Performance of Newly Developed Integrated Space Conditioning and Domestic Water Heating Device

M. M. Rahman1*, H. Y. Rahman1

1Department of Mechanical Engineering, Universiti Tenaga Nasional, Putrajaya Campus, 43000 Kajang, Selangor, Malaysia

KEYWORDS

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Space conditioning
Domestic water heating
Environment friendly

ABSTRACT

This paper presents the performance of the recently developed integrated space condition and domestic water heating device. A conventional split type air conditioner is modified to reclaim the superheated portion of the heat leaving the compressor to be utilized to heat up water for domestic purposes. The experimental investigation revealed that this device could heat up water from room temperature to 82°C within 9 hours of operation (8:00 am to 5:00 pm) at the same time cool down the room air to the desired level. By using this type of energy recovery device, compressor efficiency can be improved and at the same time, hot water for domestic purposes can continuously be obtained free of charge. The end result is expected to be faster cooling and prolonged compressor life. This system is simple yet affordable and able to save water heating cost and environment friendly, i.e., less heat is rejected to the environment.

1. INTRODUCTION

Energy saving becomes an essential measure due to the recent hike in fossil fuel price. The efficient use of energy has become a major issue in the refrigeration and air conditioning domains. Gains thanks to the use of equipment producing the same amount of cold with reduced energy consumption benefit everyone: the user, who of course has lower energy expenses, and the atmosphere, which absorbs less carbon dioxide (CO2). Renewed interest in energy efficiency can be explained by the fact that the overall global warming impact of refrigerating equipment is now considered and reflected in TEWI (Total Equivalent Warming Impact) or LCCP (Life Cycle Climate Performance) concepts. The use of energy-efficient refrigerating installations certainly contributes to overall reductions in or limiting of global warming, but the manner in which such gains are measured needs careful consideration. Emissions reductions will probably not be tallied under HFCs. Instead, they will probably be lost in a sea of figures on electrical consumption and the refrigeration and air conditioning practitioners who have achieved emissions reductions probably won’t even get any credit for their efforts. Whatever method is used in tallying emissions reductions, it is vital to continue to address this issue and to ensure that the efforts of the refrigeration profession as a whole are widely publicized.

The rapid economic growth during the last few decades in Malaysia has been accompanied by more building which in turn generates more energy and environment related problems. Accordingly, the energy consumption of buildings is growing year after year. As the demand for air conditioning increased greatly during the last decade, large demands of electric power and uncertain availability of fossil fuel have led to a surge of interest in the efficient energy application in air conditioning system. The rejected (sensible and condensation) heat from air conditioning systems is a readily available energy source, that can be used to produce low temperature hot water for washing and bathing [1-4]. Energy consumption of building space heating, air conditioning, and household sanitary water will continue to increase with economic prosperity. Air conditioning system is widely used in building cooling, however there are several problems associated with utilizing the air conditioning system. A great deal of useful waste energy, which can be used for other purposes, is directly dissipated to the environment. This dissipated heat not only wastes energy, but also causes severe pollution in the surrounding area. It is observed that plentiful waste condensing heat from traditional air conditioning system is directly exhausted to the environment.

Nowadays, besides the air conditioning unit, another comfort providing equipment that can be found in many homes in Malaysia is the instant water heater system which is often used in the morning when both the weather and water temperatures are low. However, instant water heater consumes a considerable amount of electricity and users have to pay for it. There is still possibility to get hot water without using any extra electric power if the air condition and water heating systems are integrated. During the operation of a conventional air conditioning unit, the heat from the targeted cooled space is transferred to the environment. The amount of
heat transferred out possesses a substantial amount of potential energy that can be put into good use. The potential source of heat to be reclaimed comes from the superheated refrigerant leaving the compressor. Schematic diagram of the conventional split air conditioning system is shown in Fig. 1. One possible way to fully manipulate this form of energy is to channel it into a water tank, where the waste heat is used to heat up the water in the tank.

