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ENERGY ANALYSIS OF VAPOR COMPRESSION REFRIGERATION SYSTEM USING R417B AS REFRIGERANT

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ABSTRACT

In this study, the energy analysis of the vapor compression refrigeration system (VCRS) using R417B was made for different operating conditions. The thermodynamic data required for the calculations were taken from the Coolpack program. In the analysis made depending on the evaporator temperature change, the highest COP value of the cycle is 4.5. This value was obtained under the operating condition of -1 °C evaporator temperature and 35 °C condenser temperature. It is thought that it would be beneficial to use the working conditions determined in this study in order to benefit effectively from the VCRS using R417B.

1. INTRODUCTION

Reducing the temperature of a place or system to the desired value and keeping it constant at that value is called cooling. For this, the devices that transfer heat from the indoor environment to the outside environment are also called cooling systems. In cooling systems, refrigerants are used to transport heat. When refrigerants pass from the liquid phase to the vapor phase, they absorb heat from the environment they are in and provide cooling. Good heat transfer properties are expected from refrigerants, as well as chemical stability, non-toxicity, non-combustibility, reasonable price, and availability. Kılıç and Arabacı made energy analysis of the VCRS using R1270. The effects of R1270 on VCRS were investigated. In their analysis, they reached the highest COP value of the cycle, 8.65, under the operating condition of -1°C evaporator temperature and 25°C condenser temperature [1]. Kılıç and İpek investigated the cooling performance of VCRS using R410A refrigerant. They determined the highest COP value as 7.3 in their analysis [2]. Kılıç et al. examined performance of two-stage with economizer refrigeration system. They used R134a as refrigerant in the cooling system. The optimum operating conditions of the system were determined as 20 °C condenser temperature and 5 °C evaporator temperature [3]. Yıldız and Yıldırım theoretically investigated the performance and the environmental effects of R134a and R513A using as refrigerant in VCRS. Energy performances of refrigerants are made for different evaporator and condenser temperatures and the highest COP values for -15 °C evaporator temperature and 30 °C condenser temperature are 3.87 and 3.77 for R134a and R513A, respectively [4]. Cingiz et al. investigated the performances of R417A, R438A, R422A and R422D refrigerants, which are used instead of R22 refrigerants in refrigeration systems, according to the first and second laws of thermodynamics. As a result of the study, it was determined that R438A and R417A would be a good alternative to R22 in terms of COP and exergy efficiency [5]. In addition to the studies in the literature, in this study, the cooling performance of the VCRS using R417B refrigerant for different condenser and evaporator temperatures was determined.

At one point, the R417B refrigerant in the form of saturated vapor is compressed by the compressor. R417B refrigerant, which reaches high temperature and pressure values at two points, becomes superheated vapor and enters the condenser at this point. At three points, it dissipates its heat to the environment and becomes a saturated liquid, and at this point it leaves the condenser and enters the throttling valve. At four points, which are the end points of the cycle, the low-pressure fluid enters the liquid+vapor phase evaporator and completes the cycle. The temperature-entropy diagram of the cycle is shown in Fig. 1.

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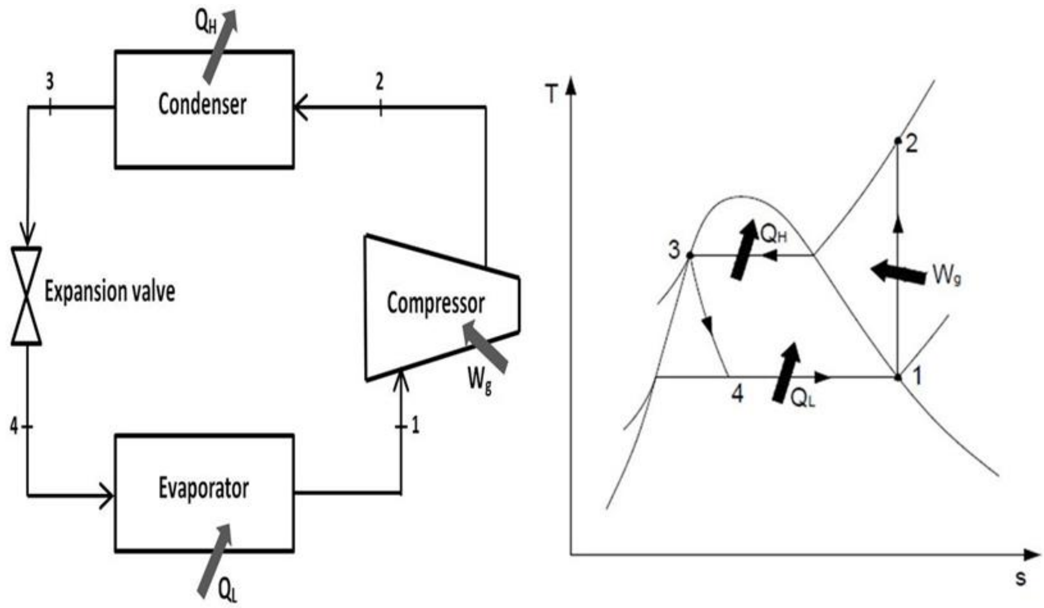

