THERMAL COMFORT CONTROL OF AIR-CONDITIONED ROOM WITH CONSIDERATION OF ENERGY SAVING

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Abstract

The effects of the rotational speeds of the air-conditioners' compressor and fan on the users' thermal comfort and energy consumption are considered in this study. To make the occupant comfortable in the least time with the least energy consumption, seven different control strategies are proposed and compared. The experiment results show that adjusting the fan speed according to the thermal comfort value can achieve the goal

Keywords: thermal comfort, energy efficiency, fuzzy control, optimum

1. Introduction

The main use of air-conditioners is to make occupants comfortable. However, the air-conditioner consumes great energy. Therefore, how to design an air-conditioner meeting occupants thermal comfort and energy saving requirments is an uppermost issue for air-conditioner designers.

The compressor speed of the conventional air-conditioners is constant and uses the on/off control. This causes big noise, serious vibration, and high energy consumption. Furthermore, the conventional air-conditioners only control the room temperature. According to ASHRAE [1-3] the most important variables which influence the condition of thermal comfort are air temperature, mean radiant temperature, humidity, air velocity, clothing insulation, and bodily heat production rate. So the conventional air-conditioners can't provide real comfortable environment.

1-1 Review of Previous Researches

There are some approaches described in [4-8] which use the thermal comfort as their control objective. McArthur [4] developed a control method based on PMV (Predicted Mean Vote) and assumed that all the six independent variables that used in PMV can be detected directly. The PMV controller designed can control the on-off status of the cooling plant to maintain comfort at the desired setpoint in the simulation. Schaetzle [5] developed a PMV based comfort index control. It evaluates occupants' comfortness according to the measurement of air-conditioned room conditions and the clothing insulation value and activity level given by the occupant. The program that utilized the expert system method controls the air-conditioner such that the PMV of the occupant's comfort status is between -1 and 0.5. Federspicl [6] modified the PMV thermal index to design a linear thermal index V and developed a user-adaptable comfort control method. This method can control the compressor speeds to make occupants comfortable. Chen [7] used the Fuzzy method to build a PMV controller under constant air velocity. According to the variation of environment conditions and thermal sensation of the user, the setpoint of temperature in the air-conditoned room can be determined by the PMV controller. Then, a temperature controller is used to adjust the speed of the compressor, such that the air-conditioned room can provide users thermal comfort. MacArthur [8] developed an optimal comfort controller based on PMV index. The control objectives are to maximize the system performance (COP) while simultaneously satisfying comfort conditions (PMV=0) and to find the optimum compressor speed and indoor airflow rate.

1-2 Motivation and Objective

Most air-conditioners with variable-speed compressor use three speeds fan. In the previous studies, the optimal comfort control with energy saving is considered under the steady state [8]. As to the effect of the fan speeds changing during the transient state was not discussed. We have proposed several fan speed control strategies based on the PMV values or temperatures. The effects of air-velocities on the time responses of thermal comfort and energy consumption are examined for a better fan speed control method.

2. Thermal Comfort and Energy Consumption

To provide the thermal comfort with consideration of energy consumption, the effect of air-conditioners' compressor and fan chould be concerned. In the following sections, first, the PMV model, a thermal comfort index, and the modified PMV model for this application are defined. Then the energy consumption of air conditioners are described in terms of energy efficiency ratio. Finally, the effects of fan speeds on the thermal comfort and energy consumption for both steady and transient states are discussed.

2-1 PMV Comfort Model

Thermal comfort is defined by Amercian Society of Heating, Refrigerating and Air conditioning Engineers (ASHRAE) as "that condition of mind in which satisfaction is expressed with the thermal environment." The most important variables which influence the condition of thermal comfort are air temperature, mean radian temperature, humidity, air velocity, clothing insulation, and bodily heat production rate. In the air-conditioned rooms, the air temperature and velocity are regulated by controlling the speeds of the compressor and fan to achieve the goal of making the occupant comfortable.

The Fanger's PMV model is used in this study. It is defined in view of the heat balance of the human body. The PMV model uses a mathematical function to describe the relationship between energy loss and metablic rate of human body. On the other hand, a psycho-physical rating scale between +3 to -3 is used to predict the comfortness of occupants. When the internal heat production in the body is greater than the loss of heat to the environment, the rating value is positive and occupants feel warm. When the internal heat production in the body is smaller than the loss of heat to the environment, the rating value is negative and occupants feel cool. The significance of PMV is

+3	hot
+2	warm
+1	slightly warm
0	neutral
−1	slightly cool
−2	cool
−3	cold

The PMV value can be calculated by the equation

$$PMV=(0.303e^{-0.036M}+0.028)\{(M-W)-3.05\times10^{-3}\times[5733-6.99(M-W)-Pa]-0.42\times[(M-W)-58.15]-1.7\times10^{-5}M(5867-Pa)-0.0014M(34-ta)-3.96\times10^{-8}f_{cl}[(t_{cl}+273)^4-(tr+273)^4]-fclhc(tcl-ta)\} \quad (1)$$

where

$t_{cl}=35.7-0.028(M-W)-I_{cl}\{3.96\times 10^{-8}f_{cl}[(t_{cl}+273)^4-tr+273)^4]+f_{cl}hc(t_{cl}-ta)\}]$

$$hc=\begin{cases} 2.38(t_{cl}-ta)^{0.25} & \text{for } h_c>12.1\sqrt{var} \\ 1212.1\sqrt{var} & \text{for } h_c<12.1\sqrt{var} \end{cases}$$

$$f_{cl}=\begin{cases} 1.00+1.290I_{cl} & \text{for } I_{cl}<0.078m^2\cdot 0OC/W \\ 1.05+0.645I_{cl} & \text{for } I_{cl}<0.078m^2\cdot 0^0C/W \end{cases}$$

The Fanger's PMV model is complex and is an implict function of the six variables affecting thermal sensation. Some assumptions are made for actual application. The simplified PMV model is a linear function of the air temperature and velocity PMV=(T,V). The assumptions made are as following.

1. The metabolic rate of occupants is constant. The occupant takes sedentary activities. The metabolic rate M=70 watt/m2.
2. Clothing insulation is constant. The occupant is dressed in light summer clothing like shirts with short sleeves. Clothing insulation Icl=0.08m2 ℃ /watt.
3. The effect of vapor pressure on the comfortness is small and can be neglected when PMV value is closed to zero.
4. The mean radiant temperature is equal to the air temperature.
5. The user stays at the same position, and the air velocity is constant at the position of the user.

