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RESEARCH ARTICLE

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# Utilization of air conditioner condenser as water heater in an effort to energy conservation

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**Abstract.** This paper presents an experimental study of utilization of air conditioner condenser as water heater. Modification of existing air conditioner system is an effort to harvest waste heat energy from condenser. Modification is conducted in order to test the system into two mode tests, first mode with one condenser and second mode with two condensers. Harvesting the waste heat from condenser needs a theoretical and practice study to see how much the AC performance changes if modifications are made. It should also be considered how the technique of harvesting waste heat for water heating purposes. From the problem, this paper presents a comparison between AC performance before and after modification. From the experiment, an increase in compressor power consumption is 4.3% after adding a new condenser. The hot water temperature is attained to 69 °C and ready for warm bath. The increase in power consumption is not too significant compared to the attainable hot water temperature. Also seen that the value of condenser Performance Factor increase from 5.8 to 6.25 or by 7.8%.

## 1 Introduction

A comfortable environment is what humans really want. Global climate change that is experienced today reduces the comfort of life on earth. Increased environmental temperatures due to the effects of global climate change have been going on for quite a while and may continue as long as people exploit nature in excess and pay no attention to the balance of nature.

A comfortable temperature environment can be conditioned through the use of an air conditioner which we know as AC. The equipment can create an air environment to cool, cold, warm or hot. To produce a cold effect the role of evaporator is needed while the heat effect can be given by the condenser. In Indonesia with a tropical climate that tends to heat, the use of cold effects of air conditioning is more needed than heat effects. Placing the evaporator indoors is an application of the use of air conditioning to get cool air. Meanwhile, the heat effect generated from the condenser is placed outdoors. In that case, the condenser continuously discharges heat into the environment during which the air conditioner is operated.

The waste heat from the condenser is theoretically large enough that it ranges from 4 to 6 times the power of the compressor [1]. The heat is discharged into the environment without any side benefit taken. With the value of heat is large enough, the heat can be absorbed to get another sense for example for the purposes of a hot shower or for drying [1]. Thus that will get double benefit from installation of AC at home that get cool effect at the same time harvesting condenser waste heat. In this paper, a harvest of condenser heat is used to heat water.

Harvesting the AC condenser waste heat needs a theoretical and practice study to see how much the AC performance changes if modifications are made. It should also be considered how the technique of harvesting condenser waste heat for water heating purposes. From the problem, this paper presents a comparison between AC performance before and after modification.

## 2 Research methodology

To obtain AC performance comparison between before and after modification it is necessary to prepare the research methodology as follows. Choosing a good air conditioner is the first thing to do. The air conditioner is then modified by adding a new condenser in addition to the old condenser. In order that the modifications do not damage too heavily on existing AC equipment then the old condenser does not need to be changed, just add a new condenser (see Fig. 3). The side effect is the addition of refrigerant fluid to keep the AC system operating normally. Type of the refrigerant is refrigerant R22 [2]. The addition of a refrigerant itself needs to get advice from an experienced AC technician.

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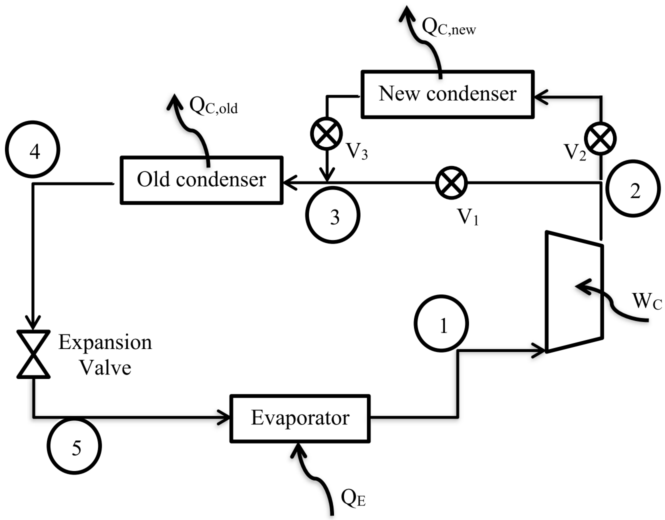


**Fig. 1.** General cycle of refrigerant system of AC.

AC modification with the addition of a new condenser is illustrated schematically through Figure 1. The modified path is just around the condenser. The refrigerant vapor compressed by the compressor is first flowed to the new condenser and then continue to the old condenser. The addition of valve $V_1$ to valve $V_3$ is intended to regulate the flow of refrigerant. If $V_2$ and $V_3$ are closed and $V_1$ is opened then AC runs as an old system, whereas if $V_1$ is closed and $V_2$ and $V_3$ are opened then AC operates with two condensers.

