Topic A1.Building energy demand and energy performance of buildings, systems, and components

Study on the Selection of home-use Air Conditioners
- COP Measurements of Air Conditioners on 2013 model year –

Xinjie Wen[1],Sin-ichi Akabayashi[2],Jun Sakaguchi[3],Yasuo Takano[1] and Yuki Arinami[4]

[1] Division of Science and Technology, Graduate School of Niigata Univ.,Niigata, JAPAN
[2] Prof.,Division of Science and Technology, Graduate School of Niigata Univ.,Niigata, JAPAN
[3] Prof.,Faculty of International Studies and Regional Development, University of Niigata Prefecture, Niigata, JAPAN
[4] JSPS Research Fellow,Graduate School of Science and Technology,Niigata Univ., Niigata, JAPAN

E-mail: akabayas@cc.niigata-u.ac.jp

Keywords: Home-use air conditioner, COP, COP MATRIX , Heating and cooling load, outdoor temperature

SUMMARY

Selection of home-use air conditioner according to room floorage is a common in Japan. It is better not to method for high insulated house, because cooling and heating load is too large due to air conditioner part-load operation in intermediate seasons. A COP (Coefficient Of Performance) of a heat pump device varies significantly according to heating and cooling load and ambient temperature. It is very important for a selection method which is considered by the house thermal performance and local weather conditions.
In this paper, the calorie meter which can carry out temperature adjustment is manufactured, and analyzed the relationship of COP , heating and cooling load and outside air temperature using the calorie meter. COP is obtained by dividing the enthalpy difference on inlet and outlet of inside air conditioner unit by the electric power consumption of air-conditioner. We constructed "COP MATRIX" using the database which is measurement results.
For energy saving, the multiple air conditioners better than a single which corresponds rated capacity with peak heating and cooling load. COP of cooling is higher when outdoor temperature is relatively low. COP of heating is higher when outdoor air temperature is relatively high. There is a tendency for COP to rise as wind velocity of inside unit outlet increases.

INTRODUCTION

Residential use accounts for 14% (The Agency for Natural Resources and Energy in the Ministry of Economy of the energy consumption in Japan), and this is predicted to continue to grow due to the pursuit of a comfortable indoor environment and the popularity of domestic appliances. In the residential sector, the consumption of heating and cooling resources is relatively higher than in other sectors. As a result, it is important to improve the thermal performance of housing and the performance of air conditioners. As the Coefficient of Performance (COP) of heat pump devices varies significantly according to the heating and cooling load and ambient temperature, when selecting a suitable device, it is very important to take into account the thermal performance of the house and the local weather conditions.

It is common to select a home-use air conditioners according to the size of the house (The heaing and cooling load value per unit floor area from 1964 has not been revised, and is still used in the case of the present air-conditioner selection (heating load standard physical unit: 275W/m^2). However, this is not the best method for highly insulated houses and leads to problems for energy conservation.
In this study, we developed a calorie meter to carry out temperature adjustment, and used it in analysis of the relationships among COP, heating and cooling load and outside air temperature. COP is obtained by dividing the enthalpy difference between inlet and outlet of inside air conditioner units by the electric power consumption of the air-conditioner. We constructed "COP MATRIX" using a database of the measurement results. Furthermore, heat load calculation was performed using the insulation efficiency and the local condition of detached housing as analysis variables. As a result of the heat load, annual COP is computed through correlation with the created "COP MATRIX". The annual average COP is compared with the catalogue APF (Annual Performance Factor : one of the efficiency index value of air conditioner in Japan), in order to clarify the characteristics of domestic air-conditioners taking into account local conditions and heat load conditions.

RESEARCH METHODS

Catalogue study

We compared the rating ability, power consumption and rating COP of domestic air conditioners (2013 model) from the catalogues of 9 major manufacturers in Japan.