Because air-conditioners have three constant fan speeds, the air velocities at the position of users are three discrete values. In this study, we assumed that the user is at the position 1.2m above the floor and 1.5m in fornt of the air conditioner. The corresponding air velocities measured are 0.39 m/sec, 0.28 m/sec and 0.2 m/sec respectively. The modified PMV equation is thus

$$PMV=\begin{cases} 0.286Ta-7.335 & \text{for } V=0.2m/s \\ 0.313Ta-8.296 & \text{for } V=0.28m/s \\ 0.344Ta-9.427 & \text{for } V=0.39m/s \end{cases}$$

2-2 Energy Consumption of The Air-Conditioner

The compressor and fan are the two major components of an air-conditioners which consume energy. The compressor provides the refrigerating capacity to cool down the air temperature of the room, and it is the primary energy consumption (about 1000 watts.) of the air conditioner. The energy consumption of variable-speed compressor is not a constant. For the normal operating frequency range, the energy consumption is in proportion to the frequency of the compressor, as Fig. 2-1 shown.

$$P = P_0 \left(\frac{N}{No} \right) \quad (3)$$

where

N_O : Rated Frequency (60HZ)

P_O : Rated Power (865Watt)

N : Frequency

P : Power

The fan is the secondary energy consumption of air-conditioner because it consumes less energy (about 100 watts.) In this study, the power consumptions of the

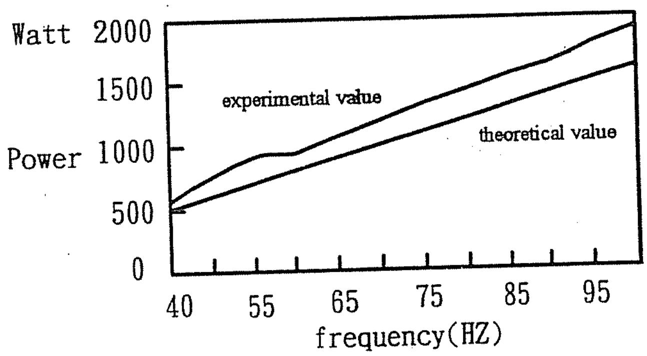


Fig. 2-1 Energy consumption as function of compressor speeds

fan are 90 watts, 84 watts and 79 watts for the three different speeds. The total energy consumption of air conditioner is the sum of the energy consumption of compressor and fan. The relationship between the energy consumption of air-conditioner and the energy efficiency ratios (EER) are

$$EER = \frac{Q_c}{P_{compressor} + P_{fan}}$$

$$Q_c = \dot{m} \times \Delta h$$

where

Q_c : Refrigerating Capacity

$\dot{m}$: Flow Rage of Mass

Δh : Difference of Enthalpy

$P_{compressor}$: Power of Compressor

P_{fan} : Power of Fan

2-3 The Effects of Air Velocity on Comfort and Energy Consumption

According to the modified PMV equation (2), we can observe that the temperatures that make PMV=0 are different for different air velocities. The temperatures are 27.4 °C for the high air velocity, 26.5 °C for the medium air velocity, and 25.6 °C for the low air velocity. However, occupants may still feel uncomfortable if the temperature of the air velocity is out of the range that can be accepted by people. On the other hand, the temperature which makes PMV=0 increases with the air velocity and the compressor speed can be lower with more energy saved. Therefore, to achieve the goal that makes occupants comfortable and saves energy in the steady state, the properly selected compressor and fan speeds are needed.

Before reaching the steady state, the air coditioned room is uncomfortable bcause air-conditioners have larger refrigerating capacity with higher air velocity such that the room temperature can decrease more quickly as Fig. 2-2 shown. So if we appropriately adjust the fan speed and compressor speed, the air-conditioned rooms can quickly reach the steady state with minum energy usage.

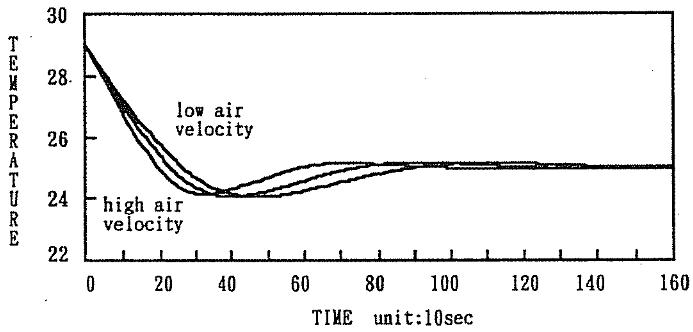


Fig 2-2 Time response of room temperature for different air velocities with same compressor speed

3. Controller

According to the analysis in the last chapter, a PMV controller is designed to determine the air temperature and velocity at the user's position for optimal thermal comfort. Then, a velocity controller for adjusting fan speed and a temperature controller for adjusting compressor speed are used such that the air-conditioned room can reach the goal state quickly with energy saving.

3-1 Steady State Control

The occupant can feel optimal thermal comfort provided the conditions of the room can meet the following terms.

1. The air temperature is between 23-26 °C.

2. The air velocity is less than 0.25 m/sec.

3. PMV=0

However, the occupant still feels uncomfortable while in extreme high or low temperature, or with very high air velocity likewise.

According to the analysis, at the occupant's position, only when the fan speed is low can the above criterions be satisfied. That is, when the HVAC system reaches the steady state, the fan has to be in the low speed and then we adjust the compressor speed to change the air temperature in order to obtain the optimal thermal comfort (PMV=0). So the air velocity usually is low and the energy consumption is the same when the HVAC system reaches the steady state.

3-2 Transient State Control

When the HVAC system is in transient states, the air-conditioned room is in an uncomfortable circumstances. It is necessary to control the compressor and fan speeds to improve the conditions of the room from the uncomfortable status to comfortable status. What we concern in this experiment is, during the transient process, how to adjust the fan speed appropriately to make the air-conditioned room reach the optimal thermal comfort status in the least time with the least energy consumption.

According to the modified PMV equation (2), the PMV values change with temperatures and the PMV vs. temperature diagram for three air velocities are as Fig. 3-1 shown. In the beginning, the room temperature is high, and the high fan speed is selected for higher cooling capacity, less energy consumption and shorter response time. However, in the final state the fan speed must be low to satisfy the comfort requirement. Therefore, how to shift the fan speed from high to low is the main concern of this study.

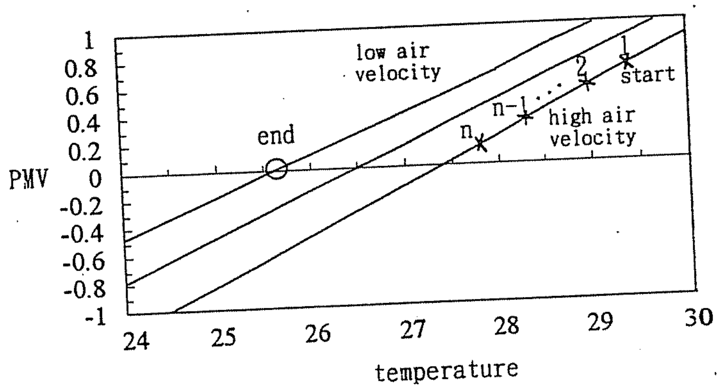


Fig. 3-1 PMV vs. temperature diagram for three air velocities

The methods we proposed are divided into two major categories. One is to adjust the fan speed based on the PMV value, and the other is based on the temperature. Described as below, the method 1 to method 5 belong to the former category, and the method 6 and 7 the latter one.

