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CONDENSATE WATER PROCESSING OF SPLIT-UNIT AIR CONDITIONING SYSTEM ON COMMERCIAL BUILDING

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Abstract

A research to measure the condensate volume produced by the split unit air conditioning (AC) system on a commercial building was done where the measured volume was then used to determine the capacity of the water storage tank required to fill in the condensate. The selected building is Scholar's Inn UTM (SIUTM) in Johor which able to operate a maximum of 162 units of 1 Hp and 81 units of 1.5 Hp AC if the building is fully occupied. In this research, by maintaining the cooling load in the conditioned room, the condensate water produced by the split units was collected and measured to find the average to condensate production of the day. Based on the practical operating hours of SIUTM, at most a 12-hours operation per day is considered. With only depending on the relative humidity and the temperature of the day, the result obtained was compared to the previous research that using psychometric analysis to determine the condensate water produced in a hot and humid country. The results show that the condensate can be produced up to 4781 liter per day, 143430 liter per month and 1721160 liter every year and the condensate water having the value of pH at 7.17, TDS at 1.0 mg/liter and copper (Cu) of 1.1 mg/liter, which is acceptable values for raw water source. For drinking purposes, treatments such as reverse osmosis, distillation or ion exchange can be done.

Keywords: Condensate recovery, Condensate water, Water source, Water quality

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1. Introduction

Nowadays, air conditioning has become a necessity especially in building ventilation. For commercial buildings such as offices, malls and shopping centers they usually used central system.

The study on condensate water recovery just started not long time ago when sustainability becomes an important practice worldwide. Boulware[1] stated that due to quality issue, condensate water often ignored as a source of freshwater. It just gets into people's attention as drinkable and non-drinkable usage to cover the water shortage lately. In addition, the investigation on water recovery also done in order to increase the coefficient of performance (COP) of the air conditioning system, as well as to increase the cost saving on operating the system[1-2].

As for the experiment on measuring the amount or volume of water produced from condensation from a split-unit air conditioning system, it can be done in many ways. Some of the ways are by collecting the condensate experimentally or through analytical model by taking the system cooling capacity into consideration.

A study on condensate water as water source was also performed by Al-Farayedhi et al.[3]. They have comparing between analytical model and experimental method results to investigate the condensate water as another water source from a vapour compression air conditioning system in hot and humid regions. Their investigation was focusing on the relationship between relative humidity and environment temperature with the amount of condensate water produced.

Barreira et al.[2] have done the thermoeconomic analysis and optimization of residential split-type using simulation-based optimization techniques. The research were focusing on the relationship between the COP of the system and the percentage of cost saving. As the COP increases, the percentage of cost saving also increases[2]. One of the ways to improve the COP is by utilizing the condensate captured from an air conditioning system, to be reuse back by the system. Typically, the condensate water from air conditioning units will just be drained away. Also, in a hot and humid climate, the amount of condensate produced is very significant and just become a waste. Therefore, it is very important to study the potential of water and energy sustainability by recovering the condensate water from air

conditioning system[4].

Buildings such as apartment blocks will usually used split-unit types for individual comfort in each room. The Scholar's Inn of Universiti Teknologi Malaysia (SIUTM) is an apartment type building which provides on-campus lodging for anyone including UTM students, staff and also outsider. The building is using split-unit air conditioning system for space ventilation. Just like the other split-unit system installation, the drainage of the condensate water will be installed too and somehow causing another problem to human comfort itself and also affecting the view of the building. Most of the piping will headed to the drain outside of the building. Improper piping installation sometimes distracting peoples lane. Furthermore, the water leaking from the broken pipe annoyed people and also causing moss problem in some part of the building. Economically, the drainage of condensate water is also a waste. From this problem, the ideas of designing the storage tank for the recovery of condensate water from the split-unit air conditioning system were carried out.

2. Air Conditioning Condensate Recovery

The water and the heat contained in the condensate can be used back for other purposes. This is called the condensate recovery. Instead of sent it to sewer drain, recovering condensate can help to significant savings of energy, chemical treatment and make-up water[2, 5].

Alliance for Water Efficiency[5] stated that the condensate water is essentially the same as distilled water which is having low mineral content and Total Dissolved Solids (TDS) level of near zero. Thus, it has to be removed to prevent damage to other equipments. Also, they stated that the collection of condensate from the air conditioning system can be used for various applications, depends on the amount produced.

The recovery of condensate water can be used as alternate water source for application such as:

a. The make-up water of cooling tower.
b. For irrigation purposes.
c. Evaporative cooler.
d. Industrial processes such as boiler feed water and heating system.
e. Cleaning applications.

