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The effect of changing superheat degrees on energy consumption in a split air conditioning

I N Ardita[1], I G A B Wirajati[1], Sudirman[1]

[1] Department of Mechanical Engineering, Politeknik Negeri Bali, Kampus Bukit Jimbaran, Bali, Indonesia

E-mail: nengahardita@pnb.ac.id

Abstract. Split air conditioning is the most widely used in the community for both commercial and domestic purpose. But it can cause inefficiency or waste of energy use by the system. For this reason, it is very important to keep the system working in optimum conditions to prevent wasteful use of energy by the air conditioning system. This research will re-investigate the effect of the superheat degree of refrigerant coming out of the evaporator on the system's energy consumption. This research is conducted by analytical methods and experimental methods whose implementation includes; designing and manufacturing of experimental equipment, installation of measuring instruments experimental data retrieval, data processing and yield analysis. Data processing is done by using thermodynamic methods to get the desired quantities such as; compressor power consumption, refrigeration effects and coefficient of performance (COP). The results were carried out by quantitative descriptive method, namely by analysing changes in the superheat degree of compressor energy consumption. Based on the analysis results show that if degree of superheat is increased, compressor energy consumption increases for all refrigerants used. Whereas COP system decreases for R22 refrigerant, is relatively constant for R410a refrigerant and raises an increase for other refrigerants tested.

1. Introduction

Air conditioning (AC) split type that cools the room is increasingly used in hotels, offices, and households. With an air conditioning system, the air in the room can be conditioned according to the needs of temperature, humidity, and cleanliness so that a comfortable condition can be obtained. With comfortable conditions, people will be able to perform better, creative and more productive.

One of the concerns in choosing an AC unit is that the user of power consumption and the coefficient of performance. Power consumption is a major concern in vapor compression cycles of air conditioning systems which is used air-cooled condensers. One of the causes of increased energy consumption in air conditioners is the increase in the superheat degree of the refrigerant coming out of the evaporator. The Superheat of gases is the increase in refrigerant temperature from the evaporator output. At the end of the evaporator, the refrigerant is in the form of saturated gas. Refrigerant in the form of saturated gas still having a lower temperature than the surrounding environment makes the heat absorption process still occur. The continued heating process at a fixed pressure after exceeding the saturated gas limit is called “superheat”. This superheat value is calculated by reducing the actual temperature with its saturation temperature. While the saturation temperature is obtained from the results of the pressure conversion where the temperature reading is carried out. The process of continued heating at a fixed pressure after exceeding the saturated steam limit is called “superheat”.

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The thermodynamic analysis of some refrigerants regarding the effect of subcooling and superheating on COP on the vapor compression refrigeration system shows that the greater the value of subcooling and superheat will significantly increase the system COP [1,2,3]. Likewise [4,5], has analysed the vapor compression refrigeration system by considering the influence of subcooling and superheating on three different refrigerants namely R22, R410a, and R32. The results of the analysis show the greater the degree of superheat, the mass flow rate of refrigerant decreases. And from the three refrigerants, the COP value of R32 refrigerant is slightly larger than the others. Whereas [6] also conducted an investigation using R407c as an alternative to the R22 refrigerant substitute. The results found that COP for R407c is slightly smaller than R22. And systems with subcooling and superheating will increase the COP [7].

Whereas, conduct thermo-economic analysis of the effect of subcooling and superheating on cascade refrigeration systems. The results of the case study show that, compared to the basic design, the use of Two Single-Objective Optimization Strategies (SOS) to maximize exegetic efficiency can increase exegetic efficiency by 94.5%. In addition, the use of second SOS can reduce total system costs by 11%. Using MOS compared to the basic design, exegetic efficiency and total system costs can increase by 99.1% and 28.6% [8].

Likewise, the greater Superheat can increase COP on R134a refrigerant which implies that to get better performance from the refrigerant then the refrigerant must be heated as much as possible. Conversely, for refrigerant R717 the greater the superheat the refrigerant will reduce the system COP. This implies that refrigerant provides better performance in a saturated state and does not require overheating [9].