Method 1: Use PMV=0 as switching condition. As shown in Fig. 3-2, when the PMV index reaches zero, the fan speed will be switched to the lower one. This switching process continues until the designated state by the PMV controller is arrived and the fan speed remains in low. Thus, the user will not feel too cold during the transient process. However, since the method changes to low speed too early, the overall energy efficiency may not be high.

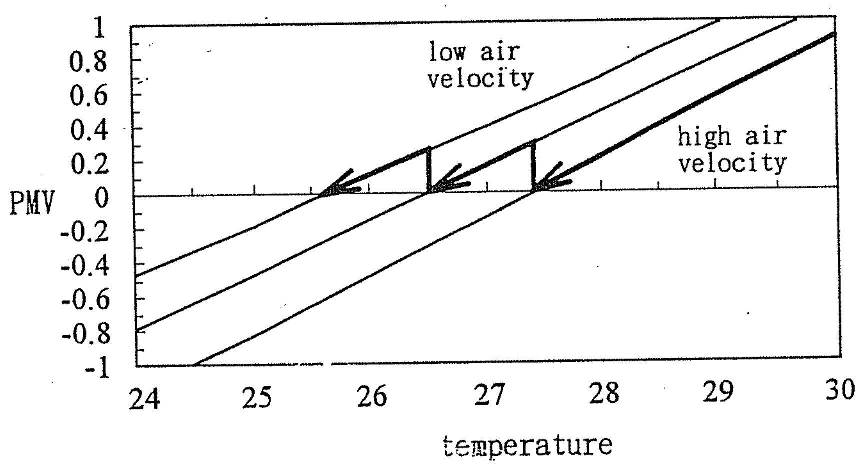


Fig. 3-2 Use PMV=0 as switching condition

Method 2: Use PMV=-0.5 as switching condition as shown in Fig. 3-3. Since most occupants do not feel much differences among the PMV value range from -0.5 to +0.5, in comparing with the method 1, this method allows more energy saving.

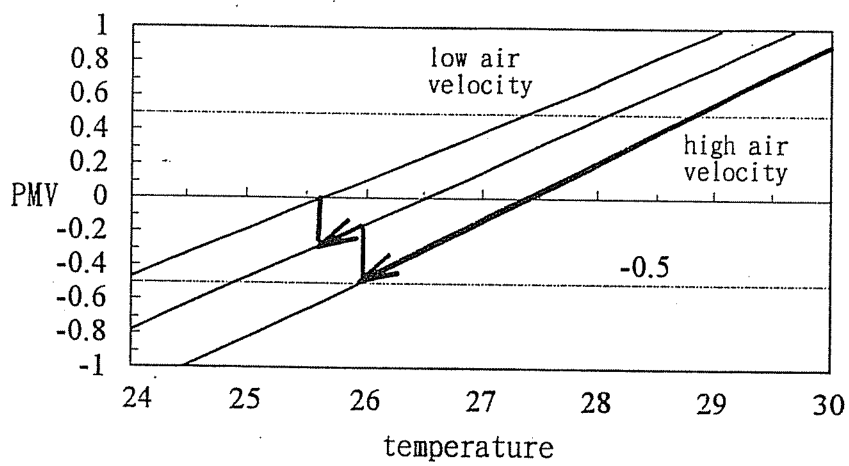


Fig. 3-3 Use PMV=-0.5 as switching condition

Method 3: Use PMV=-0.25 as switching condition as shown in Fig. 3-4. In this range, some occupants with higher demand for thermal comfort will be satisfied in additon to the ones satisfied by the method 2.

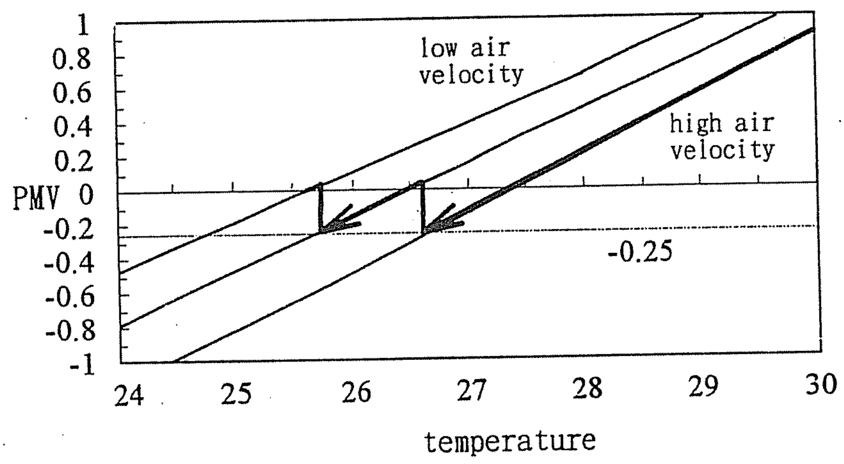


Fig. 3-4 Use PMV=-0.25 as switching condition

Method 4: Use PMV=-0.1 as switching condition as shown in Fig. 3-5. The reason why we propose the method is the same as the reason of method 3, and which can satisfy much more people than method 3.

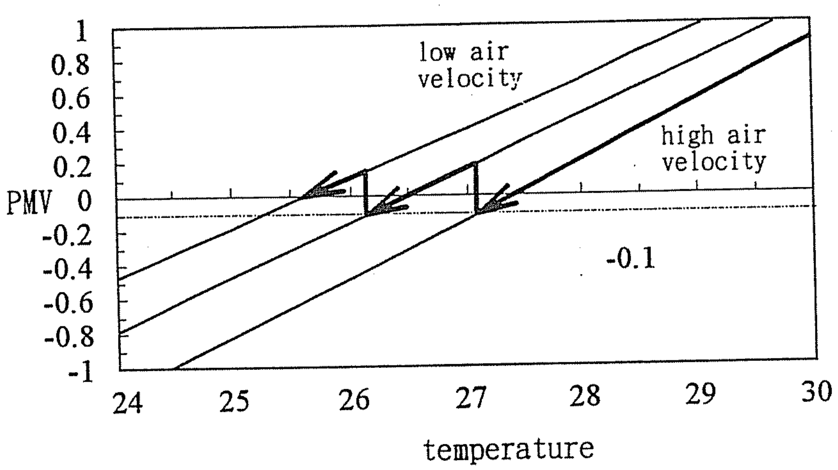


Fig. 3-5 Use PMV=-0.1 as switching condition

Method 5: The switching condition is when the absolute PMV vales are the same for different air velocities as Fig. 3-6 shown. By using the method to adjust the fan speed, the value of PMV will oscillate around zero.