Because the new condenser will have a role as a water heater then the condenser shape needs to adjust. The condenser form in this case is a coil of copper tube of a certain length and placed in a water tank (Fig. 2). The waste heat from this new condenser will be absorbed by water so that the water temperature eventually rises to a certain level.

To obtain AC performance it is necessary to test and measure temperature and pressure at terminals 1, 2, 3, 4 and 5. The installation of temperature and pressure instruments at the five points is related to the data acquisition. The test of the air conditioning system is done by two modes: first mode test with single condenser (valve $V_1$ opened and two other valves closed) and second mode test with double condenser (valve $V_1$ closed and two other valves opened). From both modes, the temperature and pressure variables are measured through the data acquisition. Temperature sensor using LM35 and signal conditioner is Labjack U3-LV [3].

After getting the steady state variable then AC performance is calculated. AC performance is expressed by COP (coefficient of performance) and PF values. The equation for calculating COP and PF is expressed by equations (1) and (2).

$$COP = \frac{Q_E}{W_C}, \tag{1}$$

$$PF = \frac{Q_C}{W_C}. \tag{2}$$

The heat of the evaporator, the heat of old condenser and the new condenser are calculated by equations (3)–(5).

$$Q_E = h_{1,(P,T)} - h_{5,(P,T)}, \tag{3}$$

$$Q_{C,old} = h_{3,(P,T)} - h_{4,(P,T)}, \tag{4}$$

$$Q_{C,new} = h_{2,(P,T)} - h_{3,(P,T)}. \tag{5}$$

Work of compressor is calculated by equation (6).

$$W_C = h_{2,(P,T)} - h_{1,(P,T)}. \tag{6}$$

## 3 Results and discussion

The histories of temperature measurement during first and second mode of testing are shown in Figures 4 and 5. The temperature history in the five terminals can be read from the graph. After 20 min, the temperature reading tends to be constant and the system is in steady state. 40 liters water temperatures rise slowly from the time the AC is switched on to a temperature of 69 °C. Water temperatures achieved are very significant and can be used for warm baths.

The temperature measurement history of Figures 4 and 5 is further processed to identify the average temperature at terminals 1–5 when steady. The mean values of the temperature measurements are presented in Table 1 and Table 2. In addition the average compressor discharge pressure reading is also presented. Pressure at the compressor suction is not measured as it is considered a saturated vapor state at a temperature of $T_1$. Saturation pressure of refrigerant increased when the second mode operation compared to the first mode, causing the compressor pressure ratio decreased. This causes increasing the compressor work as the rising of rejected heat by the condenser. An indication of compressor power rising is indicated by the rising of electric current required by the compressor (see Tab. 3).

The temperature and pressure measurements listed in Table 1 and Table 2 is used to find refrigerant enthalpy and entropy from the thermodynamic table [2]. In first mode test at state 1, refrigerant vapor is considered as saturated. When compressed to higher pressure (state 2), refrigerant saturated vapor change to superheated state. Process statement of refrigeration cycle may be ilustrated such as in Figure 6.

A superheated refrigerant is then condensed to become saturated liquid inside the condenser and throtthled by expansion valve to change its phase. To find refrigerant enthalpy and entropy, the state of the refrigerant has to be known first. State 1 is considered as saturated vapor and enthalpy will be found refer to measured temperature. State 2 is superheated which enthalpy and entropy is found refers to measured temperature and pressure. State 4 is considered as saturated liquid and state 5 is mixed phase which enthapy similar with enthalpy at state 4.

The installation of a new condenser on the path after compressor affects the addition of heat dissipation area from refrigerant to the environment. But the heat of the

**Fig. 2.** Copper coil of new condenser.

**Fig. 3.** Modified AC system with a new condenser.

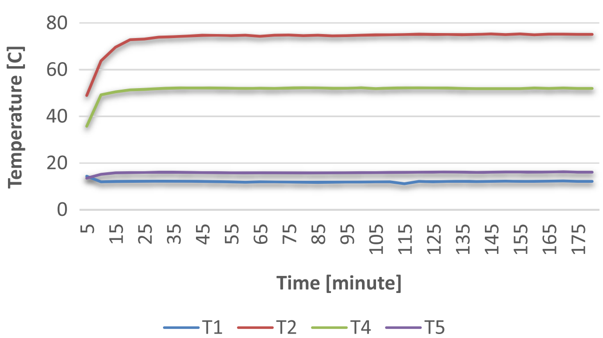


**Fig. 4.** History of temperature measurement in first mode testing.

**Table 1.** The measured average temperature and pressure of refrigerant in the first mode test.

| $T_1$ (°C) | $T_2$ (°C) | $T_4$ (°C) | $T_5$ (°C) | $P_2$ (psig) |
|---|---|---|---|---|
| 12.16 | 75.15 | 51.97 | 16.12 | 315 |

