, the types that are often used are propane, HCFC (hydrochlorofluorocarbon), and HFC (hydrofluorocarbon*)* [6].

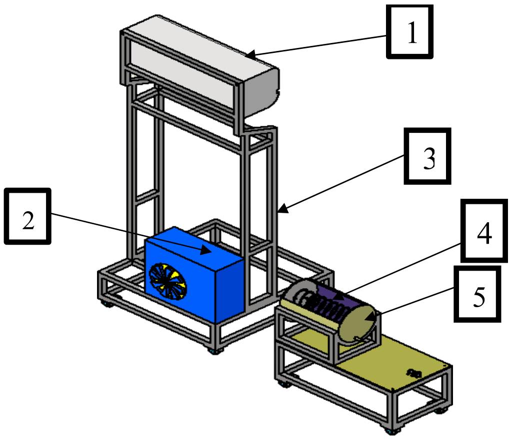
Research conducted previously on ACWH applications using R22 refrigerant and did not compare with R290 with a smaller AC-Split capacity compared to the current research. [7]. In addition to having low ODP, R290 refrigerant also has low global warming potential [8]. Previously conducted research compared R290 to R22 on a regular Split AC unit, with the result that the COP is higher than R22 and there is a decrease in electric power [9]. Research using R290 is expected to reduce GWP values and electrical power consumption and increase COP.

In this research, the heat exchanger coil used is a spiral coil with a length of 2.7 meters long using R290 refrigerant instead of R22. This type has the advantage of being shaped like a horizontally rotating mosquito coil so that it can deliver heat efficiently [10], [11]. In this study, refrigerant R290 will be used as a replacement for R22, with the aim of eliminating the Ozone Depleting Potential (ODP) and Global Warming Potential (GWP) associated with R22. Calculations are carried out to ensure the performance of the split AC by testing each refrigerant, R22 and R290, installed in the heat exchanger system.

METHODS

The test method is carried out through direct experiments on testing equipment. The refrigerant used for testing on ACWH consists of two refrigerants R290 and R22. The heat exchanger used is a spiral pipe 2.7 meters long with an inner diameter of 6.0 mm. The parameters observed include the performance of the system, temperature, pressure, power, and voltage generated by both types of refrigerant. The main parts of the test equipment consisting of indoor unit, outdoor unit, construction, heat exchanger and water tank is described in Figure 1.

The preparation process before testing the tool is first carried out by vacuuming the system to remove the air trapped in the system for 30 minutes or until the manifold gauge needle shows the number -30 Psi, the next process is to fill the refrigerant according to the density and standard on the AC unit (R290 = 268 grams, and R22 = 670 grams), then after the refrigerant charging process the system is operated for 1 hour (60 minutes) to stabilize the performance of the AC unit, then if the system has stabilized then data collection can be done by recording temperature, pressure, power, and voltage data for 60 minutes with 5 minutes recording time once. The data collection process is carried out for 3x data collection with the same time and different days for AC and ACWH systems for both R290 refrigerant and R22 refrigerant [12].



1	: Indoor unit
2	: Outdoor unit
3	: Construction
4	: Heat Exchanger
5	: Water tank

Figure 1. Desain tools of air conditioning water heater

The initial step in the research is to look for journal references that discuss the research discussed. Designing tools, determining the heat exchanger coil to be used and the water tank, collecting tools and component materials that will be used later in the assembly of the water heater air conditioner. After planning, the assembly of indoor, outdoor, 2.7meter spiral coil heat exchanger and frame components is carried out on the water heater air conditioner system. Then, all components have been installed and can be operated the tool can be tested in accordance with the research conducted, if the test is successful then data can be taken and analyzed.

However, if the test is unsuccessful or fails, the test must be considered again in the planning and make sure whether there is an error in the component or not. Testing is done by taking data on temperature, pressure, power, voltage, room temperature, and humidity. Taking temperature, power and voltage data using a data logger. Taking pressure data with a pressure device gauge, room temperature and humidity with a hygrometer then recorded in a notebook.

Testing condition of this research tool with environmental temperature conditioning of 32 degrees Celsius with RH: 75-80% tolerance 1-2 points. Test Equipment used for recording temperature data using Arduino Uno, to measure the working pressure of the suction and discharge sides of the compressor and expansion valve using a manual pressure gauge, while to measure electrical power using Arduino with output voltage, current strength, power factor and power.

