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Analysis Management of Collection Condensate to Enhance the Refrigeration Cycle Performance

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Abstract: This study investigates the main parameters that have effects on the amount of condensate collection from an air-condition unit and also try to design a cooling system to deliver this condensate collection to the outdoor unit which is condenser to improve the COP of air-condition. During this study, three different experiments was done to show and prove the effects of room temperature, room humidity and cooling coil temperature on the amount of condensate collection. It is found that by increasing the room temperature from 16-24°C the amount of condensate collected increase by 34.6% which means that as the temperature is higher the amount of condensate collection is higher. Also, it is found that increasing the room humidity by 13.7%, the amount of condensate collection also increase by 50.8%, this result shows that as much as the area is much more humid so the condensate collection is much more and it has much more benefit from the economic point of view. For the last experiment after deliver the condensate collected to the condenser the COP of the air-condition unit increase by 12.96% in compare with the normal condition and it has a good effect like decrease the energy consumption by the air-condition unit and decrease the electricity bill.

Key words: Effects, cooling, humid, normal condition, energy consumption

INTRODUCTION

In a time of increasing the population, most of the countries are going to face so many different types of problems like: provide sufficient energy for their needs or enough potable water and also economic problems is another problem for people to live in a way that they want to, most of the people think that for solving the problem needs to innovate a new solution but most of the time solution are near to us and in our daily life we saw them so many times but we do not pay attention to them. One of the very important resources for water is condensate collectionwhich these days most of the developed countries are going to use it in a different way.

Further more, so many researches were done in this field and show that this amount of condensate collected can be used in many useful ways; some countries which have a very hot and humid climate and have a shortage problem for the potable water try to collect the condensate collection and after doing short process in laboratory could use it as an potable water (ASHRAE, 1996). There is another research about using the water condensate which is using the amount of water condensate to flow it in the secondary cooling coil system which is smaller than the first one and use it to cooling down the warm air which is supplied into another AHU. They found that by applying this process, the work done by the next AHU decreasing and the performance of the second unit start to increase.

In another research they try to use of the water condensate in two ways, firstly they deliver the water condensate to pre cooling a second unit and after that collect remain water and deliver it to the main cooling tower. The result of this investigation showed decreasing in the amount of needed water for cooling tower up to 50% and energy saving for the AHU up to 10%.

Another research that was done in this field was about cooling the air coming to the condenser which is similar to this study but the differences is that they use an extra fan to cool down the air temperature instead of condensate collected, this new fan work in such a way that increase the speed by increasing the inlet temperature of the condenser and vice versa decreasing the speed when the inlet temperature cool down.

They found that as much as the condenser inlet temperature decrease the cop of the air condition will increase which is mathematically around 10% decrease in the work done by the compressor in another word it has results of increasing around 10% of COP for the air-condition unit (Hajidavalloo and Eghtedari, 2010).

MATERIALS AND METHODS

Amount of condensate collected: In this study two methods were done to calculate the amount of condensate collection. For the theoretically part the amount of condensate collected from air-condition unit is calculated using Eq. 1:

$$\begin{aligned} mv &= (\omega 1 - \omega 2) \times p \times v \\ mv &= \omega \times mam_a = \frac{PV}{RT}\frac{p}{p = RT} \end{aligned} \quad (1)$$

Where:
m_v = Amount of moisture air holds
m_a = Mass of dry air
ω = Specific humidity
d = Density
v = Volume flow rate

For experimental part there was a piping design to deliver the condensate collected to a container and collect it there (Fig. 1).

Calculate cop: In this study COP was calculated two times first before deliver the condensate collection to the condenser which is before improving and another time is after deliver the condensate collection to the condenser which is after improving and then compare the results with each other. For calculating the COP Eq. 2 used:

$$\begin{aligned} Cop &= \frac{QL}{W} \\ QL &= \Delta h \times ma \\ ma &= \frac{PV}{RT} \\ \Delta h &= h_R - h_c \end{aligned} \quad (2)$$

Effect of dry bulb temperature on the amount of condensate collection: This experiment was done for four different temperature which means that first the room temperature adjusted to 24°C and after 5 min measure the room humidity and dry bulb temperature and wait for another 5 min and repeat this steps until the room temperature became constant and after that turn off the air-condition and open the window to achieve the temperature and humidity as same as the outdoor air and then adjusted the room temperature to 20, 18 and 16°C and repeat the same procedures. By having the change in the specific humidity and dry bulb temperature by the using of Eq. 1 (Cengel and Boles, 2007) it is easy tocalculate the amount of condensate collection.

