Evaluation of performance an air conditioning systems using t-junction flash gas refrigerant

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Abstract. The purpose of this study was to determine the performance of air-cooled chiller system using T-junction flash gas bypass refrigerant. The experiment was conducted by installing T-junction after expansion device to separate the phase of refrigerant liquid and gas which flows to the evaporator. The working fluid is used as a cooling medium is R-290. To get performance data, measurements performed at the time of steady state when the water chilling temperature $T = 15^\circ C$ up to $T = 10^\circ C$ and flow rates kept constant at 1 GPM ($6.3 \times 10^{-5} m^3/s$). Finally, the use of T-junction mode in AC system generates an increase in the refrigerating effect and coefficient of performance systems (CoP) by 6% and 17.8 %, respectively. Also, it can decrease the heat of compression by 8.5%. This has implications for the lighter compressor work and saving the power consumption of the AC system.

1. Introduction

Junctions can be found in various applications of piping systems such as chemical processes, refrigeration processes, oil and gas production and distribution processes. When a two-phase flow of incompressible fluid flows in the pipe and then passes through T-junctions, rarely are both divided in the same separation ratio. Occasionally all fluid flows into the side arm, but at other times all fluids may flow toward the run arm (horizontal branch). This phenomenon is termed phase maldistribution. The maldistribution phases have negative and positive consequences for the equipment used. On the negative side, the occurrence of phase maldistribution will cause a decrease in the efficiency of the equipment used in the downstream part of T-junction [1]. On the positive side, the maldistribution phase that occurs can be used as a partial separator phase [2].

The phase separation method using T-junction was first introduced by Oranje in 1973 which examined the separation of the two-phase gas-liquid stream [3]. Based on the results of his research stated that the separation ratio is influenced by various factors such as side arm and run arm, mass inertia from fluid, upstream flow pattern, and geometry of T-junction. In the refrigeration process, the refrigerant condition when at the end of the expansion process is a mixture of vapour-liquid phase. The liquid refrigerant flowing in the evaporator will evaporate and can increase the cooling capacity whereas the vapour refrigerant will produce superheat gas. The two-phase flow distribution arrangement of the refrigerant leading to the evaporator can improve the performance of the AC system [4, 5]. The phase separation of the R-134a and R-410a refrigerant streams using vertical T-junctions on the AC system has been carried out by utilizing gravity and inertial forces [6]. Subsequent research on flash gas bypass (FGB) in car air conditioning systems using refrigerant R-134a has resulted in a 4% - 7% increase in COP compared to direct expansion (DX) systems [7]. However, some problems are still found. The use of synthetic refrigerant based on halokarbon has a high global warming potential [8].

Recently, the use of working fluid for an environmentally friendly air-conditioning system has been done in various countries in the world. In the application of air conditioning system, hydrocarbon
refrigerant R-290 is more often used as a working fluid. R-290 is a pure hydrocarbon compound that is non-toxic and compatible with materials and lubricants used in refrigeration machines. He can mix better with the lubricating oil so that the lubricating oil that goes back to the compressor is not a problem [9]. R-290 is also environmentally friendly that does not damage the ozone layer and has a low global warming potential [10]. Several studies using R-290 as a working fluid stated that there was an increase in the efficiency of the RAC window system by 10% - 15% [11], an increase in cooling capacity and CoP in small heat pump and refrigeration system applications [12,13], and the R-290 refrigerant fill up into a 50% - 55% air-conditioning system of the R-22 refrigerant weight [14]. The purpose of this research is to know the performance of air cooled chiller system using T-junction flash gas bypass refrigerant with working fluid R-290.

2. Methods
Figure 1 shows the schematic of T-junction flash gas bypass refrigerant in air cooled chiller systems with R-290. R-290 (Musicool Pertamina, Indonesia) is used as a working fluid that plays a role in absorbing heat from the water (H2O) as a cooling load. T-junction is made from a copper pipe (Nippo Stell, Japan) with diameter 9.53 mm. AC installation line uses a copper tube (Nippon Stell, Japan) diameter 6.35 mm for discharge line and diameter 9.53 mm for suction line. AC pipeline insulation (Superlon, Malaysia) is installed in a suction line and cold water distribution line using PVC (Maspion, Indonesia) pipe diameter 12.7 mm.

The equipment used in this study consists of the main equipment of air conditioning system (Sanyo, Japan) with a cooling capacity of 9495 kJ. Further, measuring equipment including flow meter (Mueller, Germany) is used to measure the cold water from evaporator to cooling coil, pressure gauge (Robin Air, USA) used to measure suction and discharge pressure, and temperature sensor (Lutron, China) Used to measure cold water temperatures in evaporators and refrigerant temperatures in inlets and outlets of compressor. Then the water pump (Waser, Korea) is used for cold water circulation from an evaporator to cooling coil.

