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Effect of Discharge Cooling using Condensate Water on the Performance of an Air Conditioner: A Field Testing

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ABSTRACT

The effect of discharge cooling using condensate water from the evaporator on the performance of an air conditioner has been experimentally investigated. Instead of laboratory testing, the air conditioner was tested under real conditions, as is generally an AC unit installed in a room. The indoor unit was installed inside the room at a height of 2.6 m from the floor, while the outdoor unit was installed outside at floor level. In this research, the air conditioner was tested under two conditions, i.e., normal condition without discharge cooling and modified condition in which the condensate from the evaporator was flown and dripped to the discharge pipe. The use of discharge cooling could decrease suction and discharge pressure, as well as suction and discharge temperature. It also slightly decreases supply air temperature. Better performance of the air conditioner with the use of discharge cooling was shown by the decrease of power consumption by 3.5% and increase of cooling capacity by 2.45%. As a result, the coefficient of performance (COP) increases by 6.31%.

1. Introduction

The increase in population and increasing levels of human welfare cause the need for energy to continue to increase, especially for buildings those responsible for more that 30% of global energy consumption [1,2]. University buildings and commercial buildings are the most types of buildings those have the highest energy consumption, and about half of buildings' energy is consumed by air conditioning system [3,4].

In addition to climate change, the demand for cooling energy will also increase significantly [5]. The number of global cooling days could rise significantly due to a slight rise in average temperature. This could lead to a significant increase in demand for cooling energy [6]. Efforts are needed to reduce the rate of increase in global energy demand. The use of evaporative cooling, condensate water, or its combination are examples of options of technologies that have been developed to reduce the rate of increase of energy demand.

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Evaporative cooling utilizes water evaporation to cool the environment. This method has been utilized by humans for centuries and thorough research has been accomplished to improve its efficiency. During the process of evaporative cooling, air is cooled and humidified as it interacts with water [7]. This cooling system can be integrated with conventional air conditioning system or operated independently. As it does not rely on a compressor, this system can decrease energy consumption and minimize environmental impact [8].

The effectiveness of an evaporative cooler relies on the environmental conditions, including both dry-bulb temperature, wet-bulb temperature, air flow rate, and evaporation rate. A cooling capacity up to 6-kW was resulted from experiment using water flow rate of 0.386 kg/s and water evaporation rate of about 450 ml/s [9]. The effect of ambient air condition on the efficiency of evaporative cooler has also been investigated [10]. It was reported that temperature reduction in the range of 0.6°C to 18°C can be achieved under a wide range of outdoor air temperature. A small-scale evaporative cooler has been developed and its efficiency depended on the ambient condition and water consumption [11,12]. Apart from cooling, Adekanye *et al.,* [13] proposed that evaporative cooler can be used to increase humidity of a space to reduce the evaporation rate of water from the fruit tissues. A range of evaporative cooling efficiency in the range of about 20% to 80% was resulted from experiments by varying water and air flowrate [14].

Incorporating evaporative cooling in an air conditioning system can enhance overall efficiency. Naveenprabhu and Suresh [15] claimed a reduction of power consumption of 43.3% when an evaporative cooler was applied in a mini chiller with a capacity of 1.5 kW. Martinez *et al.,* [16] demonstrated in their study that employing an evaporative cooler led to an 11% decrease in power consumption and a 1.8% increase in cooling capacity. Similarly, in chiller systems, integrating an evaporative cooler with cold water resulted in reduced power consumption and an enhanced coefficient of performance (COP) [17]. Another investigation focusing on window air conditioners found that integrating an evaporative cooler could yield energy savings of up to 13% [18]. By varying the mass flow rate of water to precool the condenser air, it was reported that improvement of COP up to 13% in a hot-humid climate can be achieved [19]. The similar method has been employed in a small air conditioner with a nominal capacity of 2.6 kW and could reduce the power consumption by 6.57% and improve the COP by 12.95% [20]. In hot-dry climate, of course, the improvement would be higher because of the easier evaporation of water. The more significant effect of the use of evaporative cooling on the performance of an air conditioner was also confirmed by the use of IEC-MVC (combination of Indirect Evaporative cooling and Mechanical Vapor Compression) [21]. It was reported that higher performance improvement up to 65% could be achieved at high outdoor temperature and low moisture content. A reduction of power consumption by 22% and an improvement of COP by up to 42.6% have also been reported in an experiment using atomizing nozzle to cool the condenser air. The experiment was carried out at an ambient temperature range of 31 to 48°C and relative humidity range of 13 to 27%. The high COP improvement could mainly be caused by the high temperature and low moisture content of ambient temperature used in this experiment, so that high latent heat of evaporation of water can be utilized [22].

