Study on Window operation advisor for efficient cross ventilation use

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ABSTRACT

The summer climate in Japan is hot and humid, and natural ventilation has long been used for cooling in individual homes.

However, there has been a recent trend for families to measure the heat using air conditioning rather than natural ventilation. Although the use of an air conditioner can easily create a comfortable thermal environment, various problems exist with dependence on air conditioning.

Therefore, we thought that we could solve these problems by natural ventilation and developed the "Window operation advisor." This device encourages residents to make appropriate use of natural ventilation and air conditioning.

We examined the most effective method for giving a resident advice on opening and closing windows by using a monitoring experiment, simulation, and experiment imitating the behavior of the residents in an experimental house. We confirmed that the air conditioner use time and air conditioner heat load were reduced by increasing the time that windows were open.

In addition, there was a problem with a rise in room temperature with open windows, but we were able to solve it by comparing the quantity of cooling of the natural ventilation with the air conditioner.

These examinations showed the effectiveness of using natural ventilation and the usefulness of the developed Window operation advisor.

KEYWORDS

Window operation advisor, natural ventilation, air conditioner

INTRODUCTION

Background and purpose of study

In the summer, people sometimes do not notice that it is cool outside and continue to run the air conditioner. The "Window operation advisor" which we developed, is a device that encourages residents to make appropriate use of natural ventilation. Specifically, the device gives advice about effective window opening and closing, air-conditioner usage, and the outdoor air situation for residents. In this way, it

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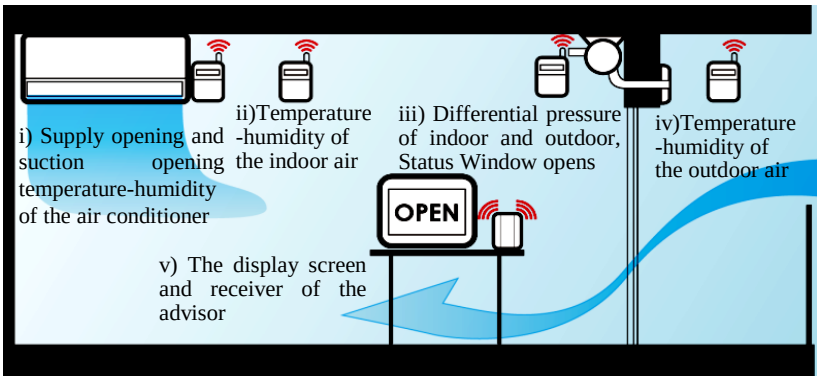
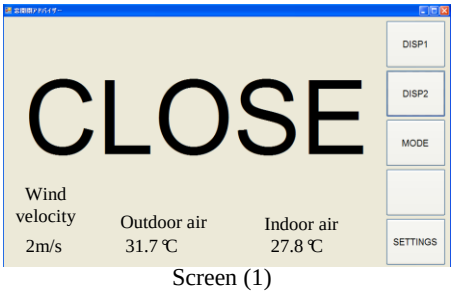
encourages the use of natural ventilation in a way that achieves both comfort and energy saving.
The purpose of this study is to develop the judgment logic of the methods for opening and closing windows and the usage of the air conditioner for the practical use of the device.

Description of Window operation advisor

First, the device measures the temperature and humidity indoors and outdoors, along with the differential pressure indoors and outdoors using wireless data loggers, and downloads this information to a computer.
Based on the governing logic, the device is displayed on the screen, showing methods of opening or closing windows. (Fig 1)



i) - iv) are measurement item to use adviser. Use by a wireless-type data logger. V) Advise residents an effective method of opening and closing windows and using air conditioner received by the receiver.