Whereas, carried out experimental studies of simple VCRS cycles and VCRS cycles with superheating obtained from the help of liquid line heat exchangers. If increasing the temperature of the refrigerant exits the evaporator or before entering the compressor at 6 0C from (-2 0C to 4 0C i.e. the superheating refrigerant) then the COP and the refrigeration effect of the cycle will increase. In general, R-134a refrigerant gives the best results for evaporator temperature conditions, condenser temperature, and the same cooling rate compared to R-12 and R-717 refrigerants [10-12].

2. Methodology

The split type of air conditioning application has a cooling capacity of 9000 Btu / hr which is made by Panasonic electric. The sketch of the experimental equipment design and positioning of the measuring instrument as shown in Figure 1. Installation of the evaporator air intake heater aims to make the load on the evaporator. The amount of load can be adjusted by controlling the energy consumption of the heater. With this change in load, the degree of superheat can be changed. Tests are carried out using various refrigerants including; R22, R134a, R410a, R404a, R407c, R290 and R600a. Data recording is carried out after the steady-state system is estimated after five minutes the system operates. Test data is recorded for each change in superheat degree.

A digital AC clamp power meter is used to measure the compressor power consumption system (Kyoritsu, with 1.5% accuracy). Bourdon tube pressure gauge measures the refrigerant pressure of the evaporator output which is suitable for the refrigerant system with the 5 psi accuracy level. In this study pressure, drops in both condensers and evaporators were ignored due to the effect on the end of the result was not significant. The K type thermocouple records the temperature of the refrigerant and the air circulation of the evaporator at predetermined measurement points.

Based on [13,14], the desired parameter is calculated by using Equation (1) to (4). Equation (1) is used to calculate the compressor power consumption. Equation (2), (3) and (4) are used to calculate Mass flow rate, cooling capacity and system performance.

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

$$\dot{m} = \frac{Wk}{h_1 - h_2} \quad (2)$$

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

$$COP = \frac{Q_r}{W_k} \quad (4)$$

In all equation, enthalpy the output conditions of the evaporator, and compressor are expressed by h1, and h2 consecutively.

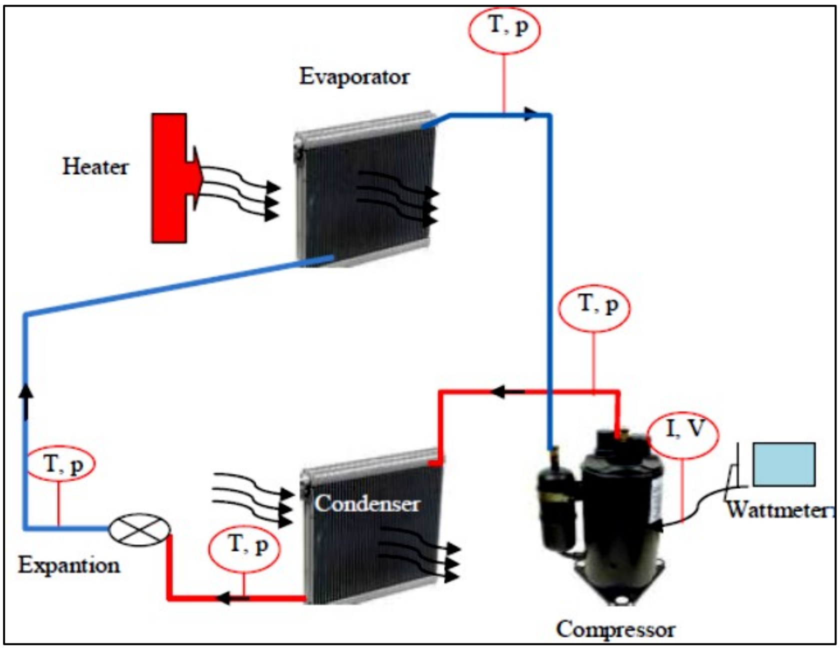

Figure 1. Experimental design and instrument tool positions.