Later, condensate water from evaporator gains its popularity to be used to improve the efficiency of an air conditioner. Condensate water is produced from condensation of water vapor when air passes through the evaporator. It can be used to improve the performance of air conditioners in two ways. First, by utilizing the temperature difference between the condensate and components or parts being cooled. Second, by utilizing evaporative cooling principle from the evaporation of condensate water. As is widely known, evaporation of a liquid will take heat from its surroundings.

By utilizing water condensate to cool the discharge line of an air conditioner using the evaporative cooling principle, it was reported that the COP could be improved by up to 16.4% [23]. The use of heat exchanger with varied length to cool the discharge line using condensate water of an air conditioner has also been studied [24]. In this study, improvement of COP by 9.1%, 14.4%, and 27.3% were reported for the use of heat exchanger with length of 18, 20, and 22 cm, respectively. By dripping condensate water from the evaporator directly to the condenser, it was reported that the method could increase COP and cooling capacity by 7% and 4%, respectively [25]. Instead of air conditioning, condensate water was also applied in refrigeration system [26]. As reported, the use of condensate water could improve the COP of an open refrigerated display cabinet by the range of 2.23% to 5.80%.

Even though it has limitations in terms of continuity of supply quantity, the use of condensate water has its own advantages. Condensate water can be obtained free of charge and generally has a high level of cleanliness because it is resulted from condensation. Not only for improving the performance of air conditioning systems, it could be used for cleaning, gardening, make up water of cooling tower, roof cleaning, roof ponds, and spray cooling [27,28].

In this study, the use of water condensate to improve the performance of an air conditioner is discussed. The novelty of this study lies in the testing method used. If in previous studies testing was carried out in the laboratory, the present study was carried out on a unit that has been installed in a room. In laboratory tests, usually the condenser and evaporator of the air conditioner were installed in different rooms maintained at certain conditions. ISO 5151, for instance, specifies the room for condensing unit should be maintained at 35°C dry-bulb temperature/24°C wet-bulb temperature. The room for installing the evaporator or indoor unit was maintained at 27°C dry-bulb temperature and 19°C wet-bulb temperature. In this test, the outside air temperature is left as is without being controlled.

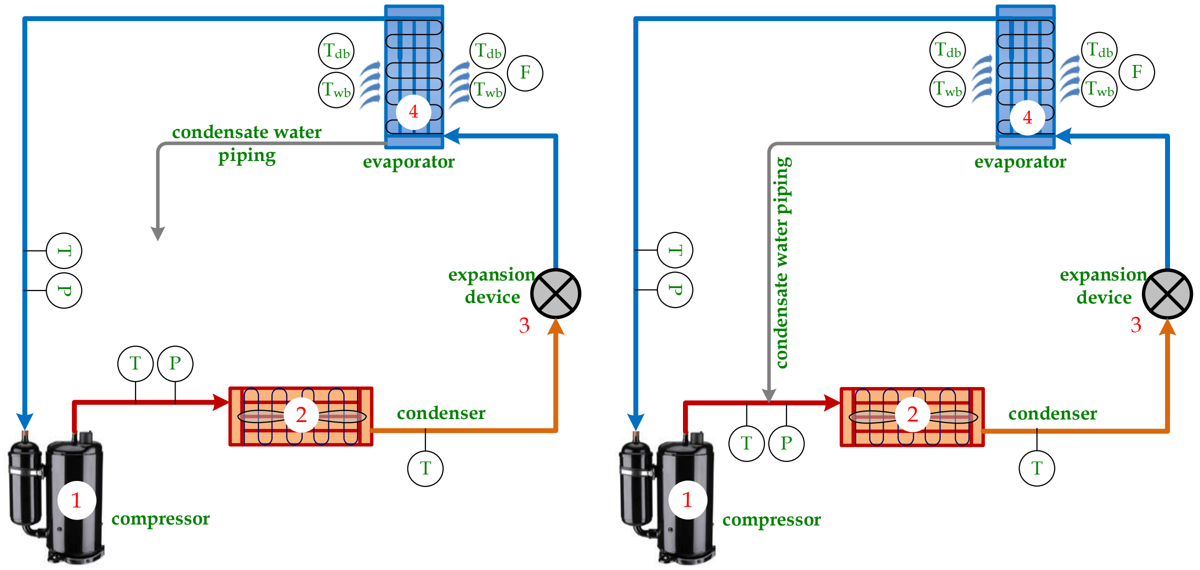
This test was conducted without any major modification of the air conditioner. The only change was made is to direct the flexible condensate drain pipe to the AC discharge pipe so that the condensate can drip into the pipe. Pumps were also not used in this study because the flow of condensate water only relies on gravity from the condensate reservoir located at the indoor unit to the discharge line located at the outdoor unit positioned lower than the evaporator.

