Research Article

Hybrid Condenser for Split Type Air Conditioner

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Abstract

The aim of this research is to experimentally investigate the application of a hybrid condenser as the condenser for a vapor compression refrigeration system. Split type air conditioner for residential use has two major disadvantages. First, it has a large pressure drop in the condenser caused by the flow of refrigerant inside a small tube which affects compressor power. Second, a large amount of heat is rejected to the surroundings since the refrigerant has to condense after passing through the condenser. To decrease pressure drop and recover heat rejection from the condensing process, this study considered using hybrid condenser instead of the conventional condenser in the split type air conditioner. The refrigeration capacity was set at 12,500 Btu/h (3.663 kW) with R22 as the refrigerant. The optimum size of the thermosyphon with water as the working fluid consists of 0.1 meter of evaporator section length, 0.1 meter of condenser section length, the thermosyphon with an inner diameter of 6.5 millimeter, and 105 tubes. Therefore, these sizes were selected to construct the hybrid condenser. The experimental results were obtained and compared with the conventional condenser. It was found that temperature difference between ambient and room of the conventional condenser system was 11.5 ºC. While thetemperature difference of the hybrid condenser system with water flow rate of 4, 6 and 8 LPM were 15.9, 16.6 and 17.3 ºC, respectively. In addition, electric power consumption of the conventional condenser system was 1,423 W. While the electric power consumption of the hybrid condenser system with water flow rate of 4, 6 and 8 LPM were 1,315, 1,309 and 1,295 W, respectively. When both systems were compared with the same heat load, it was found that the electric power consumption of the hybrid condenser system of 4, 6 and 8 LPM were decreased by about 8.2, 8.7 and 9.9 %, respectively. Finally, the outlet temperature of the cooling water which recovers heat from the condenser section of the hybrid condenser with the water flow rate of 4, 6 and 8 LPM were 6.6, 8.2 and 9.8ºC, respectively.

***Key Words*:** Conventional condenser; Hybrid condenser; Split type air conditioner; Thermosyphon

Introduction

Refrigeration is the process of moving heat from one location to another by means of refrigerant in a closed refrigeration cycle. The refrigeration is developed and applied to use in various applications such as food industry, chemical industry and air conditioning for sustainable well-being. The air conditioning is commonly used in a wide range of residential and commercial buildings. Most of the air conditioner types used for this purpose are called “split type”. This type of air conditioner is divided to two parts, a fan coil unit and a condensing unit which the fan coil unit is located inside the room and another one is located outside the room. The split type air conditioner based on the vapor compression refrigeration is

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shown in Figure 1. It has two disadvantages. First, it has a large pressure drop in the condenser caused by the flow of refrigerant inside a small tube which affects compressor power. Second, a large amount of heat is lost to the surroundings since the refrigerant has to condense after passing through the condenser. To reduce pressure drop and recover heat from the condensing process, in this investigation we used a hybrid condenser instead of the conventional condenser in split-type air conditioner as shown in Figure 2. The figure shows that refrigerant as superheated vapor from the compressor flow into the refrigerant inlet side and then flow through a large copper tube. When the refrigerant flow through the large copper tube, heat is removed from the refrigerant by two ways. First, heat is removed by fundamental of the thermosyphon. Second, heat is removed through the large copper tube wall by cooling water. The cooling water flows outside the large copper tube but inside the shell. Therefore, the refrigerant is condensed after passing through the hybrid condenser while the temperature of cooling water is increased.Many researchers studied the effects of different working fluids and fluid flow rate on the thermal effectiveness of heat pipe for air-conditioning. The studies showed that the thermal effectiveness decreases when the working fluid was changed from R134a to MP39 or the mass flow rate of cooling fluid was increased (Kammuang-lue et al., 2006). The CLOHP with check valves has been applied for reducing relative humidity in drying system and it can reduce relative humidity and achieve energy thrift (Meena et al., 2007). Heat rejected from a split-type residential air conditioner was recovered for clothes drying in residential buildings. The results indicated that the system was effective for its reasonably short drying duration and high energy use efficiency during air conditioning seasons (Shiming and Han, 2004). From the previous literature it can be seen that, there are no substantial studies on applying the thermosypton as a condenser in the refrigeration system to reduce pressure drop and recover heat from the condensing process. Therefore, the aim of this study is to experimentally investigate the use of a thermosyphon as the condenser for vapor compression refrigeration system. Our optimization technique will be on the basis of a thermo-economical method (Soylemez, 2003).