3. Result and discussion

Plotting data into the P-h diagram uses Mollier Chart program. On the P-h diagram, the value of enthalpy can be founded. The refrigeration effect, mass flow rate, cooling capacity and coefficient of performance (COP) system is calculated by using the amount of enthalpy at each measurement position. One of the experiment results on the P-h diagram can be seen in Figure-2. The graph shows that the greater the degree of superheat causes the increase in the effect of refrigeration and energy consumption by the compressor.

In a system that uses R22 refrigerant, it shows that by increasing the superheat value the compressor energy consumption increases. But on the contrary with increasing superheat value causes the COP of the system to occur as a decrease, as seen in Figure-3. The Figure also shows that the increase in compressor energy consumption for each superheat increase is not very large.

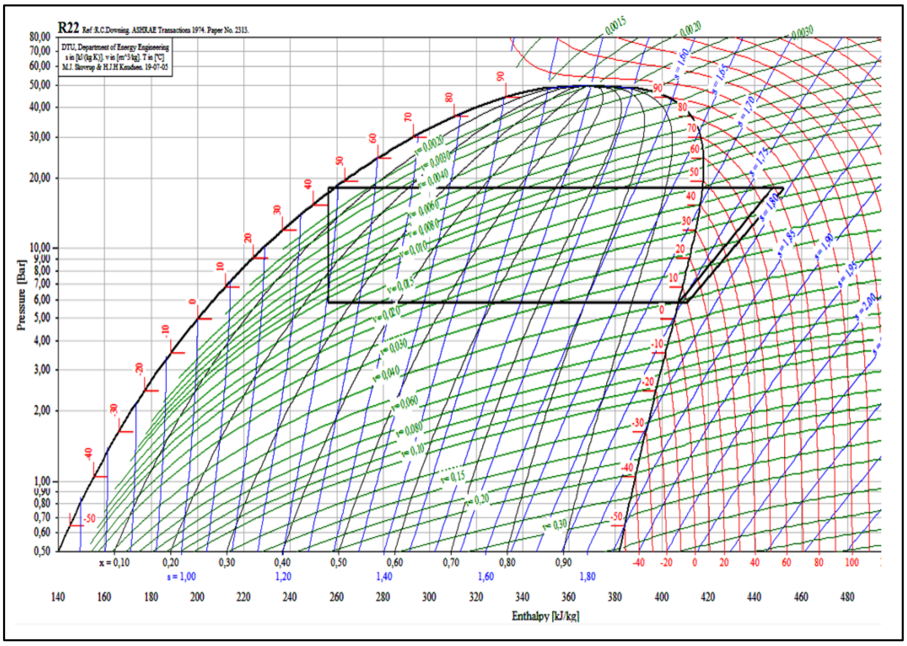

Figure 2. P-h diagram of system without and with superheat.