2. Methodology

A room air conditioner usually utilizes the vapor compression refrigeration system to produce cooling. The cycle consists of compression (1-2), condensation (2-3), expansion (3-4), and evaporation (4-1). The sketch of the system is presented in Figure 1(a). During its operation, an air conditioner usually produces condensate water due to the condensation of water vapor in the evaporator. The condensation occurs when water vapor contacts a surface with a temperature lower than that of dew-point temperature of the air. Room air with a temperature of 25°C and a relative humidity of 50% has a dew point of about 13.9°C. Therefore, an evaporator coil with a mean surface temperature of about 5°C could cause condensation of water vapor as the evaporator temperature is below the dew-point temperature of the room air. This condensate is usually drained to the sewer through a flexible drain pipe as a part of the room AC purchase package. However, before drained to the sewer the condensate was collected in a measuring cylinder to determine the rate of condensation of water vapor in the evaporator.

In this research, the condensate water of the air conditioner was drained to the discharge line of the compressor. The object of this research is an air conditioning unit installed in a staff room of Laboratory of Air Conditioning, Politeknik Negeri Bandung, Indonesia. The indoor unit was installed as usual at a height of 2.6 m in the staff room, while the outdoor unit was installed outside the room shaded by a balcony. So, the outdoor unit is never exposed to the sun. A minor modification of the

AC piping was applied so that the condensate could wet the outer surface of discharge pipe at a sufficient length. Some of the water evaporates due to the high temperature in the discharge line, while the rest is allowed to flow down. The sketch of the discharge cooling system for this experiment is presented in Figure 1(b).



(a) (b)

Fig. 1. Sketch of a room air conditioner, (a) Normal configuration, the condensate water is drained through a flexible drainpipe to a sewer. (b) Modified configuration, the condensate water is drained to the compressor discharge pipe.

The vapor compression refrigeration system could also be expressed in pressure enthalpy diagram as shown in Figure 2. As can be seen, the cycle involves the low-pressure side and high-pressure side. Under normal operation, the cycle can be expressed using the solid line in Figure 2 (process 1-2-3-4). If discharge cooling is applied, the cycle will be shifted to the dashed line (1-2’-3’-4’). In normal operation, the refrigeration effect and the specific work of compression can be expressed as

$$q_e = h_1 - h_4 \tag{1}$$

$$w = h_2 - h_1 \tag{2}$$

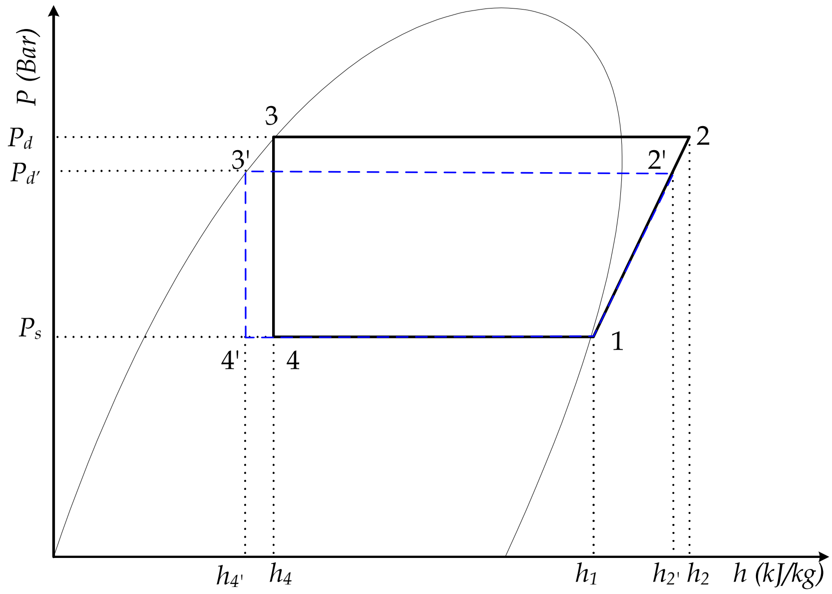


Fig. 2. Refrigeration cycle in pressure-enthalpy diagram. The black solid line represents the cycle under normal operation. The blue dashed line represents the cycle when the condensate water is drained to the discharge line, causes the decrease of discharge and condensing pressure

In Eq. (1) and Eq. (2), q_e expresses the refrigeration effect, w is the specific work of compression, and h_1, h_2, and h_4 express the enthalpy of refrigerant at the compressor suction line, discharge line, and evaporator inlet, respectively. The enthalpy of refrigerant can be obtained if the temperature and pressure are known.

The cooling capacity at refrigerant side ($Q_{e,r}$) and work of compression (W_r) can be calculated using

$$Q_{e,r} = \dot{m}_r(h_1 - h_4) \tag{3}$$

$$W_r = \dot{m}_r(h_2 - h_1) \tag{4}$$

where $\dot{m}_r$ is the refrigerant mass flow rate.