Calorie meter

Table 1 shows the specifications of home-use air conditioners manufactured by Manufacturer P. Figure 1 shows a summary of the calorie meter. The indoor chamber of the calorie meter is 3 m wide, 3 m deep, and 2.7 m high. The outdoor chamber is 2 m wide, 2 m deep, and 2 m high. The wall of chamber is constructed of 60-mm high-performance insulation material and plywood panels. In each chamber, an air-conditioning system for temperature adjustment is installed.
In this study, the air-conditioner for experiments is assumed to be a maximum performance model (rated cooling capacity: 7.1 kW, rated heating capacity: 8.5 kW) as shown in Table 2. One temperature and humidity sensor (Temperature resolution: 0.1℃, humidity resolution: 0.1%, temperature-survey accuracy: 0~35.0℃ ±0.5℃, 35.1~70.0℃ ±1.0℃, hygrometry accuracy: Although based on the measurement temperature and relative humidity, it is ±5~10% in general) and one thermistor anemometer (By an exploratory experiment, the relationship between the blowing air volume and wind suction port is measured in order to calculate the process air volume from the suction port wind speed) are installed in the inlet of the inside air conditioner unit. Two temperature-and-humidity sensors are installed in the outlet of the inside air conditioner unit. One temperature-and-humidity sensors are installed in the inlet of the outside air conditioner unit, the temperature at this point is the outside temperature. Furthermore, in order to examine experimental accuracy, two thermo couples are separately installed in the inlet and three thermo couples are separately installed in the outlet of the inside air conditioner unit.
To calculate the COP, the inside air conditioner temperature uses the average value of the value measured by the temperature-and-relative-humidity sensor and the thermo couple. COP measurement of the air-conditioner is performed by domestic air-conditioner COP simplified assay. The amount of wind of the measured air-conditioner was assumed to be 4(maximum quantity of wind) of wind, and the amount 3.