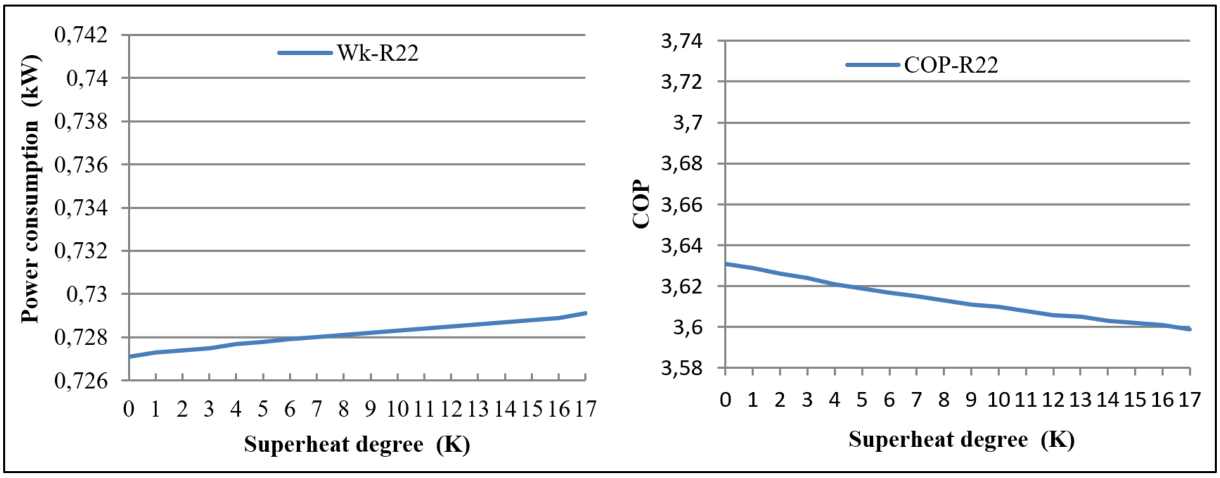

Figure-3. Power consumption and COP system with R22 refrigerant.

For R410a refrigerant, Figure-4 shows that by increasing the superheat value of the refrigerant output of the evaporator it will cause the compressor's energy consumption to increase, but the change in superheat degree does not significantly affect the system COP.

Figure-5 with R404a refrigerant shows that increasing the superheat value of the refrigerant coming out of the evaporator causes the compressor's energy consumption to increase. On the other hand, there are beneficial benefits that superheat value can increase system COP. Judging from the slope of the graph, the increase in energy consumption and system COP is quite significant ranging from 0.1% and 0.23% for each increase in superheat degree by 1K.

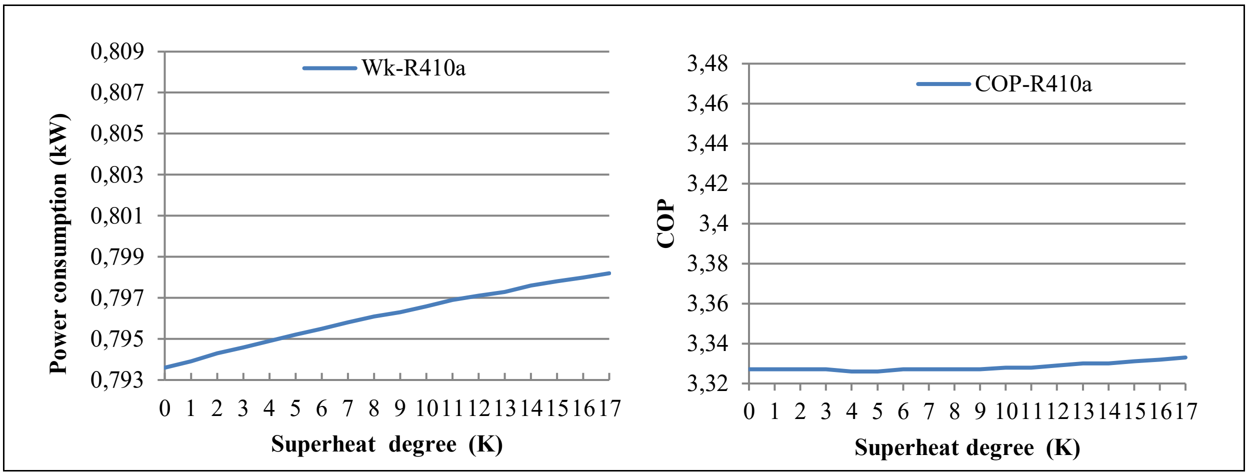

Figure 4. Power consumption and COP system with R410a refrigerant.