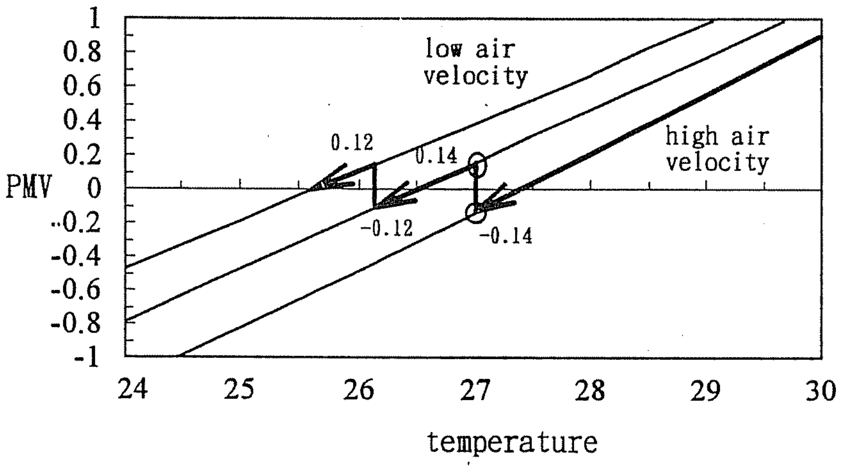


Fig. 3-6 Use equal absolute PMV values as switching condition

Method 6: Use the designated temperature (in our case, 25.6 °C) as switching condition as Fig. 3-7 shown. When the room temperature is high in the beginning, we select high fan speed to operate the air-conditioner. Until the temperature reaches 25.6 °C and then we change the high fan speed to the low fan speed.

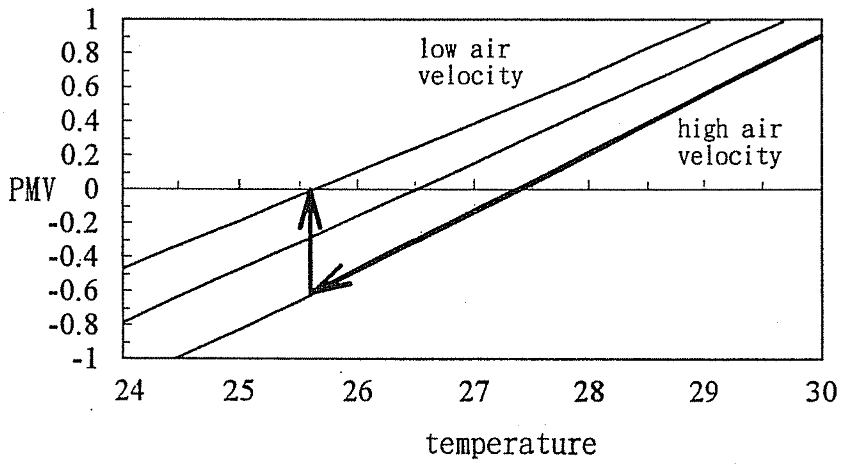


Fig. 3-7 Use the designated temperature as switching condition

Method 7: the fan speed is changed according to the air temperature error, which is the difference between the setpoint temperature and the temperature at the user's position as Fig. 3-8 shown. When the air temperature error is higher than 3 °C , we select the high fan speed. When the air temperature error is between 1 °C and 3 °C , we select the medium fan speed. When the air temperature error is less than 1 °C , we select the low fan speed.

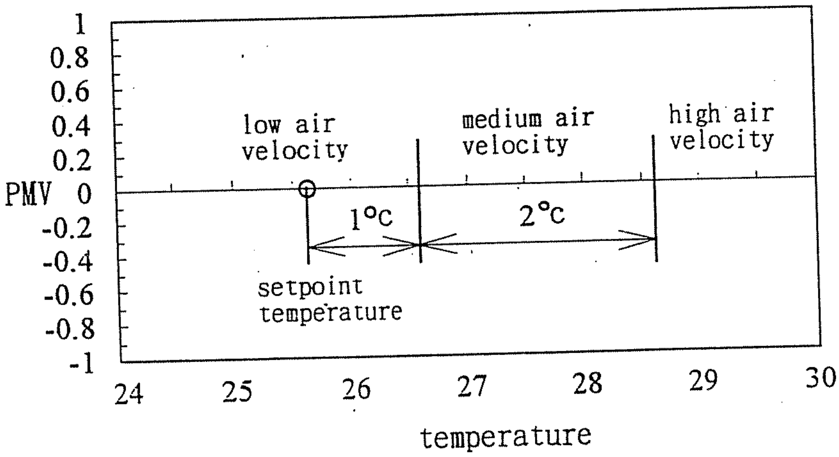


Fig. 3-8 Use air temperature error as switching condition

3-3 Structure of Controller

According to the analysis above, a controller is designed which includes three parts as shown in Fig. 3-9.

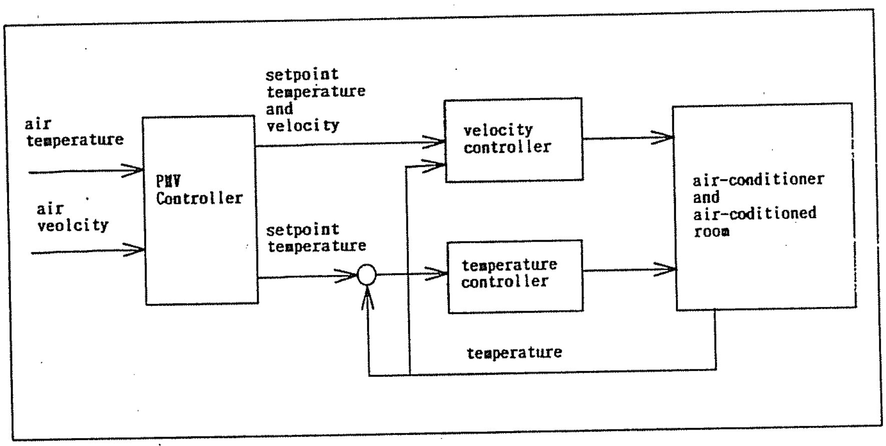


Fig. 3-9 Structure of control system

1. The PMV controller analyze the user and room conditions and decides the temperature and the air velocity of the steady state.
2. The air velocity controller controls the fan speed according to the methods proposed in the above section.
3. The temperature controller controls the compressor speeds to reach the temperature determined by the PMV controller.

3-3-1 PMV Controller

According to the modified PMV model equation (2) the PMV controller determines the temperature and the air velocity to satisfy the comfortness need of the user. For the occupant's position selected in this study, only at the low fan speed can the air velocity at the user's position keep the occupant comfortable. And the corresponding temperature is 25.6 °C. This designated state is then sent to the velocity and temperature controllers for controlling the air-conditioner.

3–3–2 Air Velocity Controller

Based on the temperature and air velocity determined by the PMV controller, the air velocity controller adjusts the fan speed by using the methods mentioned in the last section according to the temperature at the user's position.

3–3–3 Temperature Controller

In order to let the air temperature at the user's positions meets the setpoint temperature predicted by the PMV controller, we have to adjust the compressor speed. But, in the cooling mode, because of the coupling between the humidity and air temperature, the air-conditioned room is a non-linearly system, and it is difficult to build the model. Also the thermal load varies under different conditions. It is difficult for the temperature controller to determine the optimal compressor speed such that the cooling capacity equal to the thermal load, except for the special design. Therefore, a fuzzy controller is designed with the air temperature error (e) and the change of the air temperature error (d) as the input, and the compressor speed difference (dFr) as the output. The membership functions for each variables are defined in Fig. 3-11, 3-12, and 3-13 respectively. The fuzzy rules for temperature controller are listed in Table 1.