![Fig. 1. Basic Operation of a Split Air Conditioning Unit [29]](image)

Air conditioning system is designed to provide a comfortable living or working environment within a specific area by controlling the surrounding at a suitable range of temperature, relative humidity, air circulation and purity of the air. For tropical weather such as in Malaysia, the use of air conditioning system helps to create a more comfortable living environment. It has become an article of faith amongst environmentalists that improving the efficiency of energy use will lead to a reduction in energy consumption [5]. However, economists of all persuasions are united in their belief that the opposite will occur. They argue that the effect of improving the efficiency of a factor of production, like energy, is to lower its implicit price and hence make its use more affordable, thus leading to greater use [6]. Despite many campaigns to reduce energy use over the last 25 years, national energy consumption in all of the world’s industrial countries has continued to rise. Therefore, energy efficiency is not environmentally friendly as many claim. Its promotion will not necessarily lead to a reduction in energy use and hence reduced CO$_2$ emissions. It will, however, save consumers money, promote a more efficient and prosperous economy, and allow the financing of the move towards fossil-free energy future [7].

Many methods have been attempted to optimize the energy use in space conditioning and domestic water heating. Several researchers tried to add a heat recovery system on the air conditioning system, i.e., a heat recovery system was added with phase change material to restore heat rejected from the air conditioning system [8]. In addition, a canopus heat exchanger for heat recovery for a refrigeration system was introduced and reported in [9]. All of these condensing heat recovery systems use the air-cooling technique. The condensing heat recovery technique has excellent potential energy saving and environment protection effects. However, these heat recovery systems do not have a high heat recovery ratio. Nguyen et al. [10] reported the results of experimental study to recover sensible heat from heat pump during heating and ventilation. An analysis of possible energy reclamation from air-conditioning system has been conducted by Sun and Li [1]. Gong et al. [11] established a kind of central hot water system using the surplus heat from the condenser refrigerating unit. Some recent efforts to recover the waste heat from air conditioning/heat pump system are reported in [12-15], however not considerable research works have been reported for tropical environment where at the day time the weather is hot and early in the morning the weather is colder.

Recently, establishment of waste heat recovery device from split type air conditioning system for tropical environment are reported in [16-28]. However, the established systems did not show the satisfactory performance due to the usage of long copper tube coiled at the outer surface of the heat reclamation tank which is expensive and compressor needs more power to flow the refrigerant through a long tube. Therefore, an integrated space conditioning and water heating system was designed and fabricated. The objective of this paper is to present the performance evaluation of the integrated system stated above. The performance test of the constructed system was done to determine whether the heat from the compressed super-heated refrigerant can be recovered to heat up water to provide free hot water supply for residential usage.

2. PERFORMANCE TEST

During the performance test, the condenser unit of the air conditioner was placed outside the testing laboratory where it was exposed to sunlight, rain and other common weather conditions that can be found in Malaysia while the evaporator unit was placed inside a room. Another room was considered as control to compare the ambient temperature without air conditioning. Therefore, the data obtained are more reliable as the performance of the air conditioning unit is dependent on the desired room space condition and the outdoor weather condition. The room space condition refers to the room temperature, whereas the outdoor condition, on the other hand, refers to the outdoor ambient temperature and the discharged air temperature from the condensing unit.

The performance test conducted on the integrated air conditioning and domestic water heating system involves measuring the power consumption by the system with time, the water temperature increment within the heat reclamation tank and the indoor and outdoor space condition during the test. For each of these measured parameters, three repeated sets of data were recorded.