**Table 2.** The measured average temperature and pressure of refrigerant in the second mode test.

| $T_1$ (°C) | $T_2$ (°C) | $T_3$ (°C) | $T_4$ (°C) | $T_5$ (°C) | $T_{water}$ (°C) | $P_2$ (psig) |
|---|---|---|---|---|---|---|
| 12.51 | 73.21 | 57.66 | 48.86 | 18.90 | 69.79 | 310 |

**Table 3.** The compressor electricity variables measurement.

| Before modification | | | After modification | | |
|---|---|---|---|---|---|
| Voltage | Amperage | Cos phi | Voltage | Amperage | Cos phi |
| 222.3 | 7.867 | 0.8 | 222.5 | 8.143 | 0.8 [4] |

new condenser does not make the refrigerant in it condensed. Condensation will occur in the old condenser. In general, there is a change in AC performance after modification by adding a new condenser. Summary of AC performance before and after modification is presented in Table 4. The AC performance calculation refers to equations (1)–(6).

From the experiment, an increase in compressor power consumption is 4.3% after adding a new condenser and refrigerant R22. The increase in power consumption is not too significant compared to the attainable hot water temperature. Also seen that the value of condenser Performance Factor increase from 5.8 to 6.25 or by 7.8%.

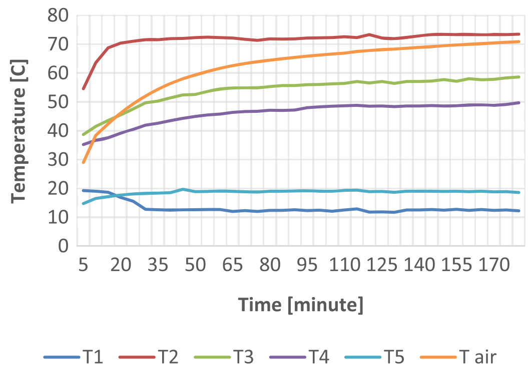


**Fig. 5.** History of temperature measurement in second mode testing.

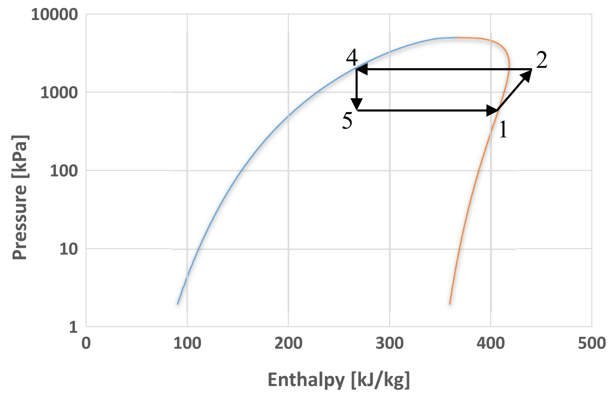


**Fig. 6.** Refrigeration cycle in Temperature – Entropy diagram.

**Table 4.** AC performance comparison before and after modification.

| No | Parameters | Before modification | After modification |
|---|---|---|---|
| 1 | Compressor actual power ($W_{C,\text{actual}}$) | 1.39 kW | 1.45 kW |
| 2 | Compressor ideal power ($W_{C,\text{ideal}}$) | 1.37 kW | 1.44 kW |
| 3 | Refrigerant flow rate ($\dot{m}_{\text{ref}}$) | 0.0460 kg/s | 0.0512 kg/s |
| 4 | Compresor isentropic efficiency ($\eta_{\text{isent}}$) | 0.86 | 0.92 |
| 5 | Heat rejected by old condenser ($Q_{C,\text{old}}$) | 7.99 kW | 8.18 kW |
| 6 | Heat rejected by new condenser ($Q_{C,\text{new}}$) | – | 0.83 kW |
| 7 | Performance factor of old condenser ($\text{PF}_{\text{old}}$) | 5.80 | 5.68 |
| 8 | Performance factor of new condenser ($\text{PF}_{\text{new}}$) | – | 0.57 |

## 4 Conclusion

- Waste heat harvesting from the condenser has been successfully conducted by installing a new coil condenser in existing AC system.
- The waste heat that was successfully harvested through the new condenser is 10.4%. The 40 L water temperature rise up to 69 °C.
- Compressor power consumption increases by 4.3% is accompanied by an increase in Performance Factor of 7.8%.

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