Eq. (1) to Eq. (4) express the performance of the air conditioning unit from the refrigerant side. The air side performance in terms of cooling capacity can be expressed using the following equation.

$$Q_{e,a} = \dot{m}_a\ (h_{in} - h_{out}) \tag{5}$$

where $Q_{e,a}$ is the cooling capacity at the airside, $\dot{m}_a$is the mass flow rate of air across the evaporator, and h_{in} and h_{out} denote the enthalpy of air entering and leaving the evaporator. The power required to operate the air conditioner can be directly measured or calculated by

$$P_i = VI\ cos\varphi \tag{6}$$

where P_i is the input power, V is the voltage, I is the current, and $cos\varphi$ is the power factor.

The ratio of the cooling capacity and input power is defined as the coefficient of performance (COP), or

$$COP = \frac{Q_{e,a}}{P_i} \tag{7}$$

To obtain the performance of the air conditioner, both at refrigerant and air side, the operating conditions of the air conditioner should be measured. For the refrigerant side, the measured data are refrigerant suction temperature, refrigerant suction pressure, refrigerant discharge temperature, refrigerant discharge pressure, condensing temperature, and liquid line temperature. For the air side, the data collected are dry-bulb temperature of air entering and leaving the evaporator, wet-bulb temperature of air entering and leaving the evaporator, air velocity, electrical power, voltage, and current. Symbols P, T, and F in Figure 1(a) and Figure 1(b) represent pressure, temperature, and air flow velocity measurements, respectively. Meanwhile, symbols T_{db} and T_{wb} represent dry-bulb and wet-bulb temperature measurements, respectively. In this experiment, the rate of water vapor condensation in the evaporator was also manually measured using a measuring cylinder.

The measurement of pressure was accomplished using pressure gauges with accuracy of ±0.34 bar (high pressure side) and ±0.07 bar (low pressure side). The measurement and acquisition of temperature data were carried out using TC-08 Pico data logger with an accuracy of ±0.2% of reading and ±0.5°C. A digital rotating vane anemometer with an accuracy of 3% full-scale was used to measure the air velocity. The electric parameters were measured by Kyoritsu digital power meter with 1.5% accuracy.

3. Results

The use of condensate water to cool the discharge line affects the operating conditions and performance of the air conditioner. The operating condition involves the suction and discharge pressure, suction and discharge temperature, liquid line temperature, and supply air temperature. The air conditioning performance involves the cooling capacity, power consumption, and energy efficiency ratio.

3.1 Suction and Discharge Pressure

The suction pressure is the pressure of refrigerant measured at the suction line of the compressor. In this experiment, the effect of the use of condensate water for discharge cooling on the suction pressure is presented in Figure 3(a). The data were collected after a stable operation of air conditioner. As can be seen, the discharge cooling using condensate water from the evaporator resulted in a slight reduction of suction pressure. When the air conditioner was operated normally without discharge cooling, the suction pressure ranges from 6.9 to 7.4 bar with an average of 7.1 bar. The suction pressure was slightly reduced to the range of 6.7 to 7.2 bar with an average of 7.0 bar when the discharge cooling was applied. The decrease in suction pressure can be caused by a decrease in discharge temperature and pressure due to cooling of discharge line with condensate water. In a room air conditioner, a capillary tube is used as an expansion device (point 3 in Figure 1). As the capillary tube has a certain constant pressure drop, a decrease in discharge pressure also causes a decrease in the suction pressure.

The profile of discharge pressure of the air conditioner tested with and without discharge cooling is presented in Figure 3(b). A range of discharge pressure from 23.4 to 23.8 with an average of 23.55 bar was obtained when the unit was tested without discharge cooling. With discharge cooling, the discharge pressure ranges from 22.7 to 23.3 bar with an average of 23 bar. Therefore, a decrease of discharge pressure of about 0.9 bar was obtained with the use of condensate water to cool the discharge line.

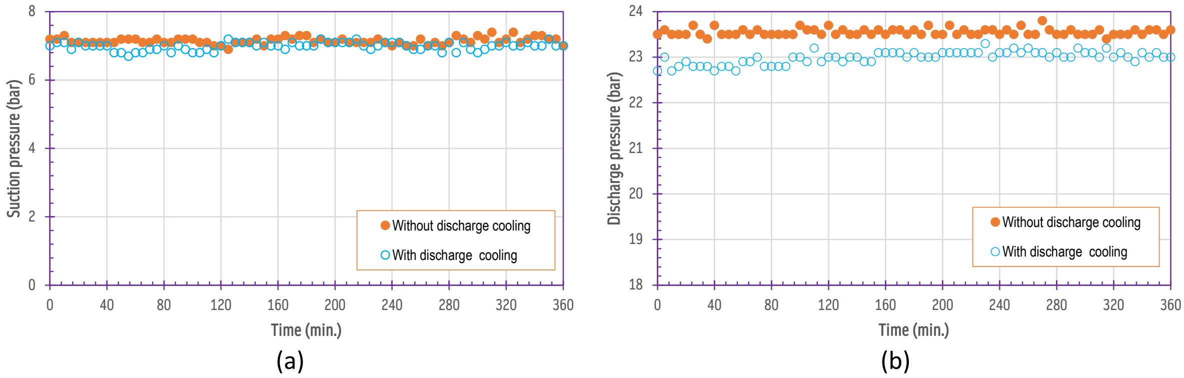


Fig. 3. Suction pressure (a) and discharge pressure (b) of air conditioning unit with and without discharge cooling.

