STUDY ON THE ENERGY SCAVENGING FROM HOUSEHOLD AIR CONDITIONING UNIT

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Abstract
This paper presents the design and construction of an energy scavenging system from a household air conditioning unit. The scavenged energy is used to heat up water for domestic purposes. The system consists of the condenser of a household air conditioning unit (existing), a pump, a plate heat exchanger, and a hot water storage tank. The condenser unit of a household air conditioner is modified to enable the flow of hot compressed refrigerant coming out from the compressor through the plate heat exchanger. The superheated portion of the heat is continuously absorbed by the water inside the hot water storage tank. Experimental investigation showed that this system can heat up water from room temperature to 82°C within 9 hours of operation (8:00 am to 5:00 pm). By using this type of energy scavenging 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 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.

Keywords: Energy scavenging, air conditioning, water heating, environment friendly

Introduction
The rapid economic growth during the last few decades in Malaysia has been manifested by more building which in turn generated 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 for 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 systems. 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 areas. It is observed that plentiful waste condensing heat from traditional air conditioning system is directly exhausted to the environment [26].

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. 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.

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 Malaysian 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 Malaysian environment are reported in [16-21, 27-32]. 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, the objective of this paper is to present the design and construction of a different type of heat scavenging system to recover the waste heat from a split type air conditioning system which is suitable to be applied in tropical environment like Malaysia. 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.

Design of the Heat Reclamation Tank

The potential source of heat to be reclaimed comes from the superheated refrigerant leaving the compressor [22]. Schematic diagrams of the conventional split air conditioning system and the developed system are shown in Figure 1 and Figure 2. In the original design of a conventional air conditioning system, the copper tube conveying the superheated refrigerant from the compressor is diverted directly into the condenser coil for heat removal. In order to reclaim the potential heat source from the superheated refrigerant, the cooper tube conveying the superheated refrigerant from compressor is passed through a plate heat exchanger (Figure 2).

The most common metallic tank materials are stainless steel, copper or glass-lined mild steel [24]. Stainless steel of 0.5 mm thickness is chosen for material in the tank fabrication because it is less expensive and can easily be available. In order to prevent heat loss, the heat reclamation tank is insulated by a 25.4 mm polyurethane insulating material. The insulating material should not degrade at the operating temperature of the tank, which is typically around 90°C. The thickness of insulating material used is governed by the optimum insulation thickness criteria [25].

Optimum insulation thickness is achieved with an appropriate insulating material at a thickness that provides the lowest total life cycle costs in materials, installation, maintenance, and loss of energy.

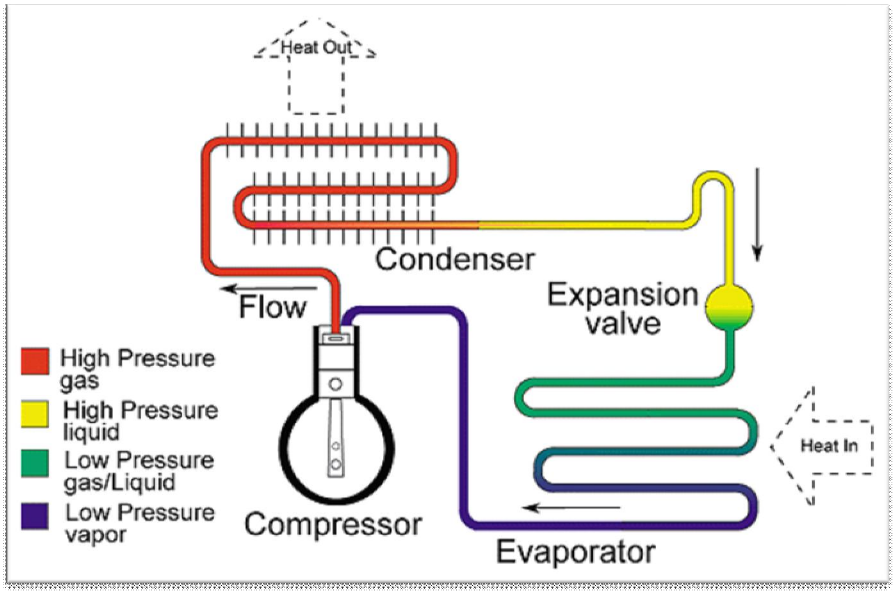

Figure 1- Basic Operation of Air Conditioning Units [23]