Effect of room humidity on the amount of condensate collection: The procedures for this experiment is as similar as the previous one and the only differences is that in this

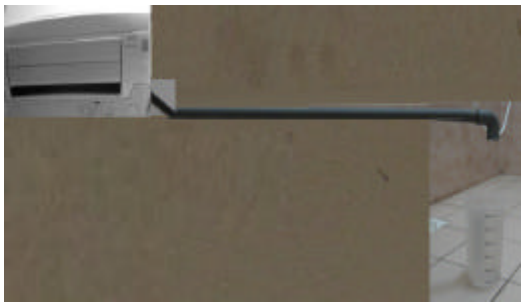

Fig. 1: Condensate collection design

Fig. 2: Boiling water sources

Fig. 3: Fan for air circulation

experiment there is two boiling water sources to increase the humidity of the room and investigate the effect of increasing the humidity on the amount of condensate collection. As can be seen in Fig. 2 there is two boiling water sources in the room.

Also before start the experiment it is needed an extra fan for air circulation to have same humidity in each part of the room, as can be seen in Fig. 3.

Effect of cooling coil temperature on the amount of condensate collection: This experiment is going to investigate the amount of condensate collection by controlling the cooling coil temperature. For this experiment need to measure the temperature of the room

(TR), temperature of The Cooling coil (TC) Temperature Supply (TS) which is the temperature of the air after it leaves the air-condition immediately and also measure the relative humidity for the room temperature (ωR) and relative humidity for the air supply temperature (ωS) and find the humidity which is ωR-ωS. And after that by the use of these data it is easy to calculate the COP by using Eq. 2.

Design piping system to deliver condensate collection to the condenser: In this experiment condensate collected is going be used to increase the COP of the air-condition piping to collect the water condensate and splash it on unit to achieve this goal first need to design a system of the cooling coil system. After that start to measure the cooling coil temperature, room temperature and humidity and again calculates the cop and compares it with the experiment three (Fig. 4-6).

Fig. 4: Measure supply temperature

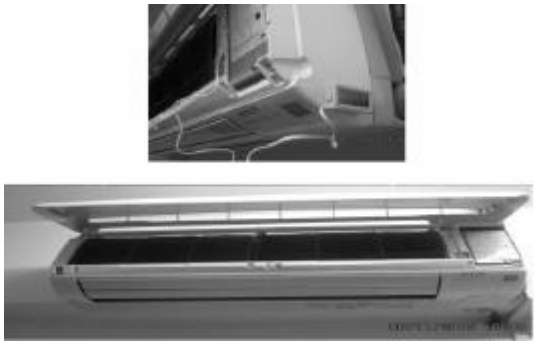

Fig. 5: Measure cooling coil temperature

Fig. 6: Deliver condensate collection to condenser

RESULTS AND DISCUSSION

Effect of room temperature: For this experiment first the room temperature and specific humidity measured and after that the amount of condensate collected calculated.

As can be seen in Table 1 there is the data for room temperature adjusted to 24°C and a sample calculation of condensate collected (Table 1). The amount of condensate collected when it goes from 0-5 min:

$$\omega = \omega_1 - \omega 2 = 18.1 - 16.2 = 1.9\times10\text{-}3 \text{ kg/kg dry air:}$$

$$p = \frac{p}{R \times T1} = \frac{101.6}{0.287 \times (27 + 273)} = 1.18 \text{ kg m}^{-3}$$

$$v = 630 \text{ m}^3 \text{ h}^{-1}$$

$$\text{Water condensate collected} = (1.9\times10^{-3})\times (1.18)\times(630) = 1.4 \text{ kg}^{-1}\text{h}$$

By calculating the amount of condensate collected for temperature adjusted to 20, 18 and 16°C it can be said that as much as the room temperature is higher the amount of condensate collected is higher (Fig. 7).

Effect of room humidity: After use of two boiling water sources the room temperature and specific humidity measure once again and calculate the amount of condensate collected and compare the result with the normal condition which is without using boiling water sources (Table 2).

By using the data from Table 3 and Eq. 1 it is possible to calculate the amount of condensate collected for two different situations. By looking at the Table 4 it can be seen as much as the room humidity in higher the amount of condensate collection is also higher (Fig. 8).

Deliver the condensate collected to the condenser: Here first the COP of the air-condition unit was calculated and after that condensate collected was delivered to the condenser and one again the COP calculated and then these two value of COP compared with each other. Here is one sample calculation to show how the COP can be calculated:

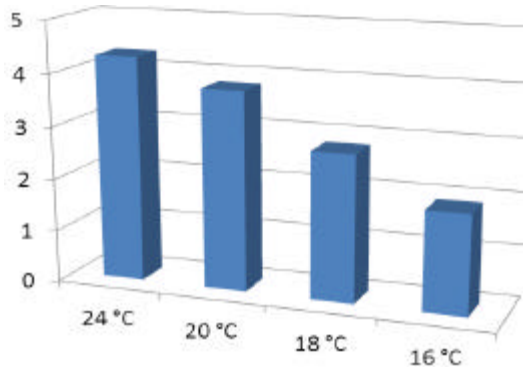

Fig. 7: Amount of COP before and after improving

Table 1: Adjusted temperature of 24°C

t (minute)	T_1 (°C)	RH (%)	ω (g/kg)
0	27	80	18.1
5	26	76	16.2
10	25	72	14.4
15	24	69	13.0
20	24	68	12.8