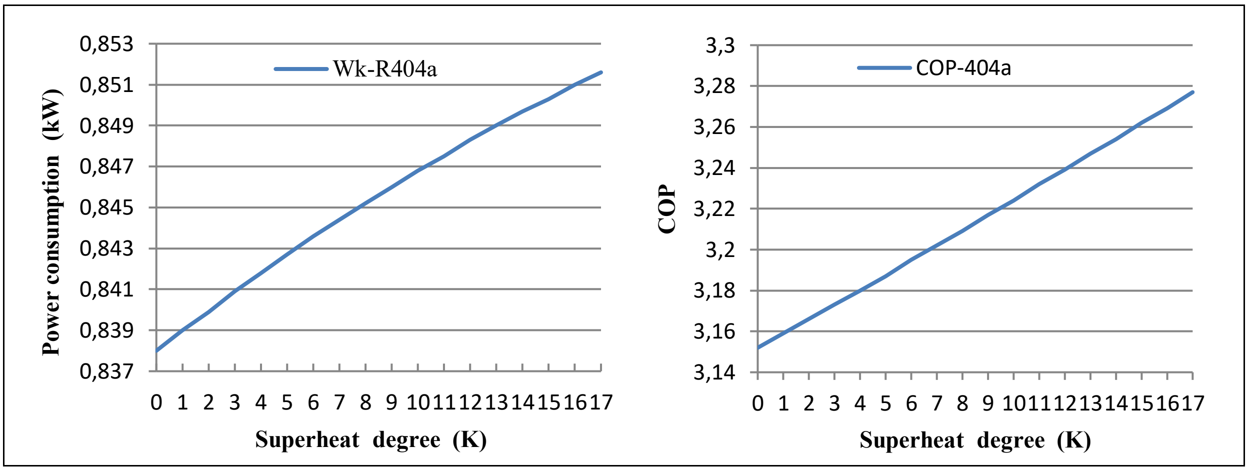

Figure 5. Power consumption and COP system with R404a refrigerant.

Figure 6 with R407c refrigerant shows that the increase in the superheat value of the refrigerant output of the evaporator causes the compressor's energy consumption to increase, but the change in the superheat does not significantly affect the system COP even though there is a slight increase.

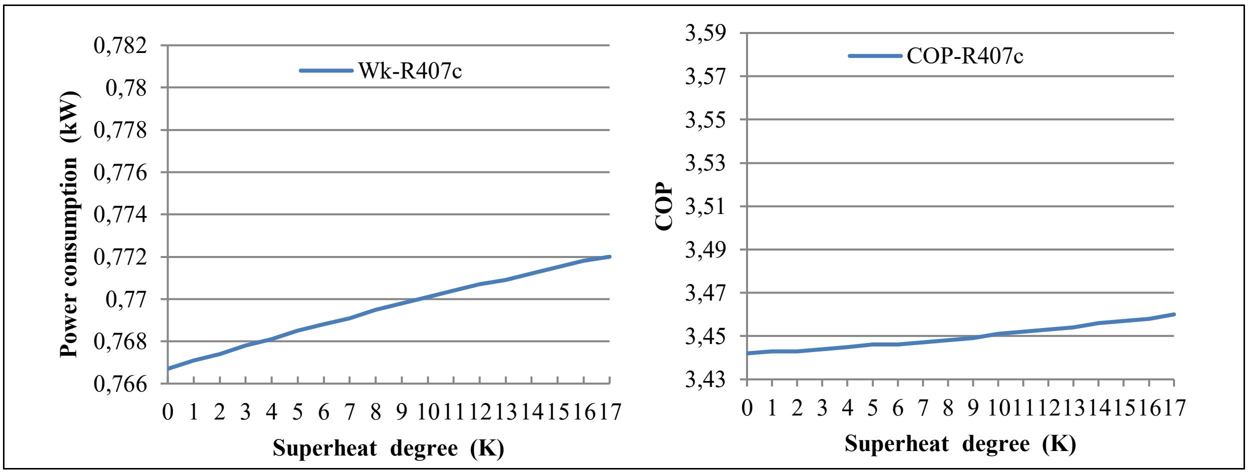

Figure 6. Power consumption and COP system with R407c refrigerant.