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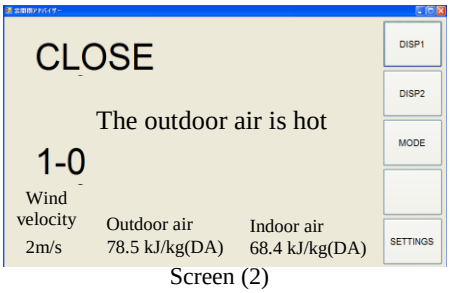

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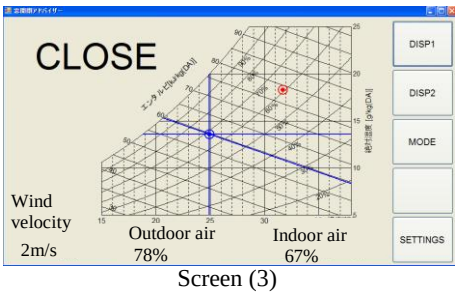

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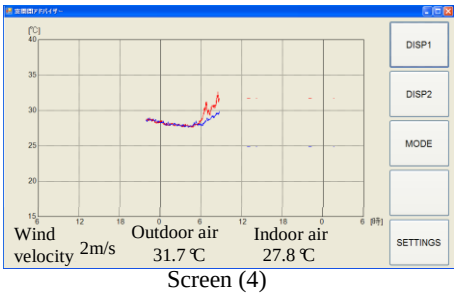


Screen (4)

The upper screen: (1)"decision to open and close windows ", (2)" sentence that gives the reason for the decision", (3)" psychrometric chart", (4) "chronological graph of the temperature indoor and outdoor for the past 2–3 days"
The lower screen: shows "temperature" "humidity" "enthalpy."

Fig 1. *Constitution and measurement item and indication screen examples of windows operation advisor*

Governing logic of window opening and closing

The first goal of the device is to advise residents about a suitable set of conditions for opening windows.This is determined by a comparison of the indoor and outdoor

temperatures, humidity, and enthalpy, taking into accounts the external wind speed. We list the assumed advice contents in Table 1.

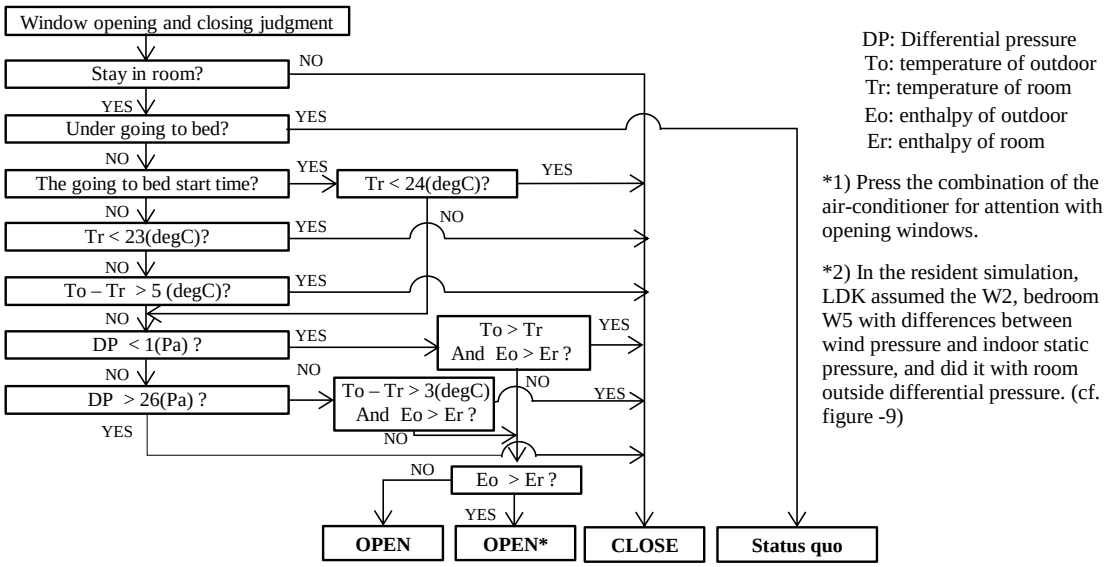


Fig 2. *Window opening and closing logic of the adviser*

Table 1. *Advice contents of the open and close window advisor*

Advice	Advice contents
1	The device judges it whether it is effective in reduction of cooling, the air conditioner load of the room when residents open windows from information such as the current temperature and humidity
2	When residents close windows and use an air conditioner, device judges it whether an indoor environment turns worse when residents shifts to open windows, and to stop an air-conditioner
3	When present of temperature of the outdoor air is cooler than temperature of the indoor air, device determines whether it is effective to use an air conditioner together with opening windows.
4	Device judges the opening in the house from what kind of combination so that colder air flows for the target room in the house whether residents should open it