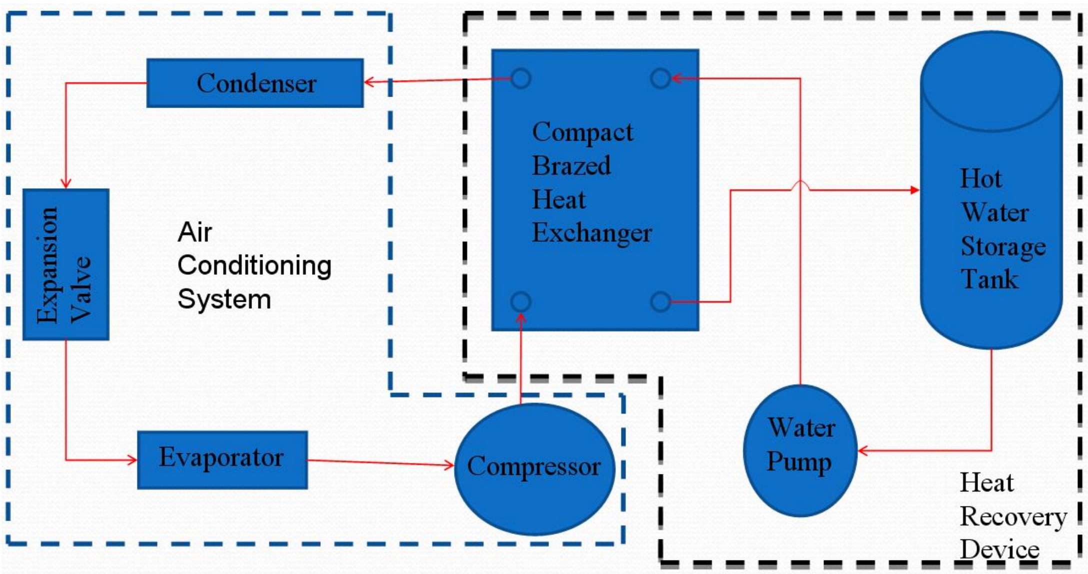

Figure 2- Diagram of Concept Design

The heat reclamation tank has a diameter of 395 mm and a height of 800 mm, is designed to store a maximum capacity of 90 liters of water. A pressure relief valve is located on the upper section of the heat reclamation tank, which is used for maintenance purposes. During maintenance period, the pressure relief valve is opened to allow balancing of pressure within the tank. Thus, by doing so, water can be drained out from the tank prior to the maintenance. Pressure relief valve also plays the role of a safety valve. If the water temperature within the heat reclamation tank reaches to 90ºC, the pressure relief valve will automatically open in order to reduce the built up pressure within the tank. The action occurs as the temperature sensitive liquid (deionised water and alcohol), is subjected to high temperature, it expands and causes the orifice of the pressure relief valve to be opened.

Results and Discussions

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 the lab. 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, wet bulb and dry bulb 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 is divided into three stages. The first stage of the performance test 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. Before the second stage of the experiment began, the average maximum temperature among the three initial data was calculated. The water in the heat reclamation tank was left to be heated up for nine hours continuously. The water temperature was recorded at least every hour during the operation of the system.