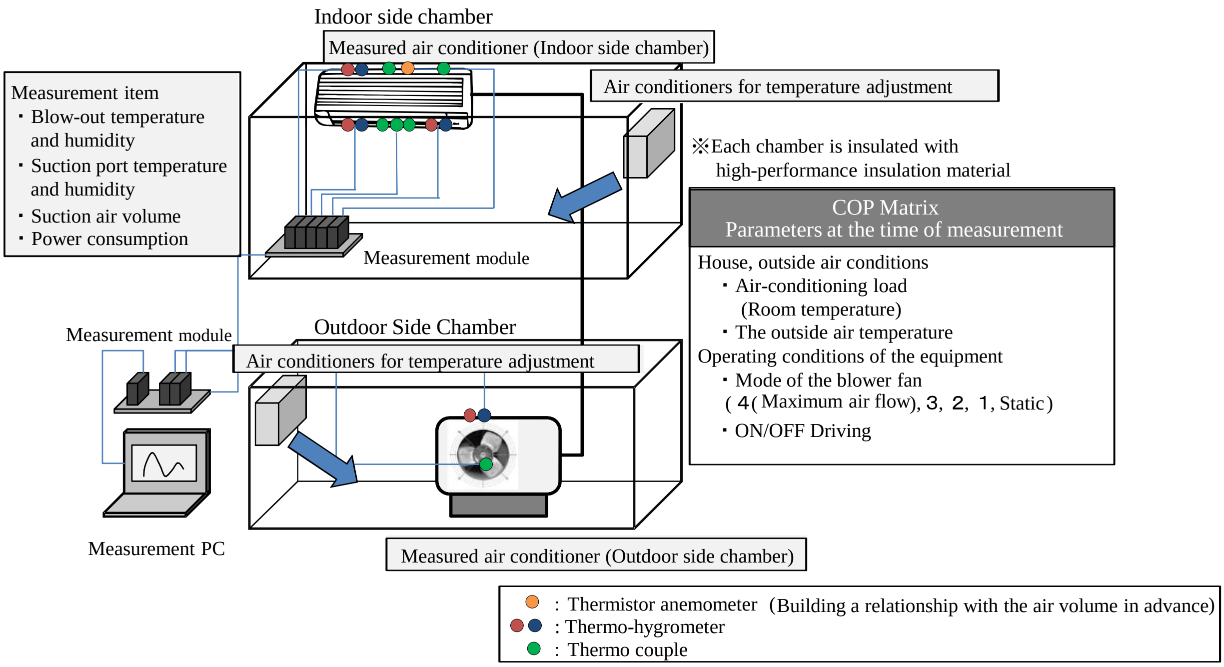

Figure 1. Summary of calorie meter

Table 1. Specification of home-use air conditioners made from Manufacturer P

Manufacturer	Performance								Indoor Unit Size			Outdoor Unit Size			Mass		Power Supply	
	Rated Cooling Capability [kW]	Cooling Rating Consumption Electricity [W]	Rated Cooling COP[-]	Rated Heating Capability [kW]	Heating Rating Consumption Electricity [W]	Rated Heating COP[-]	APF [-]	Period Power Consumption [kWh]	Width [mm]	Depth [mm]	Height[mm]	Width [mm]	Depth [mm]	Height[mm]	Interior [kg]	Exterior [kg]	Phase	Voltage [V]
Company P	2.2	395	5.6	2.5	420	6.0	7.2	612	798	287	295	619	299	619	15.0	38.0	Single Phase	100
	2.8	585	4.8	3.6	710	5.1	7.0	802				799			14.0	39.0		
	4.0	1,010	4.0	5.0	1,025	4.9	6.7	1,196								43.0		200
	5.6	2,190	2.6	6.7	1,720	4.0	5.6	2,004										
	7.1	2,990	2.4	8.5	2,630	3.2	4.9	2,903										

COP and APF Equations

$$COP = \frac{\Delta H \times (F \times \rho)}{W}$$

ΔH is the enthalpy difference on inlet and outlet of inside air conditioner unit [kJ/kg]
F is processing air volume of Air conditioning [m^3/s]
ρ is Air density [kg/m^3]
W is electric power consumption [kW]

Annual Performance Factor (APF) is the one of the efficiency index value of air conditioner in Japan based on the standard called "JIS C 9612" as defined in Japanese Industrial Standard (JIS).The APF shows the operation efficiency of the air conditioner in one year in Tokyo.

$$APF = \frac{a+b}{c}$$

a is the sum of the required cooling capacity in one year [kWh]
b is the sum of the required heating capacity in one year [kWh]
c is the sum of the required electric power consumption of cooling and heating [kWh]

The creation method of a COP matrix

A COP matrix is created from the relationship of COP, heating and cooling load and outside air temperature. COP plots in a COP matrix every 0.1 degree of outside air temperature, and output 0.1 kW from each measurement result. The points without a measurement result are interpolated by regression from the surrounding values.

The calculation method of COP

Figure 2 shows the Standard Model issued by the Architectural Institute of Japan. Table 2 shows the thermal load calculation conditions. Table 3 shows a summary of each analysis. In order to consider the change of annual COP, analysis was performed by changing the insulation efficiency according to the Standard Model issued by the Architectural Institute of Japan. We set the object city regions as Tokyo and Niigata, and used the meteorological data of the Architectural Institute of Japan extended AMEDAS meteorological data. Analysis was performed with the heat load calculation in 12 cases as shown in Table 4 by heat load simulation software TRNSYS. Annual COP was calculated by collation with the computed COP matrix, which was measured by the outside air temperature each time for the standard meteorological data.

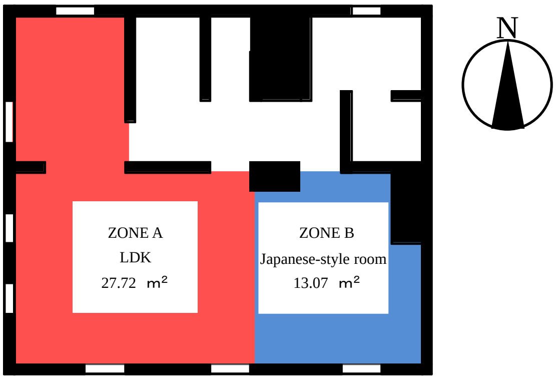

Figure 2. Standard Model issued by the Architectural Institute of Japan

Table 2. Thermal load calculation conditions

Item		Setting	Note
Set Cooling Temperature [℃]		27	
Set Cooling Humidity [%]		50	
Set Heating Temperature [℃]		20	
Set heating Humidity [%]		50	
Heating and Cooling Period	Cooling	From the third day on which the average outside temperature exceeds 22℃ and until the third day before the average air temperature exceeds 22℃	JIS C 9612 Conditions
	Heating	From the third day on which the average outside temperature is 14℃ or below and until the third day before the average air temperature exceeds 14℃	JIS C 9612 Conditions
Heating and Cooling Load Conditions Occur	Cooling	Outside air temperature is 24℃ or more	JIS C 9612 Conditions
	Heating	Outside air temperature is 17℃ or less	JIS C 9612 Conditions
Air-conditioning System		Time zone air conditioning	6:00-23:59
Personnel Number		3	Father,Mothor,1 Child
Target Housing Model		Standard Model issued by the Architectural Institute of Japan	
Air Conditioning Installation Rated Capacity [kW]	Cooling	7.1	Catalog Aim：32m³
	Heating	8.5	Catalog Aim：31m³
Air conditioning Air Flow [m^3/min]		19.5	Air flow 4 (maximum air volume)