The equation used in the test results is lower, although the refrigerant R290 shows lower but in regular electricity consumption will be much more efficient [13].

- Work of Compression
  $W_c = h_2 - h_1$ (1)
- Heat of Condensation process:
  $Q_{out} = h_2 - h_3$ (2)
- Refrigeration effect:
  $Q_{out} = h_1 - h_4$ (3)
- Coefficient of Performance:
  $COP = \frac{Q_{in}}{W_k}$ (4)
- Power of Electrical
  $P = V \cdot I \cdot \cos \varphi$ (5)

RESULT AND DISCUSSION

The test data uses R22 and R290 refrigerants with a time of 60 minutes. The test process is carried out continuously. This test is assisted by using data acquisition on temperature and pressure measurements. Table 1 explains the test results of each refrigerant at each temperature and pressure point.

Table 1. Average result data test

Description	**Non WH**		**ACWH**	
	R290	**R22**	**R290**	**R22**
P1 Suction (Psig)	67,4	74,1	68,4	72,1
P2 Discharge (Psig)	237,0	289,5	237,1	276,9
P3 Inlet Exp (Psig)	215,6	247,6	212,2	234,8
P4 (outlet Exp) (Psig)	82,8	96,9	75,6	75,5
T1 Suction (°C)	21,3	22,9	21,8	22,9
T2 Discharge (°C)	71,7	94,9	71,4	93,1
T3 Inlet Exp (°C)	38,8	40,9	37,4	38,8
T4 outlet Exp (°C)	16,7	20,6	17,1	19,9

Performa AC dan ACWH refrigerant R290 dan R22

The test results on the AC and ACWH system using refrigerant R290 and R22 are presented in the diagram, the pressure performance on the AC and ACWH system refrigerant R290 and R22 there is a significant difference when compared to refrigerant R290. Suction pressure, R290 discharge is lower than R22. Refrigerant R290 has a low density / density so that at the time of charging the refrigerant into the system decreased by 40% (refrigerant R290 = 268 grams, and refrigerant R22 = 670 grams). This shows that R290 refrigerant is better than R22 refrigerant. Comparison of R290 and R22 pressure is described detail of the result we can see in Figure 2.

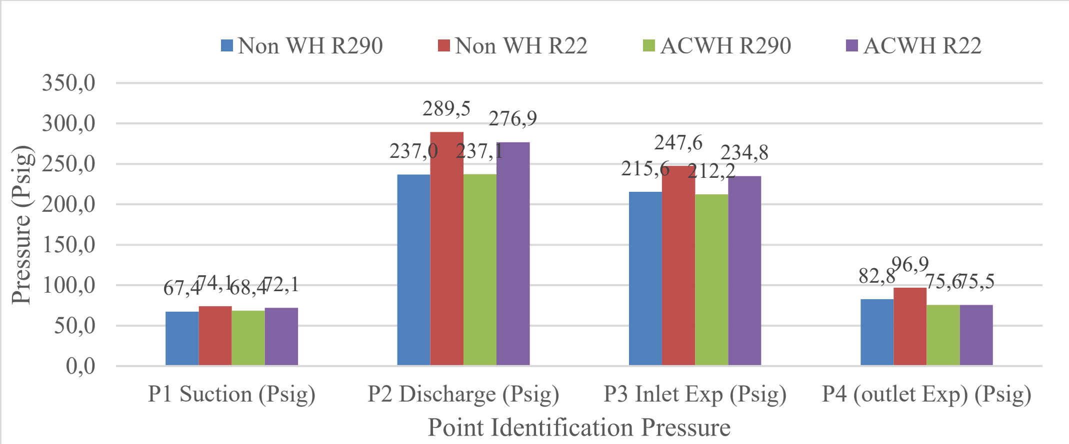


Figure 2. Pressure of comparation each refrigerant

The temperature in each system shows a difference where the R22 refrigerant is higher in fluid temperature. This is caused by differences in the characteristics of each refrigerant including critical pressure, boiling point, dew point, specific heat, and other refrigerant properties. The difference in the amount of refrigerant mass can also affect the resulting temperature, but in this case the more mass of refrigerant does not mean the better the performance of the system, Figure 3 shows the refrigerant R290 with a 40% refrigerant mass percentage (268 grams) because the density of R290 is 35% lower than the total mass of refrigerant R22 according to the nameplate of 670 grams (100%) [14].