For the third stage of the experiment, the heat reclamation tank was removed from the system. The original design of the condenser unit has two additional service ports to connect the condenser unit to the heat reclamation tank. Thus the tank requires additional two copper tubes to complete the refrigerant cycle, where one of the tube connected to the heat reclamation tank acts as the main line where the superheated refrigerant from compressor is transferred into the tank while the second copper tube is to divert the sub-cooled refrigerant from the heat reclamation tank back to the condensing unit to be cooled by air.

The removal of the heat reclamation tank from the air conditioner condensing unit was done by connecting the two additional compressor service ports with one single copper tube to complete the refrigeration cycle. This was done in order to measure the power consumption of the air conditioning unit and compare it against the first stage recorded power consumption data. The comparison is made to determine whether the air conditioning system alone without the heat reclamation tank consumes either more or less power compare to the original setting, where the heat reclamation tank is attached to air conditioning unit. For the measured power at this stage, three sets of data were recorded.

For the first stage of the test, the following information was recorded at the beginning of the experiment:

Air-Conditioning Set Point Temperature	:	16.0ºC (Full Swing)
Initial Water Temperature of the Tank	:	28ºC
Room Temperature (Indoor)	:	29.0ºC
Initial Wet Bulb Temperature	:	26.0ºC
Initial Out Door Temperature	:	31.0ºC

The increase of the temperature at the heat reclamation tank is plotted as a function of time in Figure 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 about 46°C (from 28°C to 74°C). The power consumption of the system is plotted in Figure 4 for both conditions, i.e., with heat reclamation tank and without heat reclamation tank. It is evident from the Figure 4 that at the beginning, the unit consumes less power if it is attached with the heat reclamation tank because the super heated portion of the heat from the hot refrigerant is absorbed by the water. Therefore, compressor does not need to work as hard as in a hot environment. As the time is going on, the water becomes hotter and the unit needs to consume more energy.

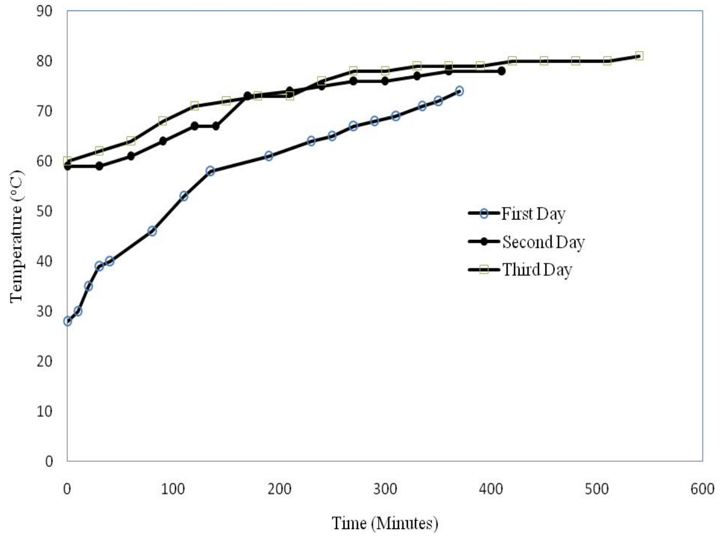

Figure 3- Temperature Profile for Three Days of Operation

The measured temperatures, i.e, discharge air from condenser, discharge air from evaporator and outdoor, are plotted as a function of time in Figure 5. 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 outdoor temperature was fluctuated due to the environmental condition, which brought into the fluctuation of the discharge air temperature of the condenser. This is obvious in tropical countries where the temperature may be fluctuated to several degrees due to the wet and humid environment.