Table 3. Summary of analysis

Case Analysis	Target Area	ZONE	Heat Loss Coefficient[W/m^2 · K]
Case 1-1	Tokyo	A	10.06 Comparable to the conditions JIS C 9612 (Target value: maximum heating load 275W/m2)
Case 1-2	Niigata		
Case 2-1	Tokyo	A+B	
Case 2-2	Niigata		
Case 3-1	Tokyo	A	5.05 And next-generation energy-saving standards Intermediate conditions of 9612 conditions JIS C
Case 3-2	Niigata		
Case 4-1	Tokyo	A+B	
Case 4-2	Niigata		
Case 5-1	Tokyo	A	2.00 And next-generation energy-saving standards of Niigata Conditions that meet the : (2.7W/m2 · K. region IV)
Case 5-2	Niigata		
Case 6-1	Tokyo	A+B	
Case 6-2	Niigata		

RESULTS AND DISCUSSION

Analysis results of catalogue study

Figure 3 shows the relation between the rated capability and the average rating COP (2013 year model). The average rated COP of heating and cooling tends to fall with the rise of rated capability. If the rated capability goes up by about 2, the average rated COP will fall by about 1.2. Two or more small models of efficient rated capability are installed in a room with a relatively large heating and cooling load, COP may become high as compared with the case where one big air-conditioner is installed. For energy saving, the multiple air conditioners better than a single which corresponds rated capacity with peak heating and cooling load.

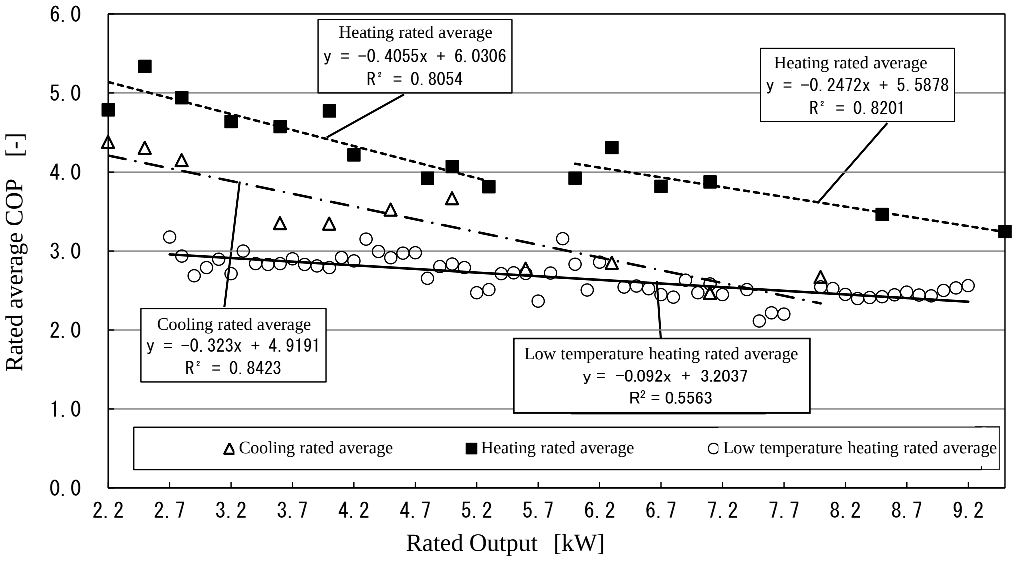

Figure 3. Relation between rated capability and the average rating COP (2013 year model)

COP matrix measurement result

Figure 4 shows the COP matrix (heating and cooling, wind velocity 3). Figure 5 shows the COP matrix (heating and cooling, wind velocity 4).The COP of cooling is higher when the outdoor temperature is relatively low. The COP of heating is higher when the outdoor air temperature is relatively high. Moreover, there is a tendency for COP to rise as the wind velocity of the inside unit outlet increases. This is probably because when the wind speed passing through the heat exchanger is high, the convection heat transfer coefficient increases, and the heat exchange efficiency of the heat exchanger is increased