MONITOR EXPERIMENT

Summary

We performed actual measurements in five houses that were inhabited for two weeks (Table 2). We had the residents live without the advice screen display for one week, in the first half of the experiment. During this time, we measured the everyday use of ventilation and air conditioning. In the second week of the experiment, an advice screen was displayed that the residents used as an advisor.

Table 2. *Summary of the measured buildings (2008)*

Case No	Case1	Case2	Case3	Case4	Case5
Measurement period	08/08-08/22	08/26-09/09	09/04-09/18	08/11-08/25	08/29-09/12
Benefit Category	detached houses	apartment house	apartment house	apartment house	detached houses
Measurement floors	2F	9F in 9F	1F in 5F	3F in 7F	2F in 3F
Structure	wooden	S	RC	RC	LGS
Age of a building	20years	12years	25years	9years	9years
Architectural area	95m^2(2F)	85m^2	93m^2	53.9m^2	52.9m^2(2F)
Location	Ome,Tokyo	Akishima,Tokyo	Tama,Tokyo	Wako,Saitama	Nerima,Tokyo
Area	Residential	Residential	residential	residential	commercial

Promotion of opening windows and its effects of reduced air conditioner use

Fig. 3 shows the percentage of time in which residents actually opened windows in response to the [OPEN] advice that they received.

In each case, in the first half, when they did not see the screen, they were much less likely to open windows than they were in the second half, when they regularly followed the instructions to open windows. The results, presented in Table 3, indicate that in the second half of the experiment, the time for which windows were kept open increased and the time for which the air conditioner was used decreased.

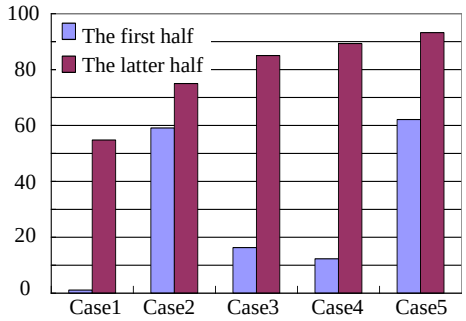


Fig 3. *The ratio that a resident opened windows when advice to open window (%)*

Table 3. *The outdoor air situation and the time windows were kept open and use air conditioner at actual measurement*

Case	Measurement period	Mean temperature (degC)		Mean humidity (%)		Temperature to stop Air-conditioner (degC)		The time to open windows (mean day) (min)	The time to use air-conditioner (mean day) (min)
		Outdoor air	Indoor air	Outdoor air	Indoor air	Outdoor air	Indoor air		
1	First : 8/8～8/15	27.6	29.5	29.5	58.3	27.2	28.0	289	351
	Latter : 8/15～8/22	25.4	27.8	27.8	61.1	29.1	28.4	551	196
2	Firs : 8/26～9/2	25.6	26.9	26.9	71.2	28.2	27.2	767	181
	Latter : 9/2～9/9	27.0	28.3	28.3	63.1	29.9	28.7	1087	257
3	First : 9/8～9/11	24.6	27.8	27.8	58.3	25.2	27.8	96	337
	Latter : 9/11～9/18	24.5	27.3	27.3	58.2	25.0	27.3	153	86
4	First : 8/11～8/17	28.9	28.7	28.7	48.7	28.7	28.2	46	1369
	Latter : 8/17～8/25	24.4	28.0	28.0	55.1	26.3	27.9	1087	269
5	First : 8/29～9/5	27.1	27.5	27.5	68.2	27.5	27.4	459	554
	Latter : 9/5～9/12	26.1	27.2	27.2	57.9	27.2	27.9	1181	224

Room temperature change after opening of window

Fig 4 shows the changes in room temperature before and after windows were opened for 1 h and the difference between the indoor and outdoor temperatures before the windows were opened based on data obtained from 79 cases. When the outside temperature was low, the windows were opened, but no effective ventilation was provided, and there were 15 cases in which the room temperature rose after the windows were opened.