Fig 1. Schematic representation of the refrigeration cycle and temperature-entropy diagram of the cycle [6]

The R417B used in the study has high energy and good thermodynamic properties. It is a zeotropic mixture refrigerant consisting of R125, R134a and n-butane. R417B is produced to replace R22. It is generally used in cooling systems between 0 and -43 °C operating range. Thermophysical properties of R417B are given in Table 1.

Table 1. General properties of R417B

Refrigerant	R417B
Composition	R125/134A/600
Mass percentage	79/18.3/2.7
Boiling point at 1 atm, (°C)	-45.20
Critical temperature, (°C)	74
Critical pressure, (kPa)	3737
Ozone depletion potential (ODP)	0
Global warming potential (GWP)	3027

2. METHODS

The following assumptions were made in the calculations for the performance analysis of the refrigeration cycle;
• All components work in steady state.
• Changes in kinetic and potential energies in the elements forming the cycle are neglected
• The cooling capacity of the system is Q_E = 1 kW and is fixed
• The isentropic efficiency of the compressor is η_{comp}=0.8

In the refrigeration cycle given in Fig. 1, evaporator capacity can be determined as follows [1]:

$$\dot{Q}_E = \dot{m}\ (h_1 - h_4) \tag{1}$$

Compressor work is;

$$\dot{W}_{Comp} = \dot{m}\ (h_2 - h_1) \tag{2}$$

Conderser capacity is;

$$\dot{Q}_C = \dot{m}\ (h_3 - h_2) \tag{3}$$

COP of the refrigeration cycle can be determined as follows;

$$COP = \frac{\dot{Q}_E}{\dot{W}_{Comp}} \tag{4}$$

3. RESULTS

Different evaporator temperatures were used while performing the cooling performance analysis for the determined operating conditions of the VCRS. The results obtained from the analysis are presented in Fig. 2. While the condenser temperature was kept constant at 35 ^{o}C in the cycle, the evaporator temperature was changed between -1 and -15 ^{o}C.

The performance analysis of the VCRS was made for different evaporator temperatures and the obtained values are given graphically in Fig. 2. The condenser temperature was kept constant at 35 ^{o}C in the cycle and the evaporator temperature was changed between -1 and -15 ^{o}C. When Fig. 2 is examined, it is seen that the highest COP value is 4.5. This value was obtained for the operating condition at -1 ^{o}C evaporator temperature and 35 ^{o}C condenser temperature. It is seen that the COP value decreases as the evaporator temperature decreases. As seen in Fig. 2, the lowest COP value is 2.82.

In another analysis, the cooling performance of the cycle was determined depending on the change in condenser temperature and the results are presented in Fig. 3. While the condenser temperature was changed between 25 and 45 ^{o}C in the cycle, the evaporator temperature was kept constant at -10 ^{o}C. When Fig. 3 is examined, it is seen that the highest COP value is 4.69. This value was obtained for the operating condition at -10 ^{o}C evaporator temperature and 25 ^{o}C condenser temperature. As seen in Fig. 3, the lowest COP value is 2.35. And this value is obtained for high condenser temperature.