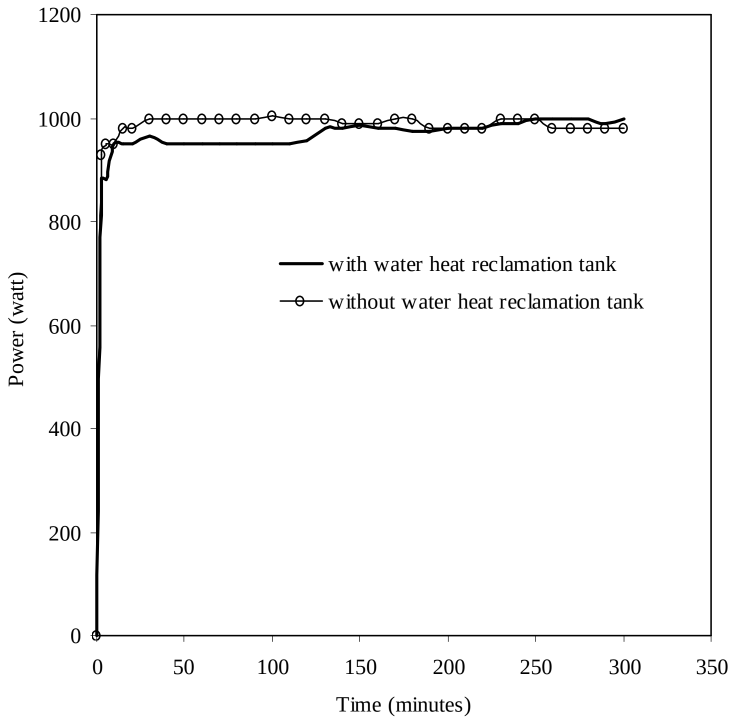

Figure 4- Power Consumption of the Waste Heat Scavenging System

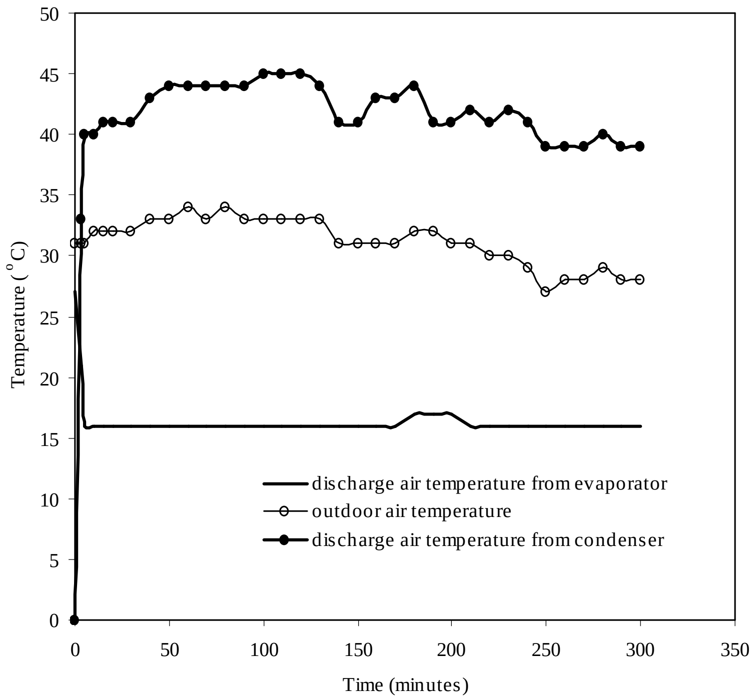

Figure 5- Temperature Reading during the Performance Test

Conclusions

From the performance test conducted, the water temperature can be raised from room temperature (around 27ºC) to 82ºC within 9 hours of continuous operation (8:00 am to 5:00 pm).. By using this design, cooling efficiency is improved by cutting costs of heating water. By providing additional condensing surface, this design improves refrigeration efficiency. This waste heat scavenging device is environmental friendly because it reduces the amount of heat discharged to the environment by an air-cooled condenser. Compressor efficiency goes up as temperatures goes down. The end result is faster cooling and prolonged compressor life since compressor does not need to work as hard as in a hot environment and less compressor run time.

Acknowledgement

This work has been financially supported by Universiti Tenaga Nasional, therefore the authors express their best gratitude to the university.

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