The test was conducted for three days during the day times only because it is the typical use of air conditioning during office hour. At the 1st day, the heat reclamation tank was filled with water and the unit was switched on after recording the necessary information, i.e. water temperature, indoor and outdoor air temperature, etc. Data was recorded every 30 minutes till the unit was switched off after about seven hours of continuous operation (8:00 am - 3:00 pm). At the 2nd day about 8:00 am, the necessary information including the temperature inside the heat reclamation tank was recorded and the unit was switched on. Similar to the 1st day, data was recorded every 30 minutes and the unit was switched off after eight hours of continuous operation (8:00 am - 4:00 pm). At the 3rd day after recording the required initial information, the unit was switched on at 8:00 am and continuously run for nine
3. RESULTS AND DISCUSSION

The power consumption of the system is plotted in Fig. 2 for both conditions, i.e., with heat reclamation tank and without heat reclamation tank. It is evident from Fig. 2 that the integrated unit consumes less power compared to the air condition alone because the super-heated portion of the heat from the hot refrigerant is absorbed by the water. As a consequence of this, the condenser fan does not need to rotate more frequently. Therefore, compressor does not need to work as hard as in a hot environment. As the time is going on, the energy consumption for both systems become stable.

The increase of the temperature at the heat reclamation tank is plotted as a function of time in Fig. 3 for three days of operation for around six to nine hours which shows that within around six hours of operation, the water temperature is raised to about 46ºC (from 28ºC to 74ºC).

It can be observed in Fig. 3 that for the 1st day of operation, the water temperature reached to 74ºC after six hours of continuous operation (8:00 am - 2:00 pm). In order to monitor the effectiveness of insulation, the hot water was kept inside the tank till the next morning (8:00 am, about 18 hours) and it was found that the water temperature dropped to 59ºC. For the 2nd day of operation, the system was switched on and continuously run for around seven hours and the temperature reached to 78ºC. For the 3rd day of operation, the system was run continuously for nine hours and the water temperature reached to 82ºC and became stable. Even though, the temperature drop was about 15ºC within 18 hours, it does not a matter because in real situation, the system is supposed to be operated for the whole night and the hot water would be used in the morning.

The measured temperatures, i.e., discharge air from the condenser and discharge air from evaporator are plotted as a function of time in Fig. 4. It is evident that initially the evaporator temperature was almost same as the room temperature and it decreased to the set point temperature within a very short period of time and finally became constant. The discharge air from the condenser was fluctuated due to the environmental condition, which is obvious in tropical countries like Malaysia where the temperature may be fluctuated to several degrees due to the wet and humid environment [30].

Fig. 5 shows the measured indoor and outdoor ambient temperatures. Indoor does not mean the room where the evaporator was placed but a room which is similar but without any air condition facility. Outdoor temperature means the ambient temperature near by the lab area but far from the condenser. It is observed that the indoor temperature was almost constant throughout the data collection period; however the outdoor ambient temperature was fluctuated a little bit due to the change of the ambient temperature.
Analysis was carried out based on the experimental results obtained to evaluate the performance of the integrated space conditioning and domestic water heating device. Comparisons were made between the developed device and the air conditioner only. Performance evaluation in terms of coefficient of performance (COP), energy efficiency ratio (EER) and power consumption were calculated and summarized in Table 1.

Table 1. Summary of the Performance of Integrated Space Conditioning and Domestic Water Heating Device

<table>
<thead>
<tr>
<th></th>
<th>Integrated System</th>
<th>Air Conditioner Only</th>
</tr>
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<tbody>
<tr>
<td>Power (Watt)</td>
<td>803.39</td>
<td>829.60</td>
</tr>
<tr>
<td>Power,comp (Watt)</td>
<td>798.36</td>
<td>801.90</td>
</tr>
<tr>
<td>COP</td>
<td>3.28</td>
<td>3.18</td>
</tr>
<tr>
<td>EER</td>
<td>11.20</td>
<td>10.85</td>
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4. CONCLUSIONS

From the performance test conducted, the water temperature can be raised from room temperature (around 28°C) to 82°C within 9 hours of continuous operation (8:00 am to 5:00 pm). By using this device, energy efficiency is improved by cutting costs of heating water. This device improves refrigeration efficiency hence is environmental friendly because it reduces the amount of heat discharged to the environment by a conventional air-cooled condenser. Compressor efficiency goes up as temperatures goes down. The end result is expected to be prolonged compressor life since compressor does not need to work as hard as in a hot environment and less compressor run time.

REFERENCES