Expansion Parallel Liquid Refrigerant On A Vapor Compression Systems With R-290

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Abstract. This study aims to determine the performance improvement of a vapor compression systems that use expansion parallel liquid refrigerant. The experiment was conducted by replacing the single expansion device with a parallel expansion device on a vapor compression systems. The working fluid is used as a cooling medium is R-290. To get performance data, measurements performed on the cooling load with various temperatures (range from 3°C to -3C). Finally, The results showed that expansion parallel liquid refrigerant on a vapor compression systems generates an increase in refrigerating effect and COP of 49% and 2,5%, respectively. This has implication to saving the power consumption of the vapor compression systems.

1. Introduction
Nowadays, the vapor compression system still dominates in the application of refrigeration for household and commercial purposes. As an example of household appliances that use vapor compression system is refrigerator. The refrigerator operates using electrical energy and the energy consumed by the refrigerator is the second largest after the air conditioner, since the refrigerator operates for 24 hours [1]. If one refrigerator is assumed to be used by every six people in the world, the electricity consumed is approximately equal to 6% of the world's total electricity production [2]. Therefore, it is necessary to find ways to save the use of electrical energy in the refrigerator.

A common way to reduce energy consumption and improved the coefficient of performance a vapor compression systems have implemented by the researchers. First, improvement of a compressor efficiency [3][4][5]. This method controlling operation of a compressor, reduction of frictionless, and reduction of loss associated with the pressure equalization during compressor off times. Second, improvement of insulation inside a refrigerator [6]. The optimization of insulation thickness to allow minimum energy consumption at arbitrarily given COP and internal volume of each compartment. Third, improvement in refrigeration systems [7][8]. In this case, an additional energy saving was obtained by the optimization of the operating sequence and refrigerant recovery operation. Fourth, the method to improve the performance of a vapor compression systems can be done by using hydrocarbons as refrigerants [9][10][11]. The experimental results show that the hydrocarbons could reduce the energy consumption and improve the actual COP. Finally, the other relevant studies on the system performance of a vapor compression systems have also demonstrated that modifying cooling system using a heat exchanger could improve energy efficient and performance [12][13][14][15]. This study is focused on expansion parallel liquid refrigerant on a vapor compression systems with R-290.

In general, a traditional vapor compression system uses a single expansion device. The parallel expansion device is an engineering method on refrigeration system to reduce throttling loss of the refrigerant liquid as it flows through the liquid line to the evaporator. The condition of the refrigerant entering the expansion device is usually assumed to be saturated liquid [16]. When the liquid flows through the expansion device, a part of the liquid vaporizes. The pressure of the liquid is reduced to
the evaporator pressure so that the saturation temperature of the refrigerant entering the evaporator will be below the temperature of the refrigerated space. The refrigerant is discharged from the expansion device into the evaporator as a liquid-vapor mixture. Obviously, only the liquid portion of the liquid-vapor mixture will vaporize in the evaporator and produce useful cooling [12]. Therefore, expansion parallel a liquid refrigerant can reduce throttling losses resulting from an isenthalpic expansion. So, it can increase the refrigerating effect and potentially improve the coefficient of performance (COP).

The purpose of this study was to determine the performance improvement of a vapor compression systems that use expansion parallel liquid refrigerant. The experiment was conducted by replacing the single expansion device with a parallel expansion device on a vapor compression systems. Therefore, the application of this engineering method to a vapor compression systems is expected to improve performance and to decrease of energy/power required as the driving force of compressor.

2. Methods

Figure 1 shows the schematic installation of parallel expansion device used for the experiment. The main components of the domestic refrigerator consisted of an evaporator, compressor, and condenser (Sanyo). Component of the parallel expansion device made from copper capillary tubing diameter of 0.97 mm. In this study, the working fluids was used R-290. Two pressure gauges (Robin Air) and two temperature sensors (Lutron) were placed on the inlet and outlet of the compressor to measure the suction and discharge pressures-temperature. On the inside of the refrigerator, a container of the brine (salt water) concentration of 12% was kept, serving as a cooling load. A thermometer (Beuer) was placed in the brine container to determine changing in temperature every 1°C.

![Figure 1. The schematic installation of parallel expansion device used for the experiment.](image)

The experiment conducted under two conditions. The first, the system was operated in a normal mode (with a cooling medium is R134a) to obtain baseline data of the refrigerator performance. The second, the system operated with a parallel expansion mode. Data retrieval conducted four times under each condition. The beginning of the study carried out calibration of all measurement equipment. Then
the process of vacuum removed water content and other substances in the cooling system. After that, checking was done to any leaks from all the parts and installation of the pipe. Then, the system was filled with R-290 weighing 30 g in accordance to the recommendation of the manufacturer. The next stage operated the refrigerator for about one hour to reach a steady state condition and then entered a container of brine into the freezer. Data capture started when the temperature of the brine was 3°C, with the assumption that the system was on steady state condition. Next, the changing were observed until the temperature of the brine reached -3°C. During the study, the temperature of the environment was kept at 28°C ± 2°C.

3. Results and discussion
The results were obtained from the performance testing of the domestic refrigerator in two operating conditions: normal mode and parallel expansion mode. Tests were carried out at an ambient temperature of 28°C in the refrigeration cycle operating mode under load conditions of 3°C to -3°C.

3.1. Refrigerating effect
Figure 2 shows the results of the refrigerating effect of a vapor compression systems under two testing conditions. In general, the refrigeration effect generated by the system using parallel expansion mode has a higher value than the normal mode. In parallel expansion mode, the refrigerating effect generated when the brine was 3°C in 258,23 kJ/kg. Then it decreased slightly to 254,83 kJ/kg when the brine temperature reached 0°C. Next, the value of the refrigerating effect back to 258,23 kJ/kg when the temperature of the brine was -3°C. On the other hand, in the system which used normal mode, the refrigerating effect generated when the brine solution reached 3°C in 131,40 kJ/kg. Further, this slowly decreased to 131,01 kJ/kg when the temperature of the brine was -3°C.

![Figure 2. The Refrigeration effects of a vapor compression systems under two testing conditions; normal mode and parallel expansion mode.](image)

Based on the results, there had been a 49% increasing of refrigerating effect in the system using parallel expansion mode. The effects of the use of the parallel expansion mode on the vapor compression systems resulting evaporation process in the expansion device become shorter followed by more liquid refrigerant flowing into the evaporator to absorb heat from cooling load (brine). Furthermore, the ratio between the discharge pressure and suction pressure generated by the system becomes lower so that the work of compression needed to compress the refrigerant from condensing pressure to evaporating pressure becomes shorter. The achievement of this value will contribute to smaller energy consumption needed to operate the compressor.

3.2. Heat of compression
Figure 3 shows the heat of compression of the vapour compression system under two testing conditions. In general, the heat of compression generated by the system using parallel expansion mode has a higher value than that of the normal mode. In the parallel expansion mode, the heat of compression generated when the brine temperature of 3°C was 117,22 kJ/kg. This value almost
constant until the end of temperature observation. On the other hand, in the normal mode, the heat of compression generated when the brine temperature was 3°C was 61.21 kJ/kg. Further, this gradually increased to 61.71 kJ/kg when the brine temperature reaches -3°C. Based on the results, the heat of compression increased approximately 48% when the parallel expansion mode is used on the vapour compression system. This is due to the pressures ratio are high and an increasing in the enthalpy of the refrigerant at inlet and outlet of the compressor.

Figure 3. The heat of compression of a vapor compression systems under two testing conditions; normal mode and parallel expansion mode.

3.3. Coefficient of performance

Figure 4 presents coefficient of performance data (CoP) of two conditions of the vapor compression systems testing. In the normal mode, the CoP decreased along with the decreasing temperature of the brine. At first, the obtained CoP was 2.15 when the temperature of the brine was 3°C; the CoP of 2.12 was obtained when the brine temperature was -3°C. Further, when the system employed parallel expansion mode, Cop was constant at 2.20 along with the decreasing temperature of the brine. These results indicate that the use of parallel expansion on the refrigeration system results in the increase value of Cop, which is 2.5%. The great value of Cop indicates that the system worked properly. The value of Cop is influenced by the amount of heat which can be absorbed by the refrigerant flowing in the evaporator (refrigeration effect), and the compression work performed by the compressor when it compressed the low temperature-pressured refrigerant vapour to high temperature-pressured refrigerant vapour. If the value of the refrigeration effect is big and the value of compression work are small, the Cop obtained will be large. The bigger the value of the refrigeration effect and the smaller the value of the compression work, the value of Cop obtained will be better.

Figure 4. The CoP of a vapor compression systems under two testing conditions; normal mode and parallel expansion mode.
4. Conclusion

Research on the use of parallel expansion device to improve the performance of a vapor compression systems has been conducted. To demonstrate the performance improvement of a systems, it was tested in two different conditions. The results indicate that expansion parallel liquid refrigerant on the vapor compression systems generates an increased 49% value of the refrigerating effect and 2.5% value of the coefficient of performance (CoP) so that it implicates for save on power consumption required a vapor compression systems.

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