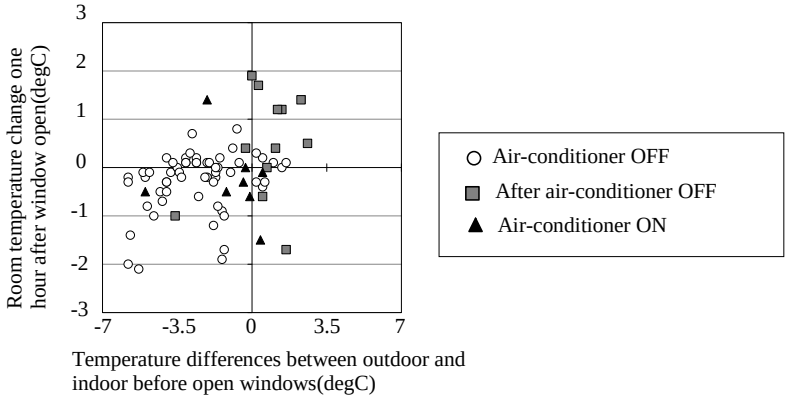


Fig 4. *Room temperature changes after window open (measurement)*

SIMULATION

Summary

We performed calculations in a heat exchange circuitry (TRNSYS, which incorporated COMIS) using weather data from June to September (Nerima) in the AMeDAS standard year, to re-examine the heat load by adding a long-term investigation under a constant climatic condition. The building targeted for our calculation is shown in Fig. 5.

We compared the "basic model," which is based on logic (Fig.6) that assumed the case of not using an advisor, with "Measurement model," which is based on the logic (Fig 2) (excluding the differential pressure evaluation item) that we used in the actual measurements. We created two types of measurement models. "Measurement model 1" opens windows in response to [OPEN*], and "Measurement model 2" closes windows in response to [OPEN*].In each model, the windows do not open when the air conditioner is in use. Based on the median of the measured data, the use of air conditioning began at a room temperature of 29 ℃ and stopped at a room temperature of 28 ℃. As a crime prevention measure, we assumed that windows would be opened by only 20 cm at bedtime. In addition, we decided not to open windows in the basic model at bedtime.