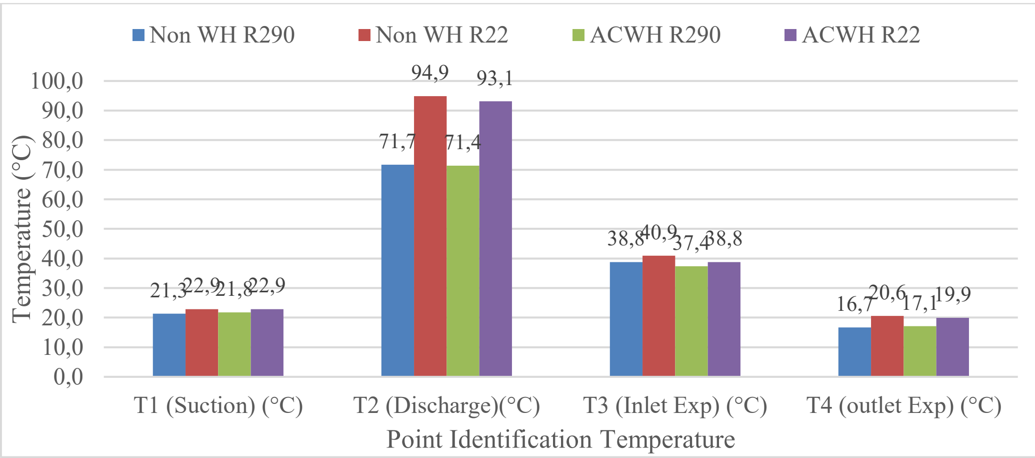
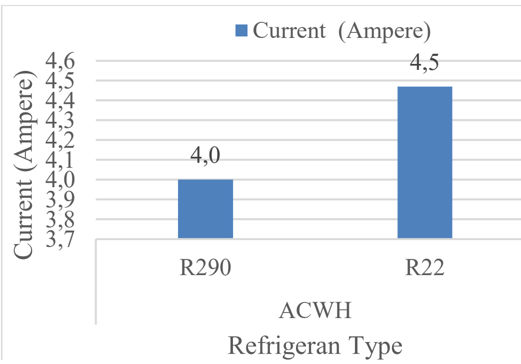
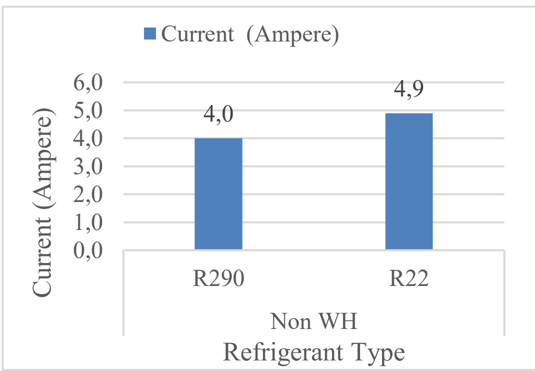


Figure 3. Temperature of Comparison each refrigerant

Figure 4 shows the electric current generated by the two systems. The electric current strength of the R290 refrigerant AC system is 20% lower than the R22 refrigerant, and the electric current strength of the R22 refrigerant ACWH system is 10% higher than R290. The difference between the two systems shows that R290 refrigerant produces a lower electric current strength, although R290 refrigerant shows lower but in regular electricity consumption will be much more efficient. R290.



(a)



(b)

Figure 4. Comparation of Current: (a) Comparation AC R290 and R22; (b) Comparation ACWH R290 and R22

Consumption increases with higher refrigerant mass, refrigerant mass R22: 670 grams in the AC system produces electric power of 1062 Watts while refrigerant R290 AC with refrigerant mass 268 grams produces electric power of 878 Watts. Likewise, in the ACWH system, the refrigerant R290 is lower in producing electric power of 881 Watt while R22 produces electric power of 976 Watt. Refrigerant entering the compressor (suction) in a vapor state at a pressure of 83 Psig and enthalpy :597.9 kJ/kg (h_1 ACWH refrigerant R290), the pressure at the suction ACWH refrigerant R22:89.9 Psia and enthalpy = 412.2 kJ/kg (h_1 ACWH refrigerant R22), then the refrigerant is compressed so that there is an increase in pressure to 251.7 Psig and enthalpy = 628 kJ/ kg (h_2 ACWH refrigerant R290), the outlet pressure of ACWH refrigerant R22 suction = 291.6 Psig and enthalpy = 438 kJ /kg (h_2 ACWH refrigerant R22).