Table 2: Before using boiling water sources

t (minute)	TR (°C)	RH (%)	ω(g/kg)
0	27	80	18.1
5	26	76	16.2
10	25	72	14.4
15	24	69	13.0
20	24	68	12.8

Table 3: After using boiling water sources

t (minute)	TR (°C)	RH (%)	ω (g/kg)
0	28	91	22.0
5	26	86	18.3
10	25	80	16.0
15	24	76	14.3
20	24	75	14.1

Table 4: Amount of condensate collected

Amount of condensate collectionTime(minute)	Without boiling water sources	Using boiling water sources
0-5	1.40	2.7
5-10	1.33	1.7
10-15	1.04	1.3
Average	1.26	1.9

Table 5: Amount of COP for both situation

Room temperature (°C)	Cop before improvement	Cop after improvement	Increasing Cop (%)
20	4.05	4.57	12.8
18	4.10	4.42	7.8
16	4.10	4.40	7.3

$$T_R = 26°C \rightarrow h_R = 67.5 \text{ kJ kg}^{-1}$$

$$T_C = 17.7°C \rightarrow hc = 46.8 \text{ kJ kg}^{-1}$$

$$ma = \frac{PV}{RT} = \frac{101.3 \times 630}{0.287 + (26 + 273)} = 743.7 \text{ kg h}^{-1}$$

$$743.7 \text{ (kg h}^{-1}) \times (1 \text{ h}/3600 \text{ sec}) = 0.2 \text{ kg sec}^{-1}$$

$$QL = \Delta h \times ma = 20.7 \times 0.2 = 4.14 \text{ kJ sec}^{-1} = 4.14 \text{ kw}$$

$$W = 1.2 \text{ kw}$$

$$Cop = \frac{QL}{W} = \frac{4.14}{1.2} = 3.4$$

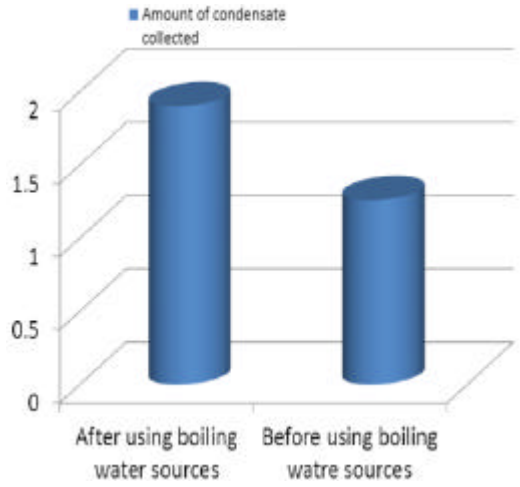

Fig. 8: Amount of condensate collected

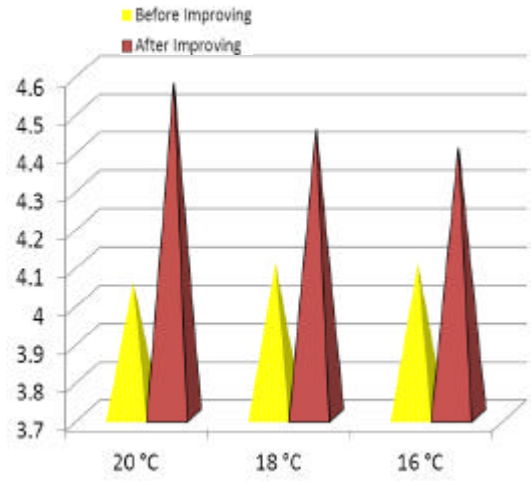

Fig. 9: Amount of COP before and after improving

By looking at the Table 5, it is obvious that after deliver the condensate collected to the condenser the amount of COP increased (Fig. 9).

CONCLUSION

Referring to the experimental conducted the effect of the several variables are investigated to study their influence. Therefore, the room temperature, humidity and cooling coil temperature was varied at different times to show their real effect on the condensate collected.

By increasing the room temperature the condensate collected increase by 34.6% (room temperature increase from 16-24°C) this is due to the capability of hot air to withstand more humid as temperature increase.

It is the clear indication that the amount of condensate collection will be increase as moisture content is increasing that is why humid zones may offer more condensate collection rather than dry one for this studied it is found that by increasing the humidity up to 13.7% the amount of condensate collection will increase by 50.8%.

By referring to the results of last two experiments it is obvious that when the condensate collected delivered to the outdoor unit and spray on the condenser it has a good effect on the Cop and cause increase the Cop of the air-condition by 12.96% which has a good result, like increase the performance of the refrigerator cycle, decrease the electricity consumption by the air-condition.

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