As the discharge pressure decreases more significantly than that of suction pressure, the compression ratio of the compressor decreases when discharge cooling is applied. Compression ratio is an important parameter in the operation of an AC unit. A properly functioning compressor will have a low compression ratio so it can operate more efficiently. Thus, the operation of a compressor must be maintained at the lowest possible compression ratio to achieve the desired cooling capacity. The compression ratio can be a tool to check whether a compressor is working properly. A compression ratio that is too high generally causes high electrical power consumption, overheating, and oil degradation [29]. A compression ratio that is too low indicates mechanical damage and compression failure. A low compression ratio is desirable; however, it should not be too low. Compression ratio (CR) is calculated using

$$CR = \frac{P_d}{P_s} \quad (8)$$

where P_d and P_s denote the absolute discharge and suction pressure, respectively.

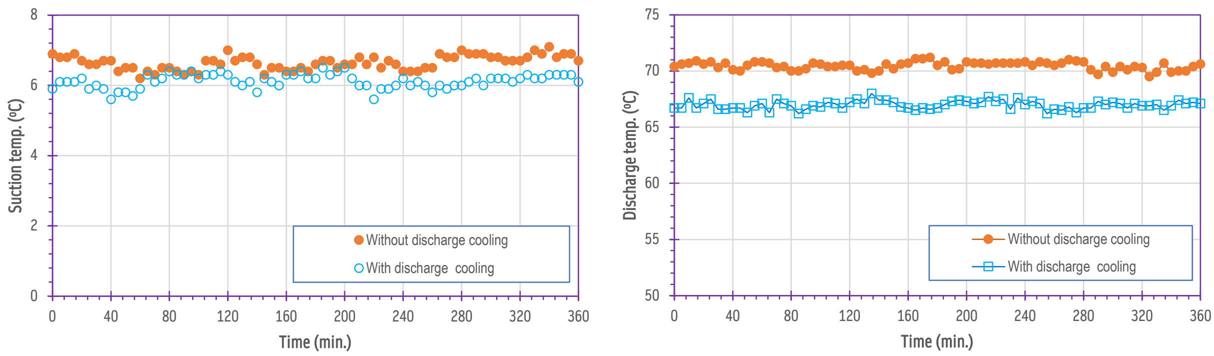
In this experiment, the compression ratio without discharge cooling is found to be 3.01, on average. Meanwhile, by using discharge cooling the compression ratio drops to 2.96. On the other words, the use of condensate water for discharge cooling reduces the compression ratio by 1.7%. A higher compression ratio of about 4.1 was reported from an experiment using the same refrigerant [30]. The higher compression ratio is mainly caused by higher outdoor air temperature used in this study, which was up to 51°C.

In a refrigeration system, the reduction of compression ratio means that the amount of refrigerant being circulated by the compressor increases. This will usually increase the cooling capacity, which will be discussed later.

3.2 Suction and Discharge Temperature

Suction temperature is measured at the outlet of evaporator before refrigerant enters the compressor. The profile of the suction temperature of this study is presented in Figure 4(a). As can be seen, a slight difference of suction temperature was observed in this experiment. A range of suction temperature of 6.2 to 7.1°C and an average of 6.6°C was observed when the unit was operated normally, without discharge cooling. When the condensate water was drained to the discharge line, the suction temperature is in the range of 5.6 to 6.5°C with an average of 6.1°C. It means that the use of discharge cooling could slightly reduce the suction temperature, about 0.5°C. The decrease in suction temperature could be caused by the decrease in suction pressure. In a vapor compression refrigeration system, the lower suction pressure will give the lower suction temperature, as signified in pressure-temperature relationship.

Figure 4(b) depicts the discharge temperature of the air conditioning unit, measured at the compressor outlet. The chart shows that the use of condensate water to cool the discharge line could significantly decrease the discharge temperature. Without discharge cooling, the discharge temperature ranges from 69.5 to 71.2°C with an average of 70.5°C. As the discharge cooling was applied, the discharge temperature decreases to the range of 66.2 to 68.0°C with an average of 67.1°C. An average decrease of discharge temperature of 3.4°C was recorded with the use of discharge cooling. In this experiment, the condensate water was drained directly to the discharge pipe of the air conditioner, so that it directly affects the discharge line temperature. Later, the effect on the cooling capacity and efficiency of the air conditioner will also be discussed.