The calculated total volume per day of condensate water is used to determine the capacity of the water storage tank. The volume of condensate water produced is defined as:

a. Average condensate produced (Q1) in one hour (L/hour) for one unit:

$$Q_1 = \frac{(\sum Volume\ of\ condensate\ water)}{4} \quad (1)$$

b. Total volume of condensate water per month (L/month):

$$Vol_{TM} = Q_1 \times N \times 12 \times 30 \quad (2)$$

c. Total volume of condensate water per year (L/year):

$$Vol_{TY} = Q_1 \times N \times 12 \times 365 \quad (3)$$

where N is number of split air conditioning unit in the building, 4 is hours of readings taken in a day, 12 is number of operation hours per day, 30 is number of days per month and 365 is number of days per year.

3. Methodology

The basic principle of obtaining the condensate produced by the split-unit air conditioner is by collecting it. The experimental work was done where the conditioned room was set to the temperature of 23˚C and the condensate produced was measured for every 4 hours. The average production per hour is determined, by considering the relative humidity and outside temperature. Based on yearly occupancy rates of the building, the maximum condensate production was determined to be use as the water storage tank capacity.

To select the proper design for the water storage tank of the condensate water, several parameters need to be considered such as tank capacity, the materials of the water tank, position of the tank and how the piping system will be installed to the tank.

As for the piping system, it will be installed in inclined position so that the condensate water will flow by gravitational force only (Fig. 1). Thus, no pump is needed to pump water down except one to be installed together with the tank.

Water quality test also done in order to determine the possible use of the condensate such as for drinking purposes, raw water sources or even for watering plants. A sample of condensate collected was randomly picked to be tested in Chemical Analysis Laboratory of Faculty of Science in UTM. Due to some limitation, only three parameters tested which are water pH, total dissolved solid (TDS) and copper (Cu) content. These three parameters are significant since the pH define the acidity level of

the condensate water, TDS reading shows the mineral content in the water while Cu content determine whether there are any Cu particles in the condensate due to the contact of the water with the cooling coil that made from copper.

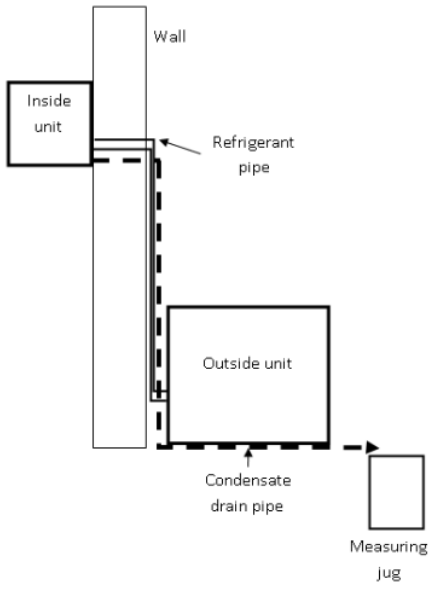

Fig.1. Experiment set up diagram

4. Results and Discussion

The experiment was done from 2.00 PM to 4.00 PM and 4.00 PM to 6.00 PM where it stated the highest temperature of the day with average high temperature of 31˚C. For actual low temperature, it is usually happen during the night where the average low temperature is 24˚C. Noted that during day and night the ambient temperature is different where at night, the ambient temperature is colder and lower than during the day thus the room temperature will also differ during the night. The lowest relative humidity ranges from 50 to 70% and highest which ranging from 74% up to 94%. Both relative humidity and temperature affect the volume of condensate water produced by the split-unit air conditioner.

Most of the occupants of SIUTM usually stay in the room during the night where they will operate the air conditioning unit. The experiment on collecting the condensate volume is however conducted during the day due to some restriction. Thus, the value of the results should be slightly different. The average volume of condensate produced per hour for 1.5 HP is 2.5 L/hour whereas for 1 HP is 2.2 L/hour. These results can be said as the minimum condensate volume produced by the air conditioner since the condition is high temperature and low relative humidity that slower the condensation process outside the cooling coil.

In SIUTM, there are total of 93 rooms where 81 of them are air–conditioned and 12 without air-conditioner. In one room there will be three units of air-conditioners; two of them are 1 HP and one 1.5 HP. Thus, the total 1.5 HP air-conditioners in the building are 81 units and the total 1 HP air-conditioners in the building are 162 units. Equation 2 and 3 is used to determine the monthly and yearly production rate of the condensate water (Table 1).