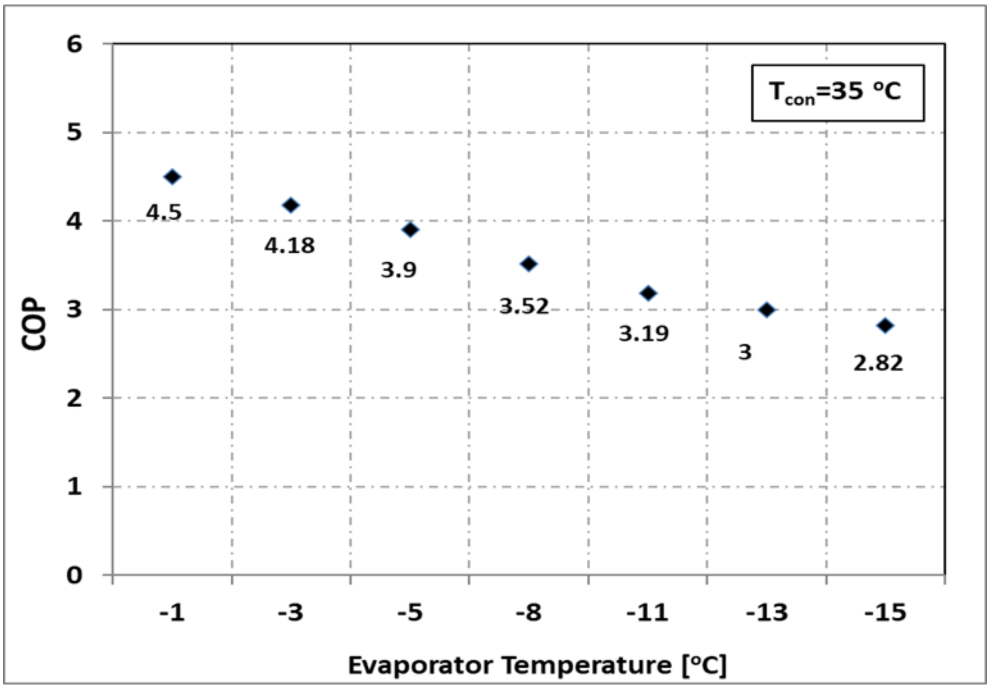

Fig 2. Variation of COP with evaporator temperature

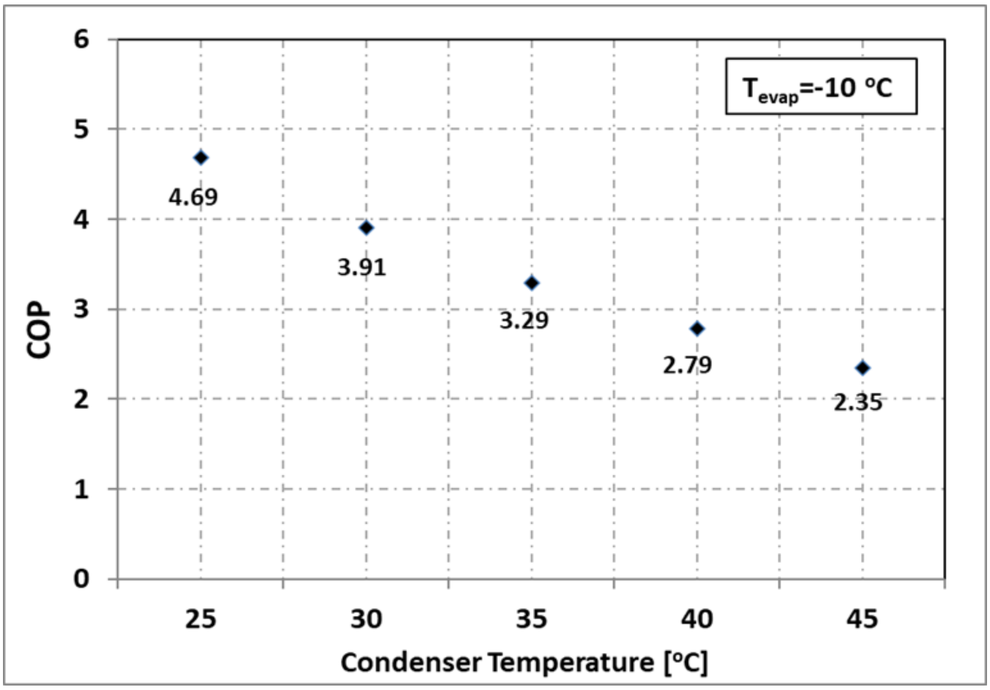

Fig 3. Variation of COP with condenser temperature

In addition, the evaporator pressure change was calculated depending on the evaporator temperature change of the refrigeration cycle and is presented in Fig. 4. It is seen that the evaporator pressure decreases with decreasing evaporator temperature. In the analysis, it was determined that the highest evaporation pressure was 0.521 MPa at -1 °C evaporator temperature.

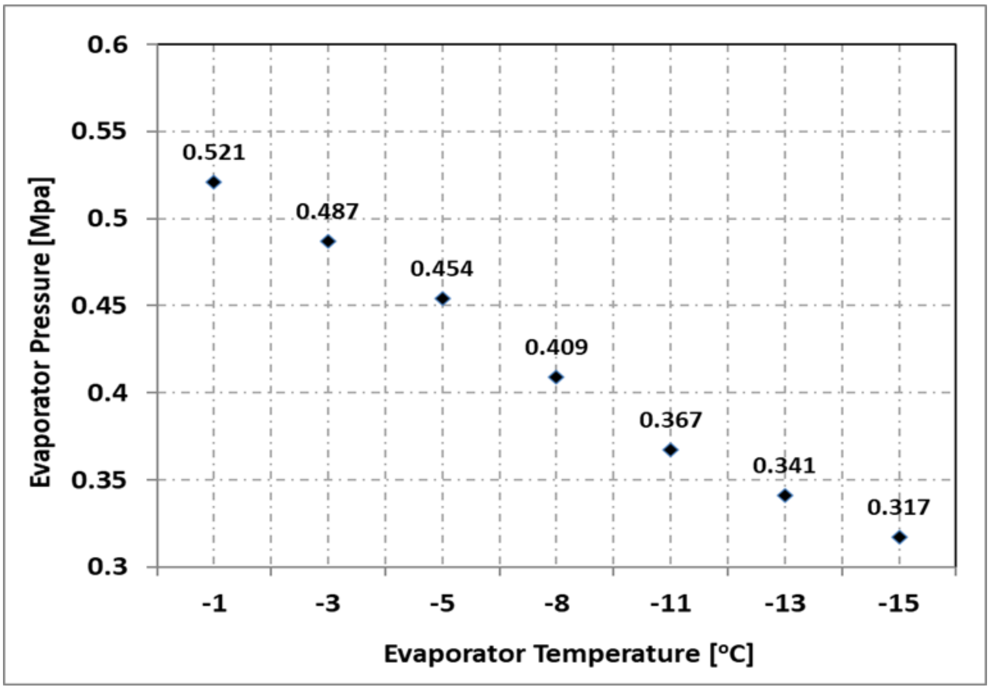

Fig 4. Variation of evaporator pressure with evaporator temperature

4. CONCLUSIONS

Today, it has been understood that the environmental effects of energy systems are extremely important as well as the efficiency of energy systems in energy applications. Therefore, while it is aimed to have a high cooling performance coefficient in cooling systems, both its performance and environmental effects are taken into account in the refrigerant used at the same time. In this study, the energy analysis of the vapor compression refrigeration system using R417B was made for different operating conditions. For the operating conditions in this study, it was determined that the COP value decreased when the evaporator temperature decreased. However, it was observed that the COP value decreased when the condenser temperature increased. In the analysis made depending on the evaporator temperature change, the highest COP value of the cycle is 4.5. This value was obtained under the operating condition of -1 ^{o}C evaporator temperature and 35 ^{o}C condenser temperature. In order to benefit effectively from the vapor compression refrigeration system using R417B, it would be beneficial to consider the operating conditions obtained from this study. R417B refrigerant has good cooling performance as well as zero ozone depletion potential (ODP). Therefore, it is a very good alternative refrigerant for refrigeration cycles and its use should be increased.

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