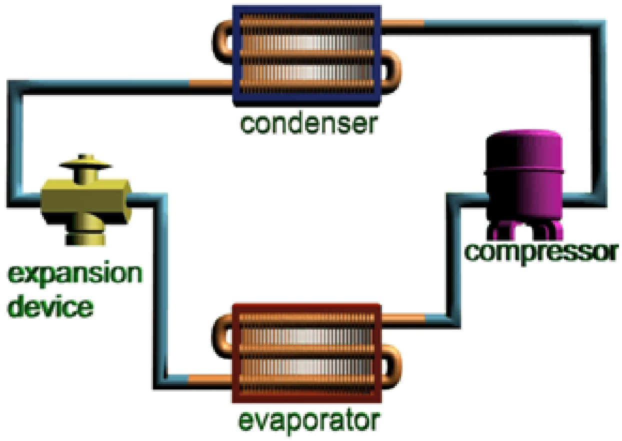

Figure 1 Vapor compression refrigeration

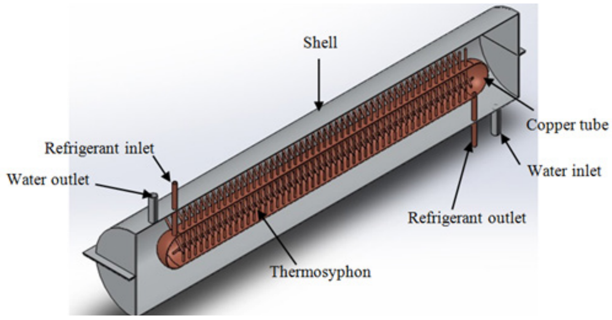

Figure 2 Hybrid condenser

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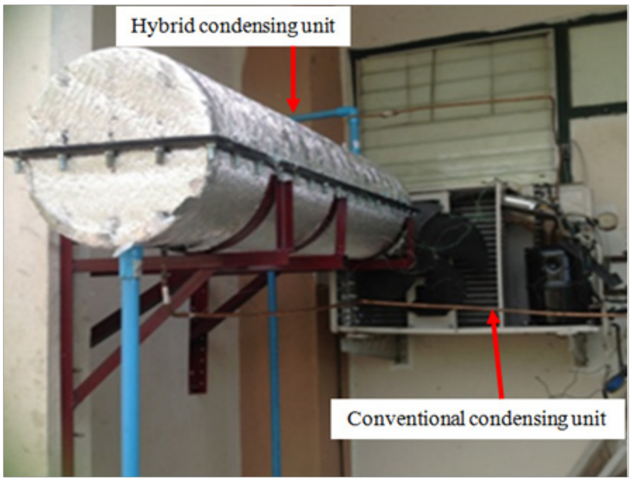

Figure 3 Experimental setup

Experimental Setup, Measuring Equipments and Experimental Procedure

Experimental Setup

The experimental setup was divided to two main parts: the conventional condenser system and the hybrid condenser system, as shown in Figure 3. The conventional condenser system consists of four major components of the system, namely compressor, condenser, capillary tube and evaporator. While the hybrid condenser system used a hybrid condenser instead of the conventional condenser. The specifications of the hybrid condenser are given in Table 1.

Table 1 Specifications of the hybrid condenser

Shell		Copper tube		Thermosyphon	
Material	iron plate	Material	Copper	Material	Copper
Inner diameter	0.25 m	Inner diameter	0.1 m	Inner diameter	0.065 m
Length	1.2 m	Length	1 m	Evaporator section length	0.1 m
				Condenser section length	0.1 m
				Number of tube	105 tubes
				Working fluid	water

Measuring equipments

Air Conditioning Unit

Cooling capacity of the air conditioning unit is 12,500 Btu/h (3.663 kW). The compressor is reciprocating type and R22 is used as the refrigerant.