Table 1. Condensate water predicting

AC Unit (HP)	Room	Day (L)	Month (L)	Year (L)
1.5	81	2430	72900	886950
1	162	4276.8	128304	1773900
Total condensate water		6706.8	201204	2660850

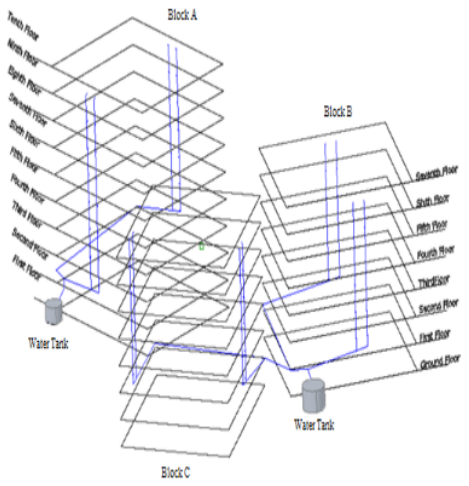

Fig.2. Piping and storage tank

The piping system will only consider on how the condensate water will be directed to the storage tanks. In the SIUTM building, the air-conditioner split-unit types were installed in 243 units is located in different levels. Also, current condensate drain pipes only let the water flow to the drain below. To collect all these water, the existing pipes will be connected to each other by adding pipe junctions and collected in one bigger pipe before entering the storage tanks. Condensate water need to be flow

smoothly through the drain pipe to prevent it from backflow and leak through the inside unit. Thus, the pipe will be in inclined arrangement where only gravitational force used to let the water flow downwards. Fig. 2 shows the piping system need to be installed and add to the current drain pipe where it will let the condensate water flow from all the split-unit's compressor into one pipe and entering the water storage tank on the ground level. The inclination of the pipe is necessary in order to use the gravitational force instead of pump to collect the water.

Table 2. Condensate water quality

Parameter	Condensate Water Quality	Recommended Raw Water Quality	Drinking Water Quality Standards
		Acceptable value	Maximum acceptable value
pH	7.17	5.5-9.0	6.5-9.0
TDS	1.0 mg/litre	1500 mg/litre	1000 mg/litre
Cu	1.1 mg/litre	1.0 mg/litre	1.0 mg/litre

Table 2 shows the condensate water has pH value of 7.17, in between the range of recommended raw water quality and drinking water quality standards by Ministry of Health Malaysia. pH value determine whether the water is acidic or alkali where in this case, it is acceptable. TDS consist of the dissolved of inorganic salts and small amount of organic matter in water. From the results, TDS value is 1.0 mg/liter, far below the drinking water standards by Ministry of Health Malaysia which is 1000 mg/liter. This is very low which is near zero and mineral free, thus makes it corrosive to most metals, especially steel and iron[5]. At higher levels, unpalatability, mineral deposition, excessive hardness and corrosion may occur. As for Copper (Cu) content, the result obtained is 1.055 mg/liter, slightly exceeding the standard made by Ministry of Health Malaysia for both raw water and drinking water types at 1.0 mg/liter. At this level, the water will staining and has bitter taste but for health concern, the level is 1.3 mg/liter[6]. From these results, the condensate water can be used as raw water source and if it were to be used for drinking purposes, certain treatment procedure need to be done to remove or reduce the copper content from the water. The treatment options can be either reverse osmosis, distillation or ion exchange. Based on previous studies, Boulware[1] and many more found that the condensate water in most ways is exactly like rain. Condensate water by itself is distilled pure water, but it may require further treatment as it might get contaminated on the way [7]. Since the condensation process occurs outside the cooling coil surface which is made from copper, there might contain heavy metals from contact with the coil and air-conditioner equipment.

5. Conclusion

Economically, the amount of condensate water produced by SIUTM building is too much to be waste. Based on the water quality test done, the collected condensate water can be used for as raw water material as well as for activities such as watering the plant, washing the car or even cleaning the floor since the properties is quite the same as distilled water. However for drinking purposes, some treatments need to be done to reduce or remove the copper contaminants in the water. Thus, the recovery of condensate water for SIUTM building is a good thing to be done where the volume of condensate water produced by the split-unit air conditioning system and the suggestion of water storage tanks already been made.

6. Acknowledgements

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References

[1] Boulware, B. Air conditioning condensate recovery. *Environmental and Energy Management News*. Pinchot University 2013; January 15.

[2] Barreira, E.M., Negrao, C.O.R. & Hermes, C.J.L. Thermoeconomic analysis and optimization of residential split-type air conditioners. *Appl Therm Eng. 2013;50(1):*629-636.

[3] Al-Farayedhi, A.A., Ibrahim, N.I. & Gandhidasan, P. Condensate as a water source from vapor compression systems in hot and humid regions. *Desalination. 2014;349:*60-67.

[4] Licina, D. & Sekhar, C. Energy and water conservation from air handling unit condensate in hot and humid climate. *Energy and Build. 2012;45:*257-263.

[5] Alliance for Water Efficiency. *Promoting the*

Vol.x (No.x). yyyy. pp.
Published online: Mmmm d, yyyy

efficient and sustainable use of water. Chicago. 2010.

[6] Kissel, D.E., Vendrell, P.F. & Atiles, J.H. Your household water quality: lead and copper. *Household Water Quality Series*. *2003*;Circular No. 858-10.

[7] Guz, K. Condensate water recovery. *ASHRAE J*. *2005;47(6):*54–56.

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