# Experimental Study Of Split Air Conditioning Modification That Changes The Function To Mini Water Chiller

Ade Suryatman Margana[1,*] Lazuardi Margana[2]

[1] Department of Refrigeration and Air Conditioning Engineering, Politeknik Negeri Bandung, Indonesia
[2] Department of Mechanical Engineering, Faculty of Industrial Technology, Institut Sains dan Teknologi Nasional, Indonesia
*Corresponding author. E-mail: adesmargana@polban.ac.id

## ABSTRACT
The use of split air conditioning (Split A/C) on residential applications, hotels and office buildings is currently the best solution to get more comfort when staying in a tropical country. The problem is Air Conditioner in a home or office building consumes 50% to 65% of the total electrical energy use in the home or office. For that problem, need innovations that can save the use of electrical energy while still getting the desired comfort. In this study was made a system that could utilize the work of Split A/C. This utilization produces cold water that can be used to cool the other room. The method is to change the construction of air conditioning by adding a shell and coil evaporator, so that the AC has a dual function as a mini water chiller. By doing this, it will certainly be able to save power consumption because to cool the room, the compressor as the largest power user does not need to be run all day, only used to cool the water. The results of the study are mini water chiller system has COPactual of 5.37. COPcarnot of 6.75 and refrigeration efficiency of 79.3%, the electricity consumed by Split A/C (direct expansion) for two hours of usage is 0,83816 kWh while the electricity consumed by the mini water chiller system is 0,25466 kWh in the same period or this system is 69% more efficient than the direct expansion system.

***Keywords****: mini water chiller, COP, kWh, shell and coil evaporator, direct expansion system*

## 1. INTRODUCTION

The use of split air conditioning on residential applications, hotels and office buildings is currently the best solution to get more comfort when staying in a tropical country. The average temperature in Indonesia is 28°C and can reach 35°C at certain times. One of the requirements of comfortable physical condition is a comfortable temperature, which is a thermal condition of the air in the room that does not interfere with his body. Indonesia based on the Indonesian National Standard (SNI 03-6572-2001) and ANSI/ASHRAE Standard 55-2017, Thermal Environmental Conditions for Human Occupancy (Supersedes ANSI/ASHRAE Standard 55-2013) Includes ANSI/ASHRAE addenda listed in Appendix N recommends that the comfortable temperature is 22.8°C-25.8ºC[1][2].
In general, air conditioning systems use direct expansion methods or use compressors to pump refrigerants as a direct calorific exchanger medium with room air. But with this method, electricity operating costs are more expensive at Peak Load Time (WBP). That's why about 50% to 65% of electricity consumption comes from the use of air conditioning [3]. Thermal storage can be made from the utilization of air conditioning work by converting the construction of the refrigeration system into a mini water chiller system the way is to add a shell and coil evaporator to the air conditioning system [4].

## 2. METHODOLOGY

In conducting this research, there are steps that must be followed systematically so that the final results of this research can be achieved as desired. The first thing to do is to calculate the cooling load to determine the length of the shell and coil evaporator pipes to be used [5] (Figure 1).
Figure 2 shows the modified mini water system layout, on the split ac added shell and coil type evaporator (figure 2) designed based on the same cooling capacity as the existing system, cooling media used water-cooled up to 6˚C then the cold water will be circulated to the other indoor unit (Chilled Water).

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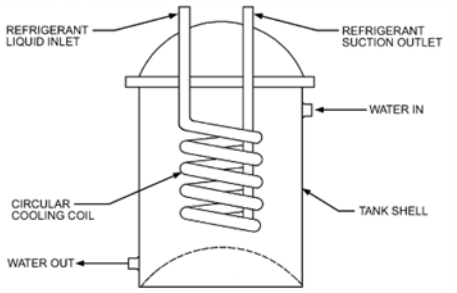