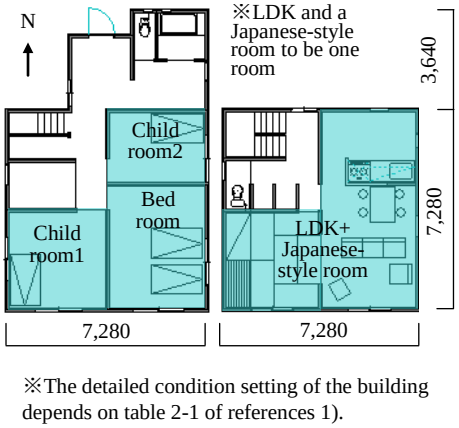


Fig 5. *House ground plan*

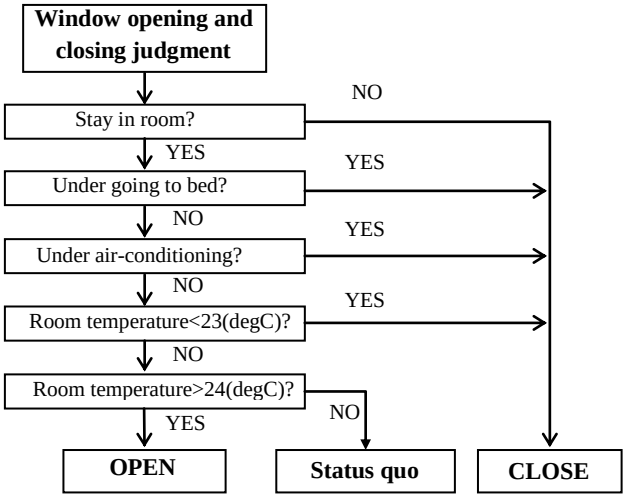


Fig 6. *Window opening and closing logic of the basic model*

Increase in time for keeping windows open and decrease in use time of air conditioner

In terms of the time that the windows were kept open in the morning when the residents were getting up, the measurement models showed an increase compared to the basic model (Table 4).Because the actual measurement models might open windows during the night for the entire period, the number of hours for which windows were kept open increased. We compared the air conditioner use by the measurement models with that by the basic model. With the windows open and a cooling effect produced by the increase in time that windows remained open, the time that the air-conditioner was in use in the measurement model was considerably reduced (Fig 7).

Table 4. *Increase the time windows were kept open and reduce the time the air-conditioner was used*

Model	Multiplication time to open windows (h)			Growth rate of the time windows were open at wake-up time	Multiplication time air conditioner was used (h)	Reduction rate of the time air conditioner was used
	Wake-up time	Bedtime	total			
Basic	609.3	−	609.3	(Standard)	722.3	(Standard)
Measurement1	867.5	375.3	1242.8	42.4%	374.0	48.2%
Measurement2	634.8	294.3	929.0	4.2%	441.5	38.9%

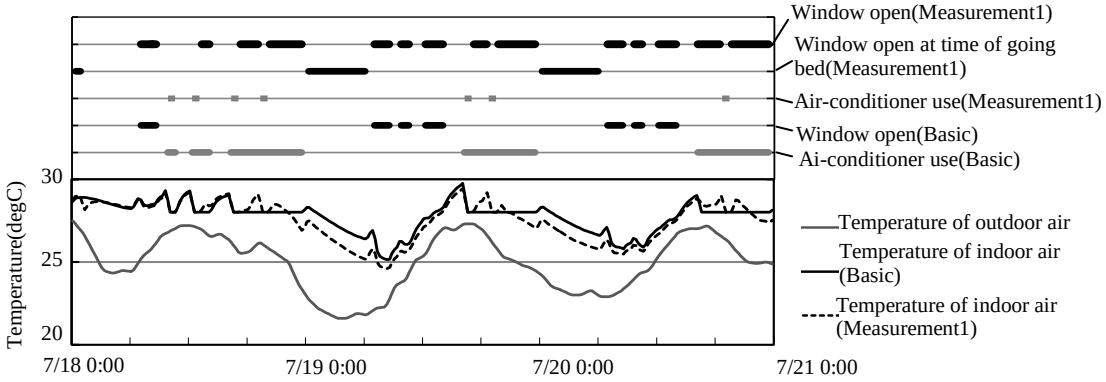


Fig 7. *Increase of the time to open windows and shortening of the time to use air-conditioner (2008/8/18~20)*

Effect of air-conditioner load reduction

A comparison shows that the entire heating load was reduced when the basic model was used than the heating load when Measurement models 1and 2 were used. In Measurement model 1, the sensible heat load was reduced as compared to the basic model, while in Measurement model 2, the latent heat load was reduced. It was confirmed that the logic that incorporated enthalpy produced the load reduction effect (Table 5).