(a) (b)

Fig. 4. Suction temperature (a) and discharge temperature (b) of air conditioning unit with and without discharge cooling

3.3 Supply Air Temperature

This parameter represents the temperature of air at the evaporator outlet. In a room air conditioner, the evaporator fan draws air from the room and passes it to evaporator. Here, cooling and dehumidification occurs, in which heat will be taken from the air by the evaporator as well as condensation of water vapor. As a result, the air temperature will drop. Water vapor condensation also causes the moisture content of the air to decrease. Therefore, supply air will have lower temperature and lower moisture content.

The plot of supply air temperature is depicted in Figure 5. Without discharge cooling, the supply air temperature is in the range of 17.0 to 18.1°C with an average of 17.5°C. Applying the discharge cooling decreases the supply air temperature to the range of 16.4 to 17.5°C with an average of 16.9°C. It means that the discharge cooling using condensate water from evaporator could decrease the supply air temperature by about 0.6°C. An average supply air temperature of 14.25°C was reported when the similar air conditioner was tested at outdoor air temperature of 28°C and relative humidity of 50% [31]. Similar supply air temperature was reported in another test of an air conditioner at outdoor air dry-bulb temperature of 28°C and wet-bulb temperature of 21.5°C [32]. Meanwhile, a test at the same outdoor air temperature with a relative humidity of 59.8% resulted in supply air temperature of 14.21°C [33]. In comparison to previous studies, this work has a significant difference due to the different methods of testing. In this experiment, an existing installed air conditioner was used. Meanwhile, the previous tests were carried out in the laboratory, in which the temperature and humidity of the test rooms are controlled.

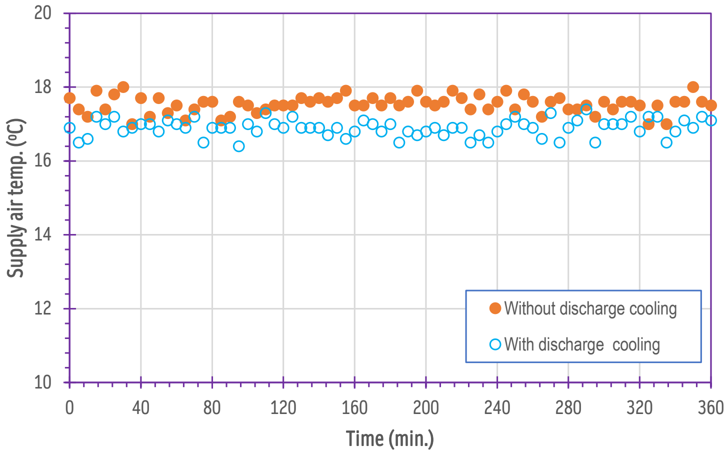


Fig. 5. Supply air temperature of air conditioning unit with and without discharge cooling

3.4 Input Power

This parameter represents the power drawn to operate an air conditioner. It can be determined directly by the measurement using a power meter or by measuring electric current and voltage and then determine the power using Eq. (6). Compressor is the part of an air conditioner that consumes most electricity for compressing and circulating refrigerant throughout the refrigeration system. The remaining are for operating the evaporator fan, condenser fan, and control system. Generally, the input power is influenced by mass flow rate of refrigerant and compression ratio, i.e., the ratio of discharge pressure and suction pressure.

Without discharge cooling, the average power is recorded at 869 Watt. Using discharge cooling, the power drops to an average of 839 Watt, or reduced by 3.55% (Figure 6). The reduction of power consumption of the air conditioners could be caused by the reduction of discharge pressure and discharge temperature by discharge cooling, as discussed in Section 3.1. As a result, the work of compression decreases and the power consumption decreases.

Prior similar test using a similar capacity of a room air conditioner at outdoor air temperature of 28°C and RH 59% resulted in a power consumption of 858 Watt [33]. Another test using outdoor dry-bulb temperature of 28°C and wet-bulb temperature of 21.5°C provides a power consumption of 860 Watt [32]. Meanwhile, the similar test using outdoor temperature of 28°C and relative humidity of 50% provided a power consumption of about 850 Watt [31]. The power consumption resulted from this test is in good agreement with previous publications. Discharge cooling using tube-in-tube heat exchanger resulted in the range of power reduction by 2.4%, 4.8%, and 9.8% for the length of heat exchanger of 18 cm, 20 cm, and 22 cm, respectively [24]. The use of condensate water by pouring it directly into the condenser coil has been investigated. As a result, compressor power consumption was reduced by 3% [25]. By applying an evaporative cooling module, Mainil *et al.,* [20] reported an energy saving in the range of 5.37% to 6.57%. Whereas, the use of atomization cooling element for precooling of condenser air inlet resulted in the reduction of power consumption by 7.3% [34].