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Figure 7 with R290 refrigerant shows that the increase in the superheat value of the refrigerant output of the evaporator causes the compressor's energy consumption to increase. On the other hand, there is a favourable benefit is the increase in superheat values can increase system COP. Judging from the slope of the graph, the increase in energy consumption and system COP is quite significant around 0.03% and 0.14% for each increase in superheat degree by 1K.

Figure 8 with R134a refrigerant, indicate that increasing the refrigerant superheat value out evaporator causing the compressor energy consumption and system COP increases. The increase in compressor energy consumption ranges from 0.04% and the system COP is 0.1% for each increase in superheat degree by 1K.

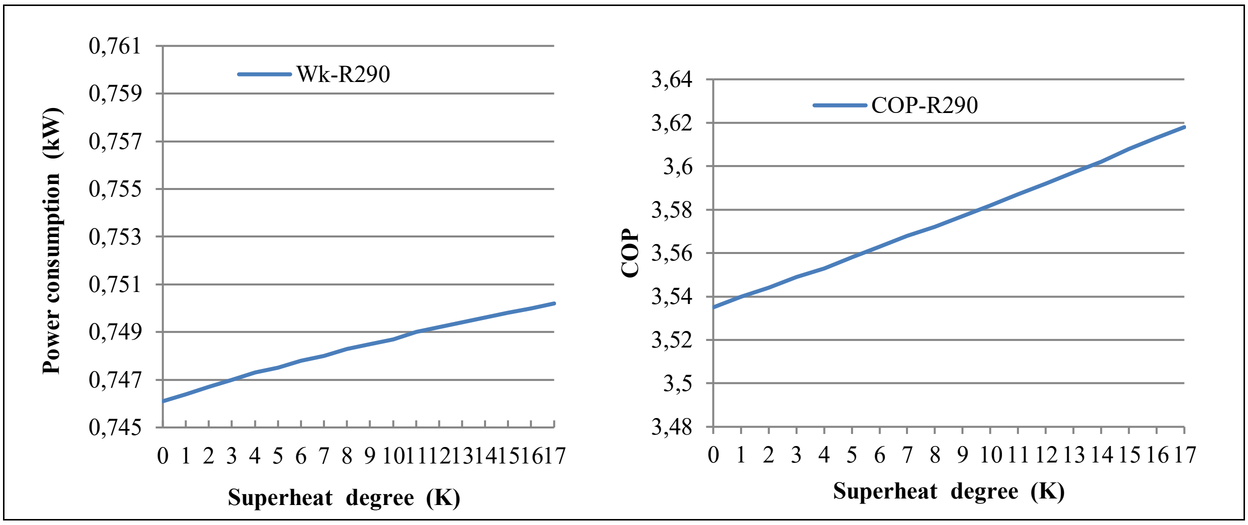

Figure 7. Power consumption and COP system with R290 refrigerant.