Table 5. *Multiplication heat load and heat load decrease rate of the air-conditioner*

Model	Multiple air-conditioner heat load			Change rate of air-conditioner heat load		
	Sensible	Latent	Total	Sensible	Latent	Total
Basic	4450	1696	6146	(Standard)	(Standard)	(Standard)
Measurement1	3481	2078	5559	21.8%	-22.5%	9.6%
Measurement2	3952	1520	5472	11.2%	10.4%	11.0%

EXPERIMENT IMITATING BEHAVIOR OF RESIDENTS

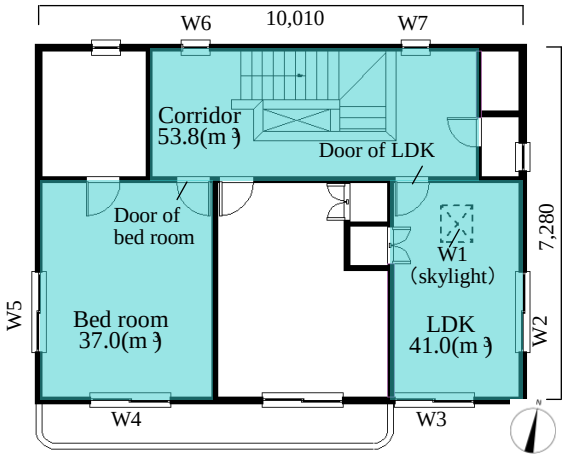
Summary

In the experimental house (Fig 8, Table 6), a total of 12 measurements were taken from August 31 to September 21, 2009, measuring the items shown in Table 7.

We did from 11:00 to 15:40 with absence time, from 22:00 to 8:00 with going to bed time and other time with at-home time and we gave internal fever.

Table 6. *Building summary of the experiment house (2009)*

Building category	Architectural area	Total of floor area	2F of floor area	Number of floors of a building	Measurement floor	Structure	Location	Ambient environment
detached house	71.79 (m²)	136.02 (m²)	71.79 (m²)	2F above the ground	2F	Wooden	Noda, Chiba	residential area



The target room in an experiment and the calculation is LDK, a bedroom, a corridor. The opening for the opening and closing assumed it window 1～7 and bedroom and LDK inside door. Other windows, doors assumed it closed at all times.
W: windows for the opening and closing

Fig 8. *Experimental house ground plan*

Table 7. *Measurement contents*

Measurement items
Temperature-humidity of the indoor and outdoor air
Wind pressure of windows side, Indoor static pressure
Direction of the wind of the roof, Outdoor wind velocity (Framework of a house 2m)
Indoor wind velocity
Drain of air-conditioner
Consumption electricity of the air-conditioner
amount of solar radiation
Supply opening and suction opening temperature-humidity of the air-conditioner
Wind velocity of air-conditioner
Opening and closing situation of the openings

Window opening and closing, and governing logic of air-conditioner use

The governing logic of air conditioner use (Fig 9) was designed to solve the problem of the rise in room temperature rose after the air conditioner was stopped and the windows were opened.

We incorporated logic to govern the use of the air conditioner by comparing the quantity of cooling provided by the ventilation that was assumed when the resident opened windows with the quantity of cooling provided by the air conditioner when the resident closed windows and used an air-conditioner.

First, the advisor uses judgment logic of air-conditioner use, and ends this judgment when it is judged that the "air-conditioner OFF window OPEN" direction is given. In the other cases, it shifts to an evaluation of windows opening and closing (Fig 2).