The enthalpy values h_1, h_2, h_3, h_4 were obtained by adjusting the pressure and temperature of the test results with the enthalpy table and refrigerant P-h diagram, and shown in Table 2 nilai enthalpy AC and ACWH.

Table 2. Pressure and entalphi of R22 and R290

Description	AC R22		ACWH R22		AC R290		ACWH R290	
	Presure (Psia)	*Enthalpy (kJ/kg)*	*Presure* (Psia)	*Enthalpy (kJ/kg)*	*Presure* (Psia)	*Enthalpy (kJ/kg)*	*Presure* (Psia)	*Enthalpy (kJ/kg)*
h_1	88,7	412,4	86,9	412,2	82,1	596,9	83,0	597,9
h_2	304,2	441,0	291,6	438,0	251,7	629,0	251,7	628,0
h_3	262,2	250,5	249,5	247,0	230,2	304,2	226,8	304,2
h_4	111,5	250,5	108,8	247,0	97,5	304,2	93,8	304,2

In the Pressure and enthalpy diagram, it can be seen that the pressure of R22 is higher than that of R290 due to the physical and thermodynamic properties of R290. As for the enthalpy of each point on the vapor compression diagram, the enthalpy value of R290 is greater than that of R22. this causes the increase in COP value and cooling effect show in the Figure 5.

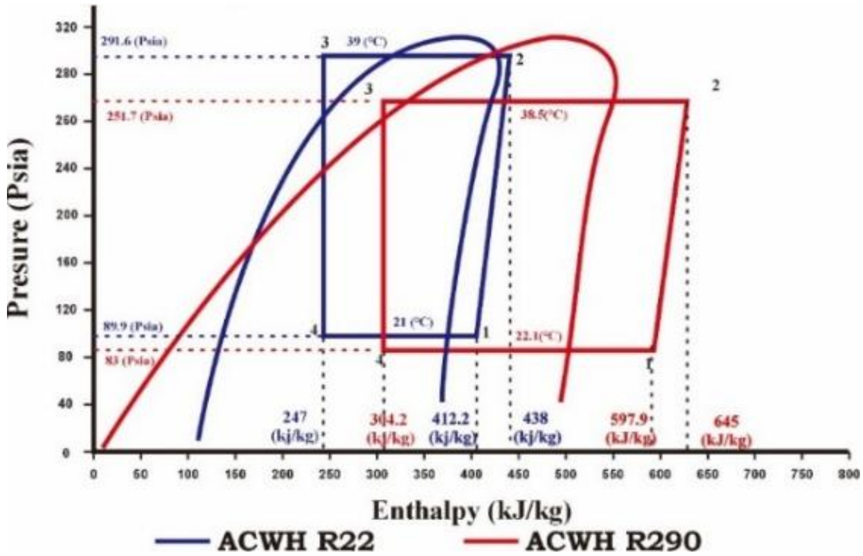


Figure 5. Diagram Pressure versus enthalpy R22 and R290

CONCLUSIONS

From the results of calculations carried out using the empirical formula formula, the performance results of R290 / R22 Refrigeration effect are obtained: 278.4/164.5 Work Compression: 28.7/25.7, COP: 9.7/6.4, Electric power is lower by 11-15% R290 has a significant advantage in COP: 6.6%, Cooling effect: almost the same average and Electric Power down: 18-20%. This ACWH system can provide benefits in providing hot water that can be used for bathing and other needs to assist in heating a process. The advantages obtained by using R290 refrigerant in addition to reducing electrical power, saving in the use of only 40% of the amount of refrigerant, friendly to the environment. Thus R290 refrigerant has the potential as a substitute for R22 with a note that its use must be carried out by people who have the ability to handle and high work safety according to the standard.

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