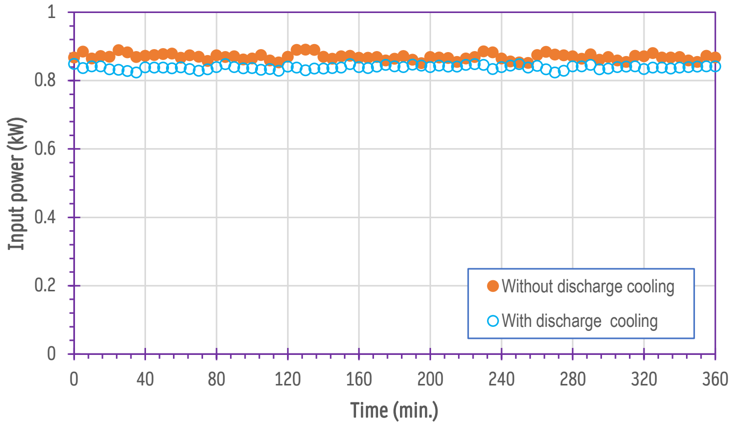


Fig. 6. Input power of air conditioning unit with and without discharge cooling

3.5 Cooling Capacity

Cooling capacity is one of the most important parameters of an air conditioner. This parameter exemplifies the ability of a system to remove heat from space. In this experiment, the cooling capacity was calculated from the product of air mass flowrate across evaporator and enthalpy difference of air entering and leaving evaporator as expressed in Eq. (5). By measuring the velocity and opening area of evaporator, the volumetric flow rate of air could be determined. The mass flow rate can be calculated from the product of volumetric flow rate and air density. The enthalpy difference could be determined by measuring dry-bulb and wet-bulb temperature of air entering and leaving the evaporator.

The comparison of cooling capacity of the air conditioner with and without discharge cooling is presented in Figure 7. Under normal operation, without discharge cooling, the cooling capacity ranges from 2.82 to 2.89 kW with an average of 2.85 kW. By using the discharge cooling, the cooling capacity increases to the range of 2.88 to 2.97 kW with an average of 2.92 kW. In other words, the use of discharge cooling increases cooling capacity by 2.48%. The higher cooling capacity with the use of discharge cooling could be explained using the illustration in Figure 2 and Eq. (1) and Eq. (3). As can be seen, the refrigeration effect increases due to the employment of discharge cooling. Point 1 in Figure 2 shows that the condition of refrigerant in the suction line remains the same (point 1 in Figure 2). This indicates that the refrigerant density, thus refrigerant mass flow rate, is constant. As a result, the cooling capacity increases when discharge cooling is applied.

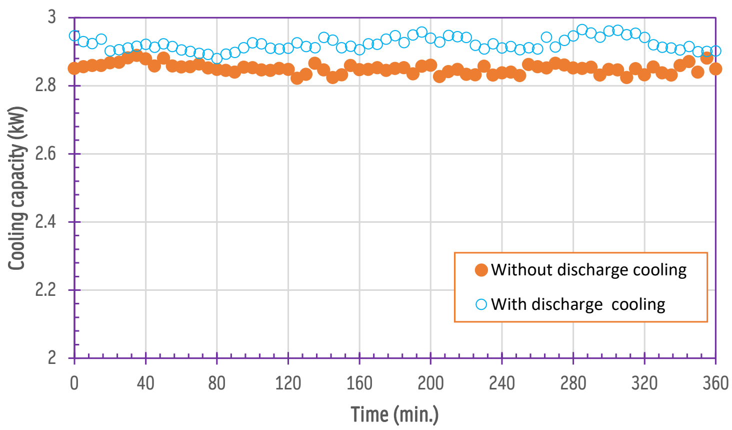


Fig. 7. Cooling capacity of air conditioning unit with and without discharge cooling

As a comparison, an experiment by dripping condensate water to the condenser resulted in an increase of cooling capacity by 4% [25]. By using an evaporative cooling module, an increase of cooling capacity of about 6% from 3.66 kW to 3.88 kW was achieved [20]. Another experiment by using a tube-in-tube heat exchanger resulted in an increase of cooling capacity up to 14.9% [24]. Improvement of cooling capacity up to 6.2% was also reported from the use of atomization cooling element for condensate water applied in condenser air inlet [34]. However, all aforementioned data were resulted from laboratory testing. Meanwhile, the present data were resulted from a real condition test on an AC that has been installed in a room.

From the test, it is also obvious that the air conditioner produced condensate water with an average rate of 980.5 g/h. With a nominal capacity of 2.6 kW (or 0.75 ton of refrigeration, TR) the condensation rate of water vapor is found to be 1.31 kg per ton of refrigeration. The production of condensate water is considered high, as the experiment was carried out in a relatively humid area. As a comparison, a condensation rate of 2.07 kg/h using a 2-ton air conditioner was reported from an experiment in a location with an average relative humidity of 48% in the Middle East [35]. Another experiment in high humidity environment reported that a condensation rate of 1.17 kg/h was recorded per ton of refrigeration [36].