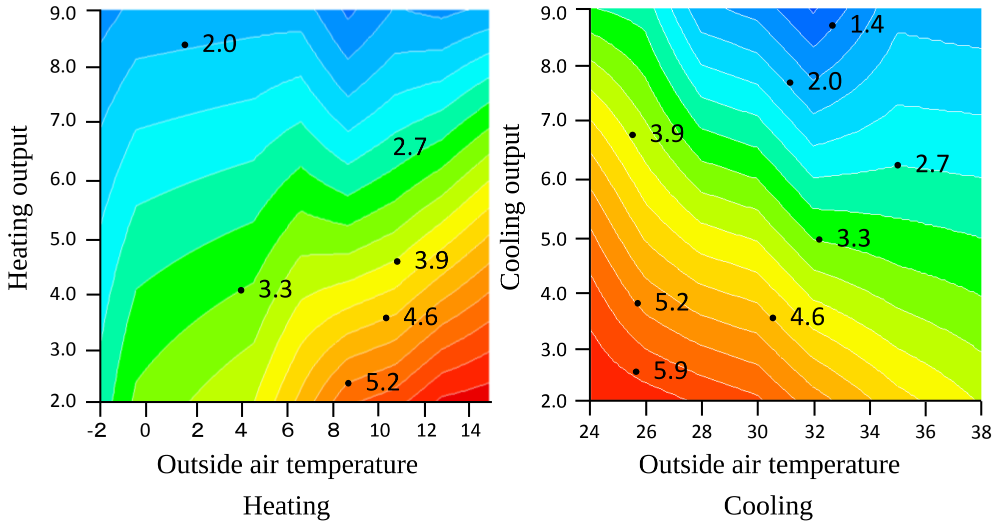

Figure 4. COP matrix (heating and cooling, wind velocity 3)

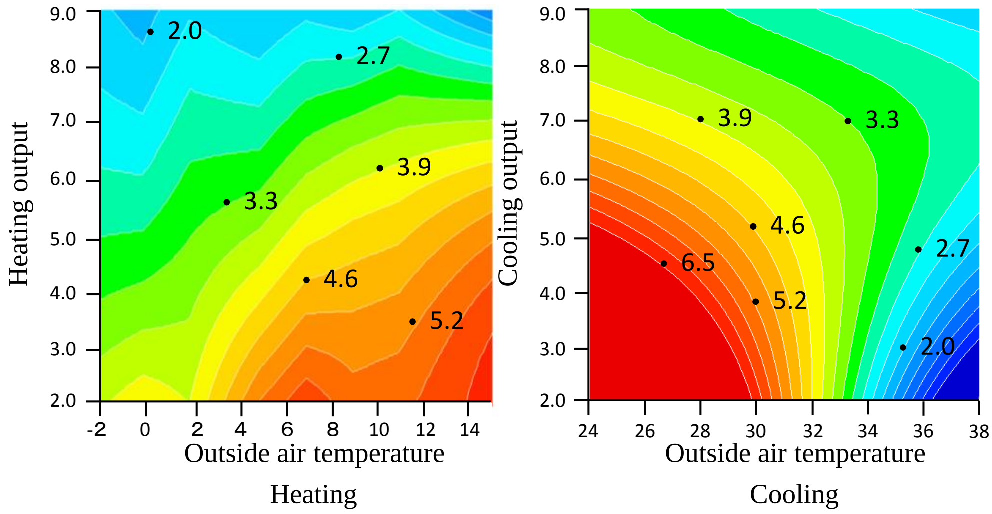

Figure 5. COP matrix (heating and cooling, wind velocity 4)

Analysis results of annual COP

Figure 6 shows the annual COP when changing the insulation efficiency. The annual COP of heating and cooling is lower when the insulation efficiency is relatively high. This is probably because the frequency of the ON / OFF (When the heating and cooling load is 3 kW or less, an air-conditioner presupposes that ON/OFF operation is performed. The COP in that case changes with the outside air temperature, and when the outside air temperature is 32℃, the cooling COP is 2.3,when the outside air temperature is 11℃, the heating COP is 2.3)operation is increased in the case where the heating and cooling load is low because the heat insulating performance is improved. Although the catalog APF of the air-conditioner for the experiment is 4.9, the annual average COP of Case2-1 (Tokyo) and Case2-2 (Niigata) is about 3.7 and about 3.6, both of which are insulation efficient compared to the APF calculation conditions; the analysis results of annual COP is about 1.2 lower than that in the Catalogue APF. Although the age multiplication amount of used electricity in the Catalogue is about 2900 kWh, that computed from COP by the COP MATRIX in Case2-1 (Tokyo) is about 3600kWh, which is about 700 kWh years difference.