Heating Load

The test room was subjected to heating loads of 1,000 W by means of an I-type electric heater.

Cooling Unit

The conventional condenser was cooled by air, while the hybrid condenser was cooled by water. Cooling water was circulated by a water pump and the temperature of water was controlled by a cold bath. A factory calibrated rotameter was used to measure the volume flow rate of water.

Refrigerant Temperature Measurements

Refrigerant temperatures were measured by K-type thermocouples at four locations at the inlet of compressor, condenser, capillary tube and evaporator, respectively. The thermocouples were installed on the outside of the refrigerant copper tube surface using thermal paste to ensure good contact. Thermocouples were calibrated in a water bath with an accuracy of ± 0.5 ºC (5-90 ºC) and connected to data logger interface with a desktop computer.

Electrical Power Input Measurement

Power input of the entire system was measured by a digital power clamp meter.

Refrigerant Pressure Measurements

Pressure of the refrigerant was measured by Bourdon pressure gauges at the same four locations that the refrigerant temperature was measured by the thermocouples. The pressure gauges were factory calibrated with an accuracy of ±1%(-30-120 psi for low pressure and 0-500 psi for high pressure).

Experimental Procedure

The experiments were divided to two main parts: one with the conventional condenser system and the other with the hybrid condenser system. Each main experiment was divided to three sub-experiments that were conducted at the water volume flow rate of 4, 6 and 8 LPM, respectively. In each sub-experiment, all of the data were recorded at an interval of five minutes and a period of one hour.

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The Conventional Condenser System Experiment

Before each sub-experiment was conducted, the data logger and the desk top computer were turned on to make sure all the measuring equipments were ready. Initial operating condition was a heat load of 1,000 Wand 4 LPM. The experimental set-up was turned on for twenty minutes to ensure that the system has reached steady state, and then all data were recorded. The refrigerant pressure, the refrigerant mass flow rate and the power input were recorded for all the locations at the same interval of one hour. The same procedure was repeated for the other two volume flow rate of 6 and 8 W.

The Hybrid Condenser System Experiment

In case of the hybrid condenser system experiment, only the conventional condenser was changed in the hybrid condenser while other components were kept the same. The inlet temperature of cooling water was fixed at 25 ºC, respectively. Before all data were recorded, the sight glass was observed to ensure that the refrigerant was in the liquid phase. Then, the experimental procedure described for the conventional condenser system experiments were followed.

Results and Discussions

Effect of Temperature Difference of Ambient and Room

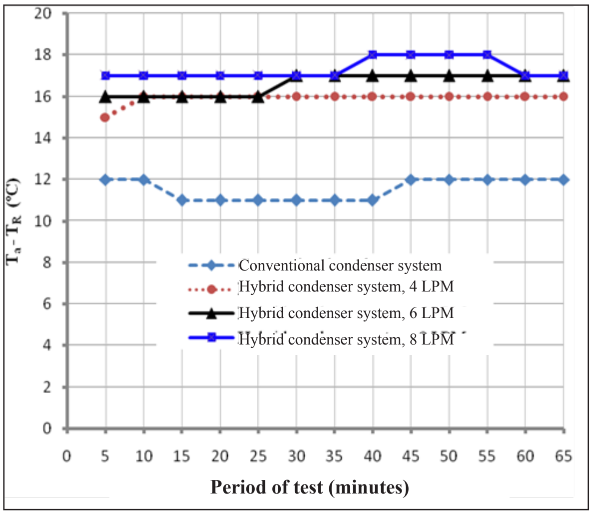

Figure 4 Effect of temperature difference of ambient and room

Figure 4 shows the effect of temperature difference of ambient and room. For the conventional system, the temperature difference was 11.5 ºC. While the temperature difference of the hybrid condenser system with water flow rate of 4, 6 and 8 LPM were 15.9, 16.6 and 17.3 ºC, respectively. When these two systems were compared with the same heat loads, it was found that the temperature differences of the hybrid condenser system were increased by about 38, 44 and 50%, respectively. The increase of the temperature difference in the hybrid condenser system because the hybrid condenser system removed heat from the room more than the conventional condenser system.