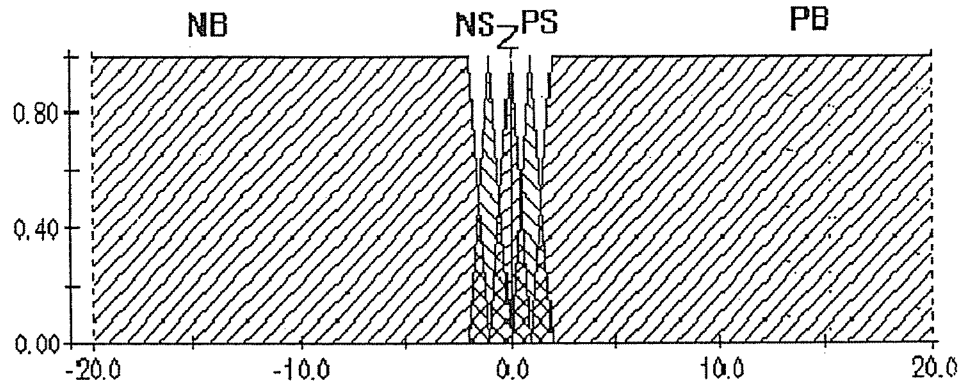


Fig. 3-10 Membership function of e

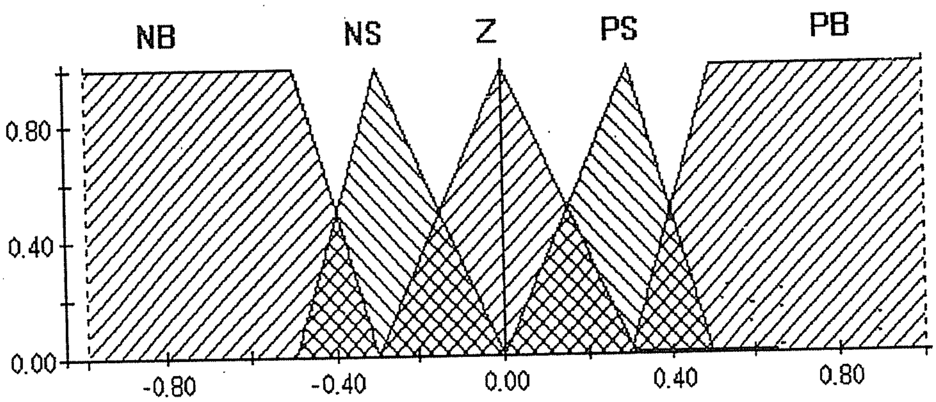


Fig. 3-11 Membership function of d

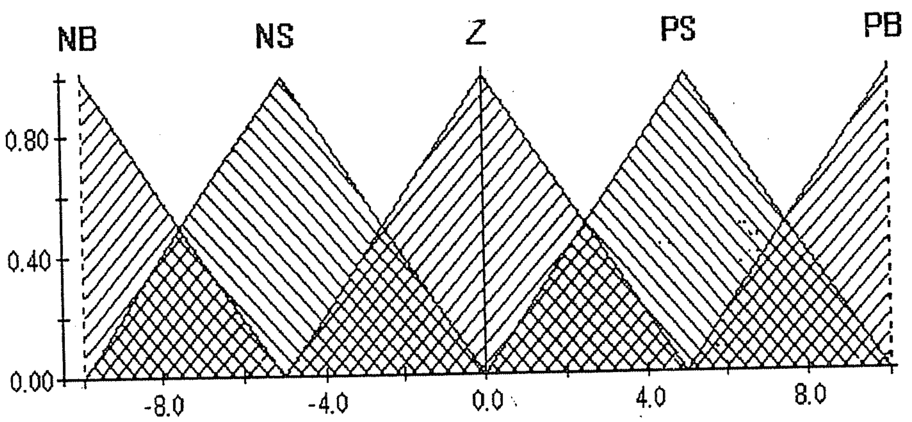


Fig. 3-12 Membership function of dFr

e\d	NB	NS	Z	PS	PB
NB	PB	PB	PB	PS	Z
NS	PB	PS	PS	Z	NS
Z	PB	PS	Z	NS	NB
PS	PS	Z	NS	NS	NB
PB	Z	NS	NB	NB	NB

Table 3-1 Fuzzy rules of temperature controller

4.Experiment System

The structure of the experimental system is showed in Fig. 4-1, it includes two parts, the control system and the measurment system of the air-conditioned rooms.

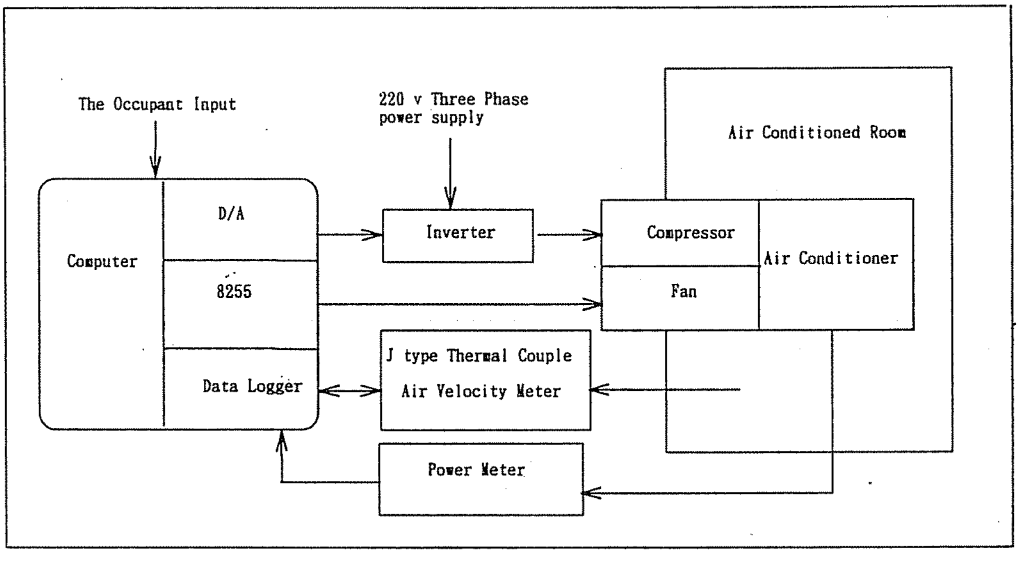


Fig. 4-1 Structure of experiment system

4-1 The Control System of The Air-Conditioned Room

A Tatung Company's TW-251 YHS air-conditioner is used. In order to regulate the cooling capacity under different setpoint temperatures, it is modified by replacing the original compressor with an inverter compressor. The compressor's speed is proportional to the frequency of the power supply controlled by an inverter. The fan motor of the air-conditioner has three speeds.

A 486 personal computer is used as the controller. It determines the desired control signal of compressor speed, and sends it to the inverter to change the frequency of power supply with an analog to digital conversion card. An 8255 interface card is used to control three relays that switch the fan motor's speeds to high, medium or low.