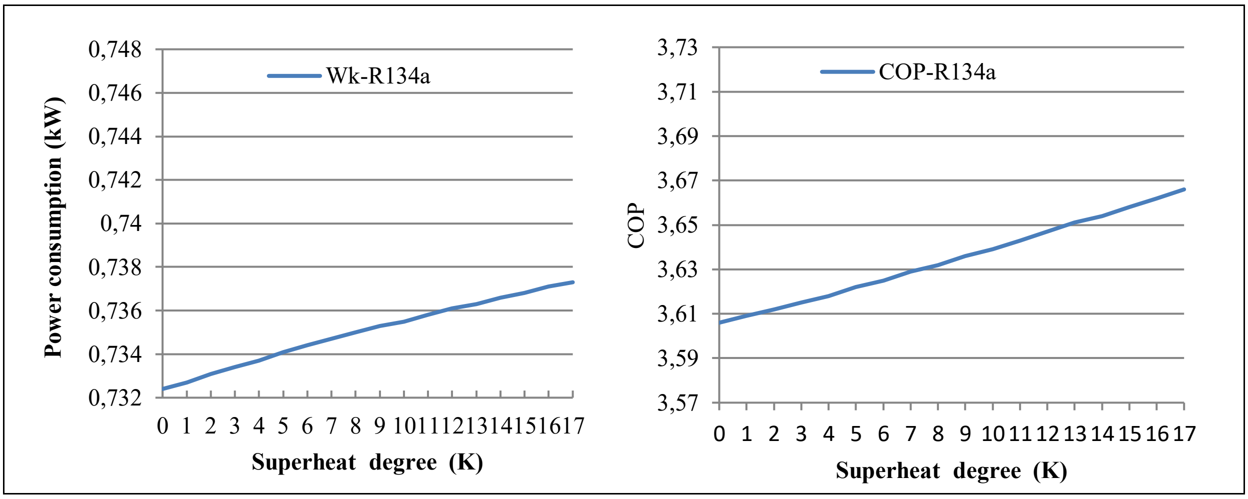

Figure 8. Power consumption and COP system with R134a refrigerant.

Figure-8 with R600a refrigerant shows that increasing the superheat value of the refrigerant output of the evaporator causes the compressor's energy consumption and system COP to increase. Increasing compressor energy consumption ranges from 0.03% and system COP by 0.2% for each increase in superheat degree by 1K.

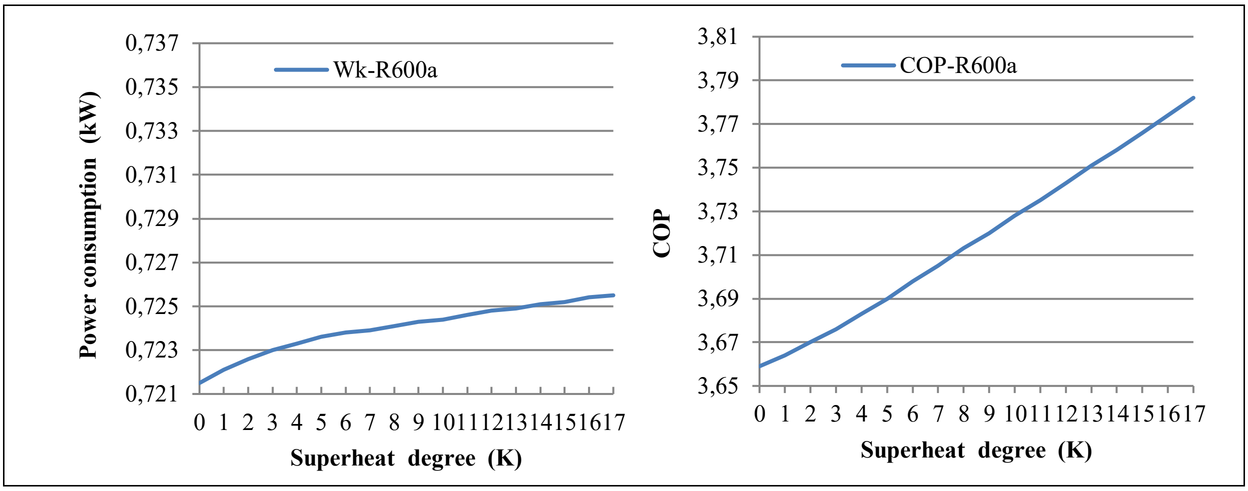

Figure 9. Power consumption and COP system with R600a refrigerant.

4. Conclusions
Based on this study, the conclusion is increasing the value of the refrigerant superheat level out of the evaporator will increase the compressor energy consumption about 0,03% until 0,1% for each increase in superheat degree by 1K. The amount of increase in compressor energy consumption depends on the refrigerant used in the system. The increase in superheat value also affects the COP system. In general, the increase in superheat value will increase the COP system about 0,1% until 0,23% for each increase in superheat degree by 1K except for the decrease in R22 refrigerant.

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