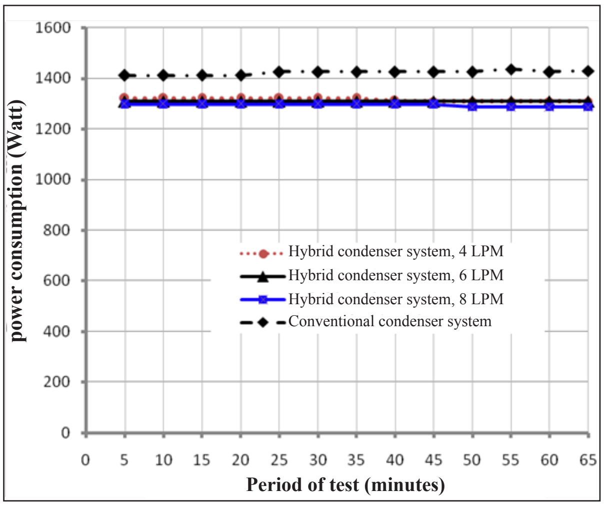

Figure 5 Effect of electric power consumption

Figure 5 shows the effect of electric power consumption. The electric power consumptionof the conventional condenser system was 1,423 W. While the electric power consumption of the hybrid condenser system with water flow rate of 4, 6 and 8 LPM were 1,315, 1,309 and 1,295 W, respectively. When both systems were compared with the same heat load, it was found that the electric power consumption of the hybrid condenser system of 4, 6 and 8 LPM were decreased by about 8.2, 8.7 and 9.9%, respectively. It can be seen that the hybrid condenser system saved more electrical power consumption for the system, the hybrid condenser system was without the condenser fan. Moreover, the refrigerant flows through a large tube during the condensing process caused

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the compressor power was decreased.

Effect of Temperature Difference of Cooling Water

Figure 6 shows the effect of temperature difference of cooling water. It was found that the outlet temperature of the cooling water which recovers heat from the condenser section of the hybrid condenser with the water flow rate of 4, 6 and 8 LPM were increased about 6.6, 8.2 and 9.8ºC, respectively.

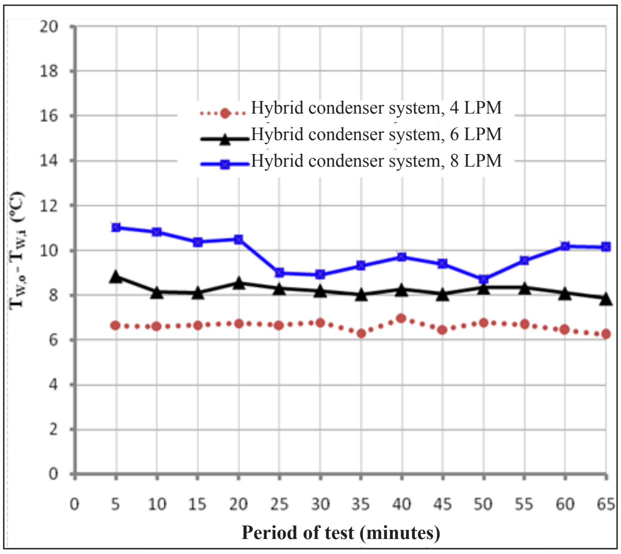

Figure 6 Effect of temperature difference of cooling water

Conclusion

The temperature differences of the hybrid condenser system were increased by about 38, 44 and 50%. The electric power consumption of the hybrid condenser system was decreased by about 8.2, 8.7 and 9.9%. The outlet temperature of the cooling water of the hybrid condenser with the water flow rate of 4, 6 and 8 LPM were increased about 6.6, 8.2 and 9.8ºC, respectively.

Acknowledgements

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