4-2 The Measure System of the Air-Conditioned Room

The temperatures at different locations, the air velocity at user's position, and th power consumption of the air-conditioner are collected by a data logger interface and transmitted to the computer for analysis and control. The user's position is selected to be in the comfortable velocity zone according to the analysis of airflow in the air-conditioned room [9]. The sensors are put at the point 1.2m above the floor and 1.5m in front of the air-conditioner. Where the high air velocity is 0.39 m/sec, the medium air velocity is 0.28 m/sec, the low air velocity is 0.2 m/sec. We measure separately the power consumption at the primary sides of the inverter and the fan motor. The specifications of equipments used in this experiment are described as the following.

Air-conditioner: A Tatung Company's TW-251 YHS air-conditioner with an inverter compressor is used. The power consumptions of the fan under three different speeds are 90.2, 83.6, and 79.2 watts.

Compressor: compressor is an inverter compressor of National Co. Its normal range of operation frequency is between 35 and 100 Hz. Its cooling capacity is 2040 Kcal/hr and power consumption is 865 watts when its frequency is 60 Hz.

Inverter: Toshiba VFA3-2015P inverter is used here.

Its performance is

1. Maximum output is 1500 Watts.
2. Maximum current is 10 A.

And its output frequency, 0 to 130 Hz, is linearly set in proportion to the input voltage, 0 to 10 V.

Air-conditioned room: A 6m × 3.5m × 3.3m room Is made of wood.

Data logger interface: Keithley Co. DAS-TC data logger interface

Low air velocity meter: The low air velocity meter is hot wire type, its measure range, between 0 and 10 m/sec, is proportion to the input voltage, DC 0-5 V.

Power meter:

1. A 3 phase 3 wire type power meter is used to measure the power consumption of the compressor.
2. A 1 phase 2 wire type power meter is used to measure the power consumption of the fan.

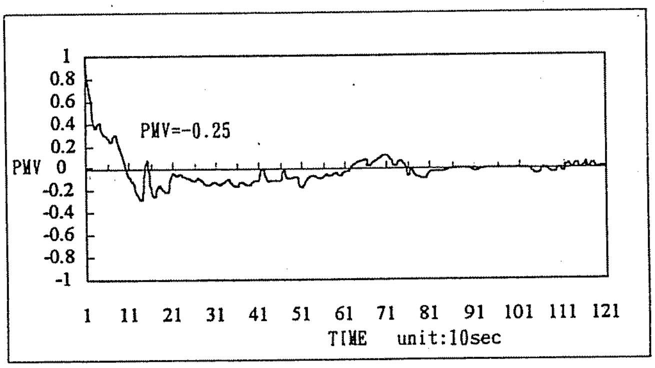
5. Experiment Results and Discussions

The results of experiments are showed from Fig. A-1 to Fig. A-6 in the appendix. The settling times of the room temperatures, compressor speeds and PMV values are not the same. The compressor speed reached the steady state first. Then it takes time for the room temperature to reach the steady state by means of heat balance. When the room temperature reaches the steady state, the PMV value also reaches the steady state at the same time. The main objective is the occupant thermal comfort. Therefore, when the PMV value is between 0.1 to -0.1, the system is in the steady state.

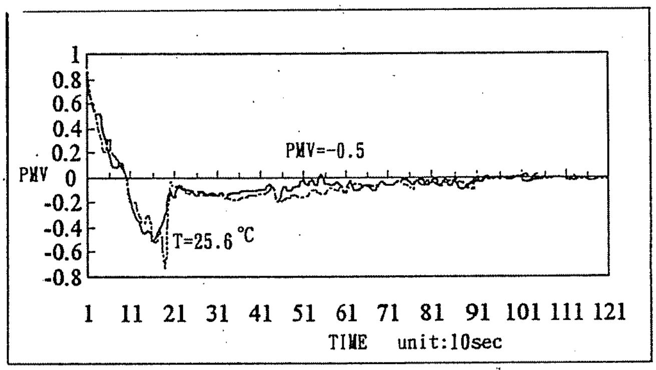
The experiments results of the PMV value and the mean energy consumption are analyzed and discussed as follows.

5-1 Classification of PMV and Energy Consumption Responses

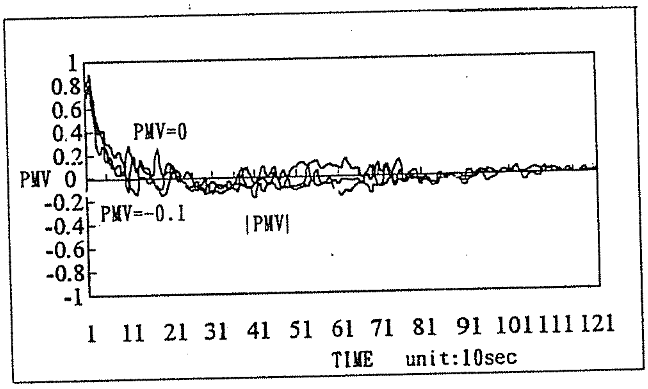
The responses of PMV value at the user's position for different methods are grouped into four categories as shown in Fig. 5-1 and Table 5-1. The first group has smaller overshoot than the second group. The Third group has the least overshoot but with more oscillations. The last group almost does not return to the positive PMV value after the overshoot. The comparison of the four groups is showed in Fig. 5-2.