**Figure 1** Shell and Coil Evaporator [6]

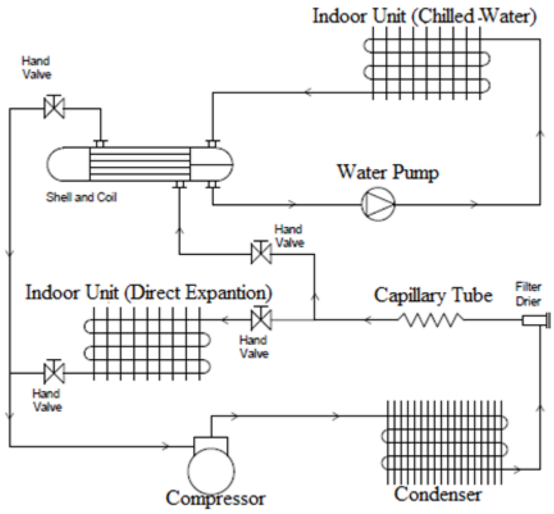


**Figure 2** Mini Water Chiller layout

In accordance with the objectives of this research, the next thing is the consumption of electrical power required by the system (1) direct expansion and system (2) chilled water. To cool the room using system (1) as a typical vapor compression system, the compressor works fully until the room temperature desired is reached. During that time, measurements are taken to determine the consumption of electrical power. For system (2) measurements must be made for two conditions, they are the work of the compressor used to cool the water in the thermal storage tank is measured its electrical power consumption until the water temperature is reached and measurements are made when only the water pump operates when running cold water to cool the room air until the water in the tank returns to the ambient temperature where it cannot absorb indoor heat anymore. From these two conditions, we can find out the total power consumption by adding the two together.
In order to determine the energy consumption, the voltage and electrical current consumed by the Air Conditioning system are measured during its operating time. The tests were carried out for 120 minutes for each room temperature. The power consumption and energy consumption of the Split Air Conditioning system are calculated by using Equation:

$$P = I \times V$$

$$E = P \times t$$

Where :

P = power consumption, Watt
V = electric voltage, Volt
I = electric current, Ampere
E = energy consumption, kWh
t = operating time, second

Meanwhile, to determine the performance of refrigeration efficiency which is defined as the ratio of $COP_{actual}$ and $COP_{carnot}$ at the same working temperature.

$$\text{COPactual} = \frac{h_1 - h_4}{h_2 - h_1}$$

$$\text{COPcarnot} = \frac{T_E}{(T_K - T_E)}$$

$$\text{Refrigeration Efficiency } (\eta) = \frac{\text{COP Aktual}}{\text{COP Carnot}} x100\%$$

Where:

h1 = enthalpy when refrigerant enters the compressor (kJ/kg)
h2 = enthalpy when refrigerant exits the compressor (kJ/kg)
h4 = enthalpy when refrigerant enters the evaporator (kJ/kg)
Te = evaporation temperature (K)

Tk = condentation temperature (K)

## 3. RESULT AND DISCUSSION

With the data that has been obtained from the measurement, the system cycle can be stated in the p-h diagram below (figure 3) so that the performance of this mini water chiller can be calculated [7].

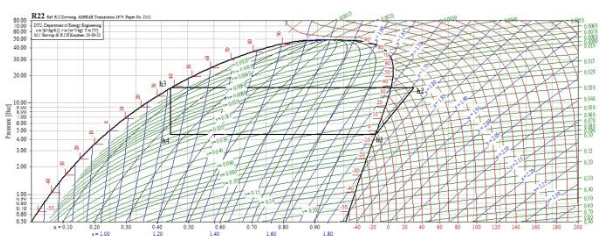

**Figure 3** p-h diagram system cycle

From the P-h diagram above, the following values are obtained :

$$\text{COPactual} = \frac{h_1 - h_4}{h_2 - h_1} = \frac{404\frac{kj}{kg} - 247\frac{kj}{kg}}{434\,\frac{kj}{kg} - 404\frac{kj}{kg}} = 5.37$$

$$\text{COPcarnot} = \frac{T_E}{(T_K - T_E)} = \frac{270.1\ (K)}{(311(K) - 270.1\ (K)} = 6.75$$

$$\text{Refrigeration Efficiency } (\eta) = \frac{\text{COP Aktual}}{\text{COP Carnot}} x100\%$$
$$= \frac{5.37}{6.75}\, 100\% = 79.3\%$$