3.6 Coefficient of Performance (COP)

The coefficient of performance (COP) is calculated on the base of cooling capacity in the air side and power consumed to operate the air conditioner, as expressed in Eq. (7). The effect of discharge cooling on the COP is summarized in Figure 8. Under normal operation without discharge cooling, the COP ranges from 3.17 to 3.36 with an average of 3.28. Applying the discharge cooling increases the capacity to the range of 3.41 to 3.55 with an average of 3.49. The increase of COP when using discharge cooling is mainly caused by two factors: the decrease in power consumption and the increase in cooling capacity. As previously discussed, the use of discharge cooling could reduce power consumption by up to 3.55% and increase cooling capacity by up to 2.48%. As a result, COP increased by 6.31%, on average. This shows that the use of discharge cooling using condensate water from evaporator has a significant influence in increasing the performance of the air conditioning unit.

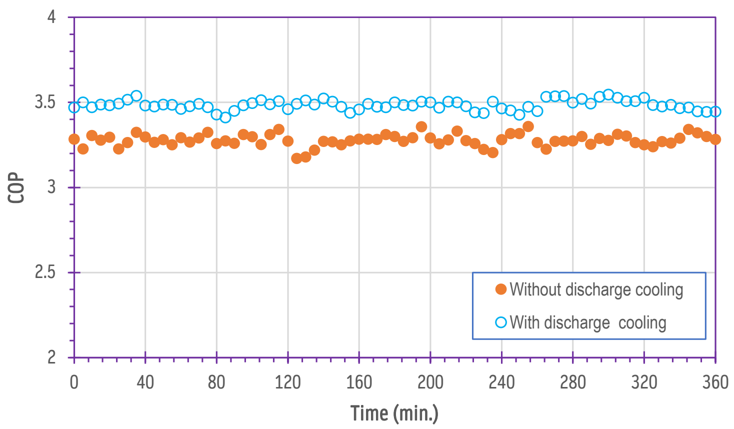


Fig. 8. COP of air conditioning unit with and without discharge cooling

The COP of this work is comparable with the result from previous studies, in which the use of evaporative cooling module could increase the COP up to 4.17% and the use of condenser air precooling could improve the COP by 7% [20,25]. Meanwhile, by using an atomization cooling element for condensate water, the COP could be improved up to 13.9% [34]. A higher improvement of COP in the range of 9.1% to 27.3% was reported from an experiment of the use of condensate water to cool the discharge line. However, this experiment employed various length of heat exchangers installed in the discharge pipe [24].

Although the COP or efficiency improvement is generally lower than that of the previous studies, this work offers some advantages, especially from a practical perspective. This experiment only requires a slight modification, namely changing the direction of the flexible drain pipe from the sewer to the discharge pipe of the compressor. Another small modification is a small hole in the outdoor casing to provide access for the drain pipe to the discharge pipe.

4. Conclusions

The effect of the use of condensate water for cooling the discharge line of compressor on the performance of an existing air conditioner has been investigated through real condition experiment. From this study, it is obvious that discharge cooling caused the change in operating conditions of the air conditioner. The discharge cooling could decrease the suction and discharge pressure of the air conditioner that caused the decrease of compression ratio by 1.7%. The decrease in suction and discharge pressure led to the decrease of suction and discharge temperature, in which a more significant effect can be observed on discharge temperature. A slight decrease of supply air temperature was also observed in this experiment. The discharge cooling affects the performance of the air conditioner in terms of power consumption, cooling capacity, and coefficient of performance. The power consumed by the air conditioner decreased by 3.5% with the use of discharge cooling, while the cooling capacity increased by 2.45%. It results in the improvement of COP by 6.31%. Although the performance improvement is not superior to the previous works, this method offers advantage in terms of practicality. Only minor modification is required to direct the drain pipe to the compressor discharge pipe.

5. Future Works

Among the important aspects in condensate utilization for improving air conditioner performance are the rate of condensate evaporation and heat exchanger. Rate of evaporation affects the capacity of the condensate in cooling the discharge line. Proper heat exchanger is also important in optimizing the utilization of the condensate water.

In this study, the rate of evaporation of condensate water was not analyzed. Whereas it is an important factor that affects the effectiveness of the condensate water in improving the performance of an air conditioning. Evaporation of condensate water can absorb more heat rather than just employing the temperature difference between the condensate and discharge pipes. Therefore, in the next studies it is important to investigate the effect of evaporation of condensate water on the overall performance.

Design of proper heat exchanger is required to improve the utilization and effectiveness of condensate water in enhancing the performance of an air conditioner. The desired heat exchanger design is one that can hold condensate water and is able to increase the rate of condensate evaporation.

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