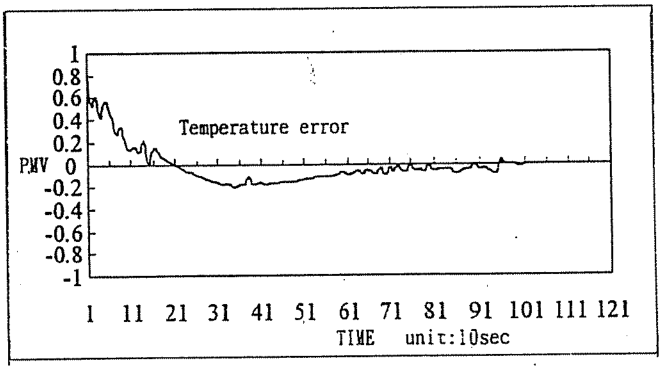
a. First group



b. Secon group



c. Third group



d. Fourth group

Fig. 5-1 Classifications of PMV response

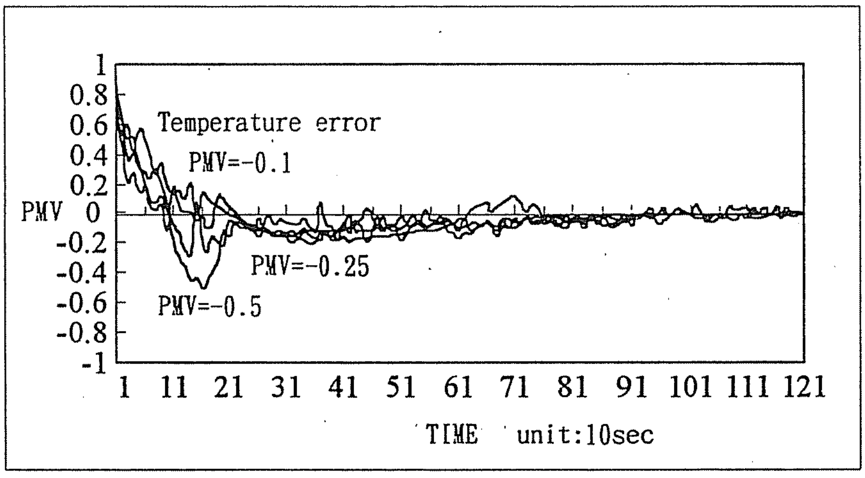


Fig. 5-2 Comparision of PMV value for four groups

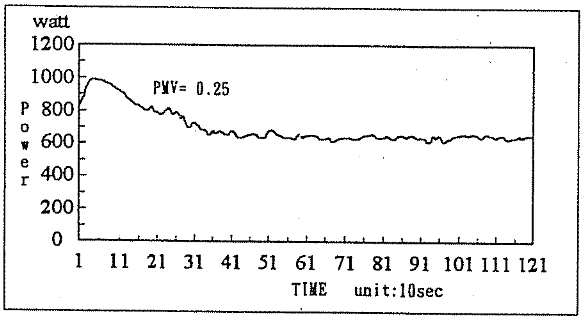
group	methods of fan speeds adjusting	t_{HL} (sec)	Settling Time (sec)	Mean Power (watts)
I	Method 3(adjusting fan speeds as PMV=-0.25)	200	810	723
II	Method 6(adjusting fan speeds as Tem.=25.6°C)	190	910	694
II	Method 2(adjustingfan speeds as PMV=-0.5)	220	890	707
III	Method 1(adjusting fan speeds as PMV=0)	160	910	754
III	Method 4(adjusting fan speeds as PMV=-0.1)	180	840	785
III	Method 5(adjusting fan speeds as $\|PMV\|_{\text{high air velocity}}=\|PMV\|_{\text{med. air velocity}}$)	190	840	754
IV	Method 7(adjusting fan speeds as error of Tem.=1,3°C)	150	960	817

Table 5-1 Classification of experiment results

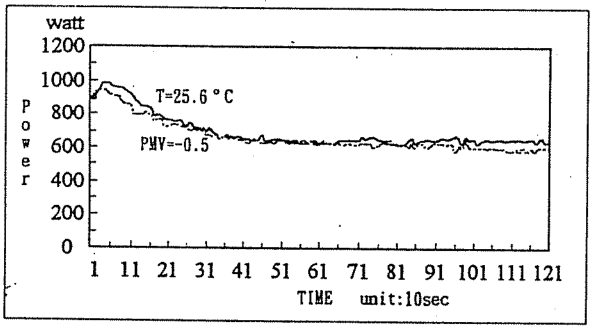
Also, the methods with simliar time response of energy consumption are grouped into the same category as shown in Fig. 5-3. The differences of energy consumption among the four groups are showed in Fig. 5-4.

5-2 Time Response of PMV Value

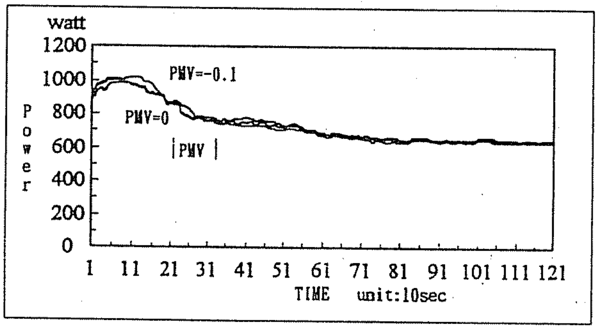
After the fan speed switched to low, the air-conditioner is mainly controlled by the temperature controller. Therefore, to see the effect of the velocity controller, the time required to switch to the low fan speed are summarized in Table 5-1 for different methods. The switching time tHL for changing fan speed from high to low increases as the PMV switching criterion changes from 0 to -0.5. It is noted that, except the method 6 which switched from high to low fan speed directly, the grouping is the same as that based on the PMV value response as shoen in Table 5-1. On the other hand, the settling time is similar for different methods (see Table 5-1).



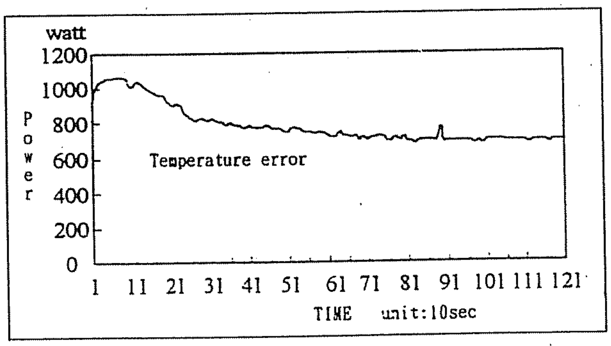
a. First group



b. Second group



c. Third group



d. Fourth group

Fig. 5-3 Classifications of energy consumption response

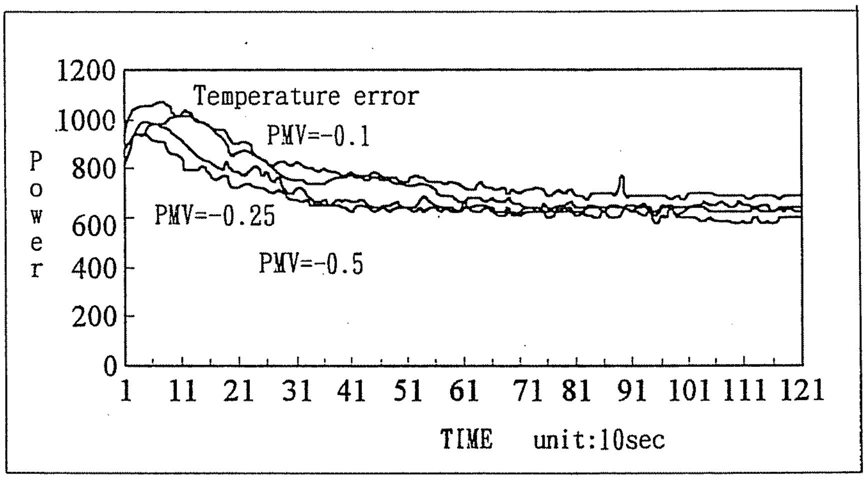


Fig. 5-4 Energy consumption differences among four categories

5-3 Energy Consumption

The mean energy consumption is considered over the interval of settling time. The methods with simliar energy consumption are grouped into the same category of Table 5-1. And the categories classified by energy consumption are the same as the categories classified by the switiching time t_{HL} as shown in Table 5-1.

According to the above results, some phenomenona are summarized as below.