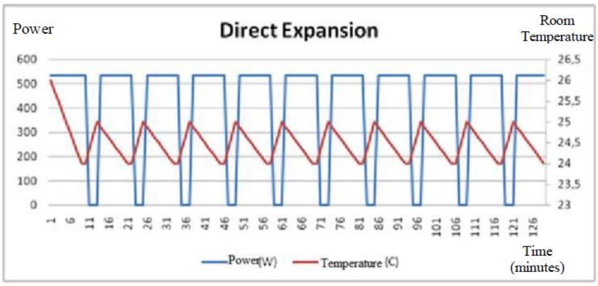


**Figure 4** Power consumption graph against temperature at a system (1)

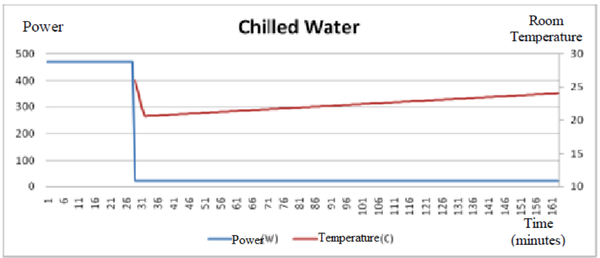


**Figure 5** Power consumption graph against temperature at a system (2)

Figure 4 and figure 5 showing for a system (2) it seems to consume more electricity, but this condition only occurs during the first 27 minutes where a system (2) cools the room and at the same time also cools the water at thermal storage. After finish cooling the water, only the water pump and blower work to cool the room, then the power consumption is very small. The cold water cools the room for two hours until the water returns to its normal temperature.

While the power usage on system (1) will be constant as long as the system (1) is run to cool the room. The system (1) will OFF because the room temperature has been reached and will ON when the room temperature starts to rise and will be cooled again.

With the data that has been obtained from the measurement, energy consumption can be calculated:

System 1 requires energy consumption to cool water from temperature 28ºC to temperature 6ºC and also while cooling the room to a comfort level.

P = I×V
= 2.5 A x 214 V
= 535 W

E = P x t
= 535 W x 1.566 h
= 836,166 Wh
= 0.836166 kWh

Costs incurred for payment of electricity system 1,

C = 0.836166 x Rp. 1.444,70,-
= Rp. 1.208/kWh

Note: Rp. 1.444,70,- is the basic electricity tariff for 2020 with a power limit of 2220 VA issued by the state electricity company (PLN) [11]

System 2 requires energy consumption to cool water from temperature 9ºC to temperature 6ºC and also while cooling the room to a comfort level.

Water Chiller P = I×V
= 2.2 A x 214 V
= 470 W

E = P x t
= 470 W x 0.45 h
= 211.866 Wh
= 0.211866 kWh

Water Pump P = I×V
= 0.1 A x 214 V
= 21.4 W

E = P x t
= 21.4 W x 2 h
= 42.8 Wh
= 0.0428 kWh

Costs incurred for payment of electricity system 2,

C = 0.211866 x Rp. 1.444,70,-
= Rp306/kWh

From table (1) it can be seen that if cooling the room by using the system (2) for two hours will consume as much electricity as 0,25466 kWh whereas if using a system (1) electricity consumption of 0,83816 kWh were 3 times more efficient than system (1).

**Table 1** Comparison table of electricity consumption between system (1) and system (2)

| Parameter | System (1) | System (2) |
|---|---|---|
| | Direct Expansion | Chilled Water |
| **Working Hours** | 94 minute | 27 minute |
| **Power** | 535 W | 470 W |
| **Energy Comsumpsion** | 0,83816 kWh | 0,21186 kWh |
| | | Water Cooled Circulation |
| **Working Hours** | | 120 minute |
| **Power** | | 21,4 W |
| **Energy Comsumption** | | 0,0428 kWh |
| **TOTAL Energy Comsumption** | 0,83816 kWh | 0,25466 kWh |
| The Mini Water Chiller 69% more efficient than the direct expantion system | | |

## 4. CONCLUSIONS

The results of the study are mini water chiller system has COPactual of 5.37, COPcarnot of 6.75 and refrigeration efficiency of 79.3%, the electricity consumed by Split A/C (direct expansion) for two hours of usage is 0,83816 kWh while the electricity consumed by the mini water chiller system is 0,25466 kWh in the same period or this system is 69% more efficient than the direct expansion system

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