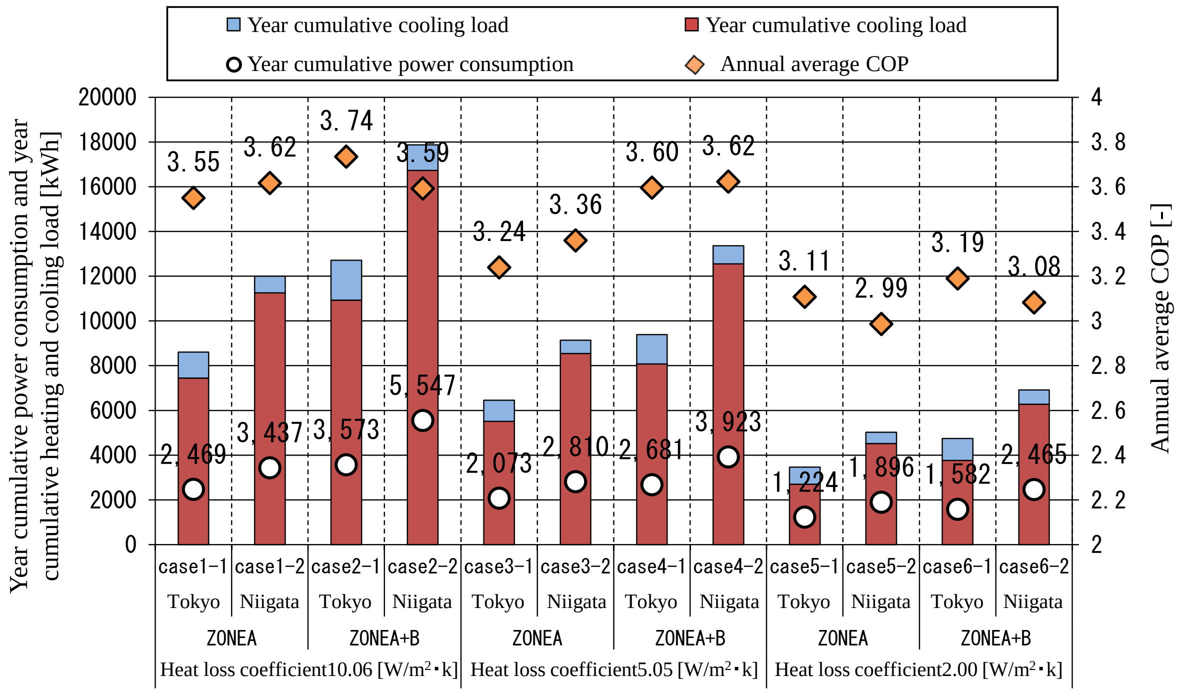

Figure 6. Annual COP when changing insulation efficiency

CONCLUSION

From the catalog study we know that the average rated COP of heating and cooling tends to fall with the rise of rated capability. If the rated capability goes up about two-fold, the average rated COP will fall by about 1.2. For energy saving, the multiple air conditioners better than a single which corresponds rated capacity with peak heating and cooling load.

From the results of COP MATRIX we know that COP of cooling is higher when outdoor temperature is relatively low. The COP of heating is higher when the outdoor air temperature is relatively high. And there is a tendency for COP to rise as the wind velocity of the inside unit outlet increases.

Although the age multiplication amount of used electricity in the Catalogue is about 2900 kWh, that computed from COP by the COP matrix in Case2-1 (Tokyo) is about 3600kWh, which is about 700 kWh years difference.

The annual COP of heating and cooling is lower when the insulation efficiency is relatively high. This is probably because the frequency of the ON / OFF (When the heating and cooling load is 3 kW or less, an air-conditioner presupposes that ON/OFF operation is performed.

REFERENCE

Akabayashi S, Sakaguchi J, Sato S, and Asama H 2005 “COP measurement of an air-conditioner is performed by home air-conditioner COP simplified assay” *Architectural Institute of Japan Technical Reports* 22 315-18