1. The method 3 can make the occupant comfortable in the least time because response is the fastest.
2. Before the air-conditioned room reaches the steady state, with high fan speed, less energy is consumed than with the low fan speed for the same heat load of the air-conditioner. Therefore, the earlier the low fan speed is used, the more energy is consumed.
3. Provided that the outdoor temperature and heat loads of the air-conditioner are the same, the effects of fan speeds on the settling time are not obvious. While the inverter compressor is used, its speed will be changed depending on the temperature error. The air-conditioner with high air velocity has higher cooling capacity to cool down the room and the error of the room temperature will be less. After then, due to the decreasing of the error of the air temperature, the compressor speed decreases and the cooling capacity becomes lower, and the time response is slow down.
4. Generally speaking, the performance of methods based on the PMV switching criteria is better than those based on temperature.

6. Conclusion

1. This study presents a strategy which make occupants comfotable with less energy consumption for the inverter air-conditioner with three constant speeds. The air velocity controller uses the PMV value to adjust the fan speed. And the fuzzy method is used to build a temperature controller.
2. Adjusting fan speed according to the PMV value can make occupants comfortable with less energy consumed.

3. Systems which use smaller PMV value as switching criterion for fan speeds have better and more stable PMV response but consumes more energy.

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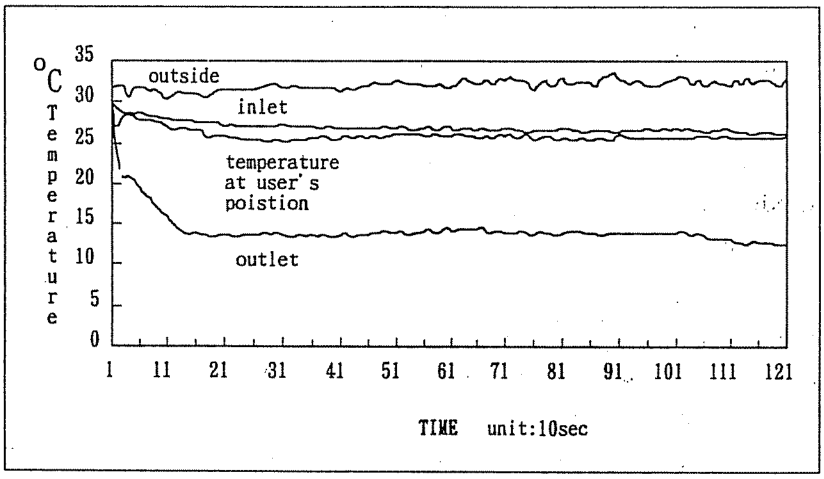
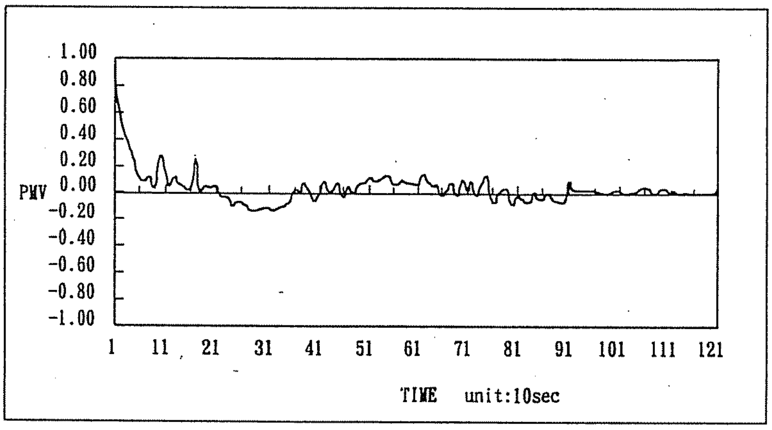
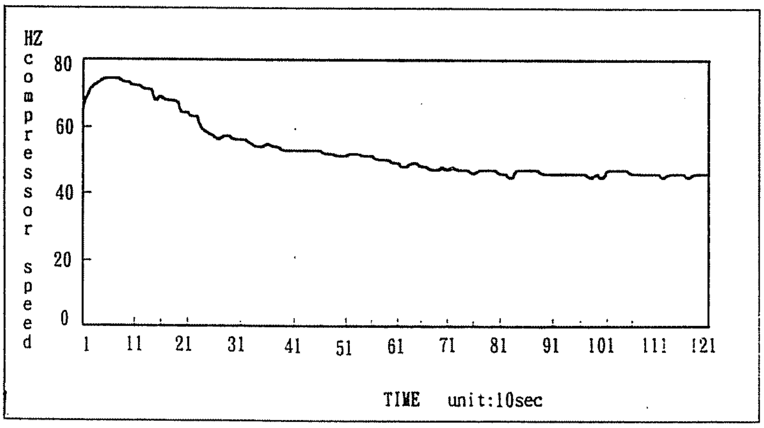
Appenix



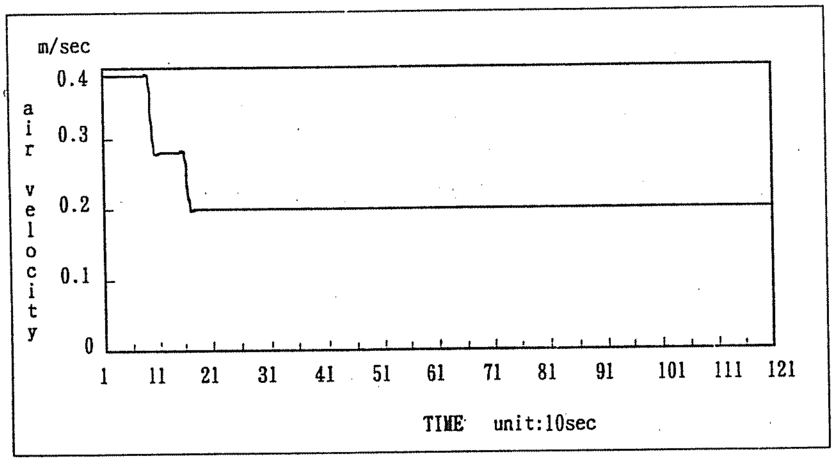
a. Time respone of temperature



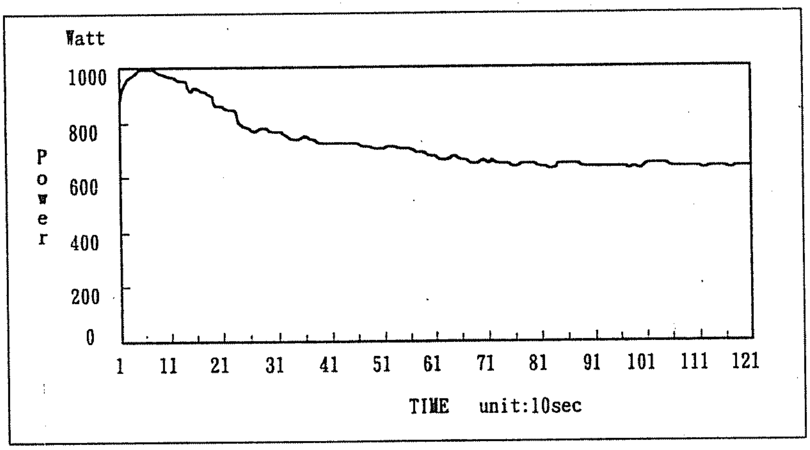
b. Time respone of PMV



c. Time respone of compressor speed