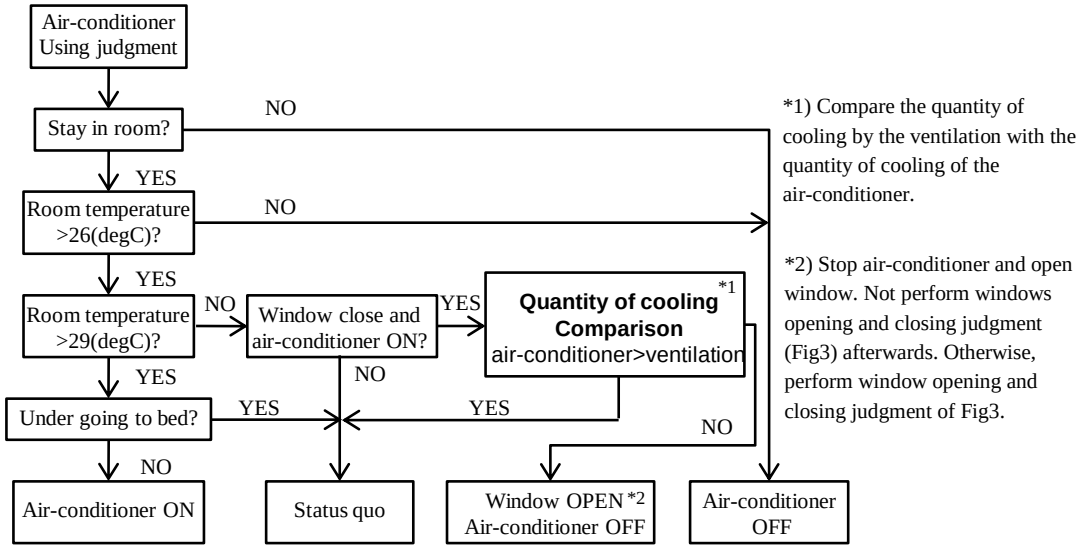


Fig 9. *Air conditioner use judgment logic*

Ex 1. *Quantity of cooling comparison expression*

$$\rho Q \Delta h > \rho Q' \Delta h'$$

ρ：Air density　1.2 [kg/m^3]
Q：Quantity of ventilation [m^3/s]
Q'：　Air volume blow from air conditioner[m^3/s]
⊿ h：Room air E- Outdoor air E [kJ/kg(DA)]
⊿ h'：Suction opening E- Supply opening E of the air conditioner [kJ/kg(DA)]
※　E：Enthalpy

Quantity of cooling judgment

The problem (Fig 4) of the room temperature rising after the air conditioner was stopped and the windows were opened was resolved by incorporating logic (Fig 9, expression 1) to compare the quantity of cooling produced by ventilation with that produced by an air-conditioner. Then, when this logic was used, the room temperature dropped after stopping the air conditioner and opening the windows (Fig 10).

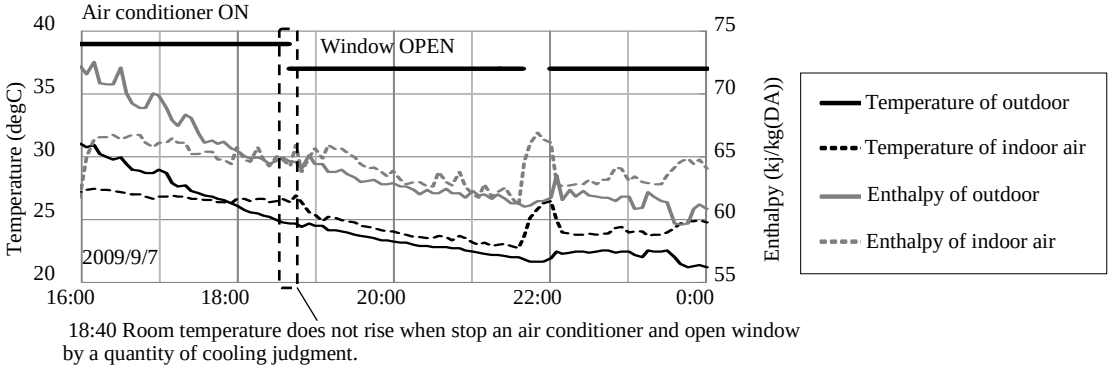


Fig 10. *Effect by stopping an air conditioner, and having opened windows*

CONCLUSION AND IMPLICATIONS

1) Monitor experiment: The advisor advised a resident to open a window, and the results were able to confirm the effect of reducing the air conditioner use time.
2) Simulation: When residents followed the advice of the "Window operation advisor," a load reduction effect of the air conditioner was observed.
3) Experiment imitating the behavior of the residents in the experimental house: The problem of the room temperature rising after the air conditioner was stopped and the temperature decrease upon opening windows were resolved by incorporating logic to compare the cooling produced by ventilation with that produced by the air conditioner.

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