![Figure 1. Schematic T-junction flash gas bypass refrigeration in chiller systems with R-290](image_url)

At the beginning of the test, the operation of the AC system without T-junction (normal mode) to get the baseline of performance data. After that performed performance testing of AC system by
T-junction mode. Before the data collection, firstly calibration of all measuring devices and records the environmental temperature. Then operate the water pump and adjust the flow of water constant 1 GPM (6.3 x 10^-5 m^3/s) on the flowmeter. Then operate the air conditioning system and observe the change of water temperature in the reservoir until the temperature is 15 C. At that temperature, it is assumed that the system is in steady condition so that the data collection can start. Furthermore, observed changes in temperature every 1 C to the water temperature reaches 10 C. During the study the temperature is maintained at a temperature of 28 C ± 2 C.

3. Results and discussion

3.1. Refrigerating effect

Figure 2 shows the refrigerating effect on any change in water temperature from 15 C to 10 C. The test of the AC system is carried out under two conditions; T-junction mode and normal mode. According to the information, the refrigerating effect of both test conditions formed a similar pattern of graphs over the time period of the test, but the refrigerating effect in T-junction mode is higher than the normal mode. At 15 C, the refrigerating effect achieved in T-junction mode is 279.49 kJ/kg and in normal mode is 262.55 kJ/kg. At the next temperature, the refrigerating effect of the two test conditions undergoes significant changes. In T-junction mode there is a gradually decrease to 279.36 kJ/kg at the temperature of 10 C. While in normal mode there is a slight increase until reach 263.56 kJ/kg at the temperature of 10 C. Although trends of the graph of T-junction mode decreased but the value is still higher than the normal mode, there is an increase of 6%. The high value of refrigerating effect in T-junction mode because it is influenced by high pressure on the suction line and low pressure on discharge line. Consequently, the aspect ratio becomes smaller and the difference in enthalpy value in the inlet and outlet of the evaporator becomes larger. These results have implications for the amount of heat that it can absorb by the system so that the cooling capacity increases.

![Figure 2](image_url)

**Figure 2.** The refrigerating effect on two test conditions of air conditioning systems; T-junction mode and Normal mode

3.2. Heat of compression

Figure 3 depicts the heat of compression on two AC system test conditions; T-junction mode and normal mode. The test is done in the range of six degrees from the water temperature between 15 C and 10 C. In general, the heat of compression value of both test modes decreases, but the heat of
compression value of T-junction mode is smaller than the normal mode. In T-junction mode, the heat of compression at 15°C is 87.62 kJ/kg. It then rises slowly to 88.90 kJ/kg when the temperature is 12°C. After that, the heat of compression gradually decrease to 88.43 kJ/kg at a temperature of 10°C. In the other hand at normal mode, the heat of compression is 96.97 kJ/kg at the beginning. Then it slightly increased to a value of 97.04 kJ/kg at a temperature of 12°C. In the final temperature, it decreased to 96.62 kJ/kg. Based on the results, there had been a 8.5% decrease heat of compression in the systems using T-junction mode. The effects of the use of the T-junction on the air conditioning systems result in a smaller ratio of discharge and suction pressures, causing the compression work which compresses vapour from condensing pressure to evaporating pressure becomes shorter. Such results will contribute to the energy consumption of the compressor, which becomes smaller.

Figure 3. The heat of compression on two test conditions of air conditioning systems; T-junction mode and Normal mode

3.3. Coefficient of performance
Figure 4 illustrates the coefficient of performance (CoP) data of two test conditions of the AC systems; T-junction mode and normal mode. The test is carried out at a temperature change of six degrees of temperature ranging from 15°C to 10°C. In general, the CoP in T-junction mode decreases, while in normal mode it increases. Although the trend of T-junction mode graph is decreasing but the value is still higher than normal mode. In normal mode, the CoP tends to be constant over the initial three degrees of temperature change in the range of 2.71. Then the value rises to 2.75 in the water temperature of 11°C. After that it drops again to 2.73 in the final temperature. While in T-junction mode, the CoP at 15°C is 3.19. After that, it gradually decreased to 3.16 in the temperature of 10°C. Referring to the data, the use of T-junction mode on the AC systems results in the increase value of CoP, which is 17.8%.

The value of CoP is influenced by the amount of heat which can be absorbed by the refrigerant flowing in the evaporator (refrigerating effect), and the heat of compression performed by the compressor when it compressed the low temperature-pressured refrigerant vapour to high temperature-pressured refrigerant vapour. If the value of the refrigerating effect is big and the heat of compression are small, the CoP obtained will be large. The greater the value of the refrigerating effect and the smaller the value of the heat of compression, the CoP obtained will be better. The greater value of CoP indicates that the system worked properly.
4. Conclusion
Research to find out the performance of air cooled chiller systems using T-junction flash gas bypass refrigerant with R-290 has been conducted. To demonstrate the performance of AC system, we tested the AC systems in two different conditions that are T-junction mode and normal mode. Based on the result, the use of T-junction mode in AC system generates an increase in the refrigerating effect and CoP by 6% and 17.8 %, respectively. Also it can decrease the heat of compression by 8.5%. This has implications for the lighter compressor work and saving the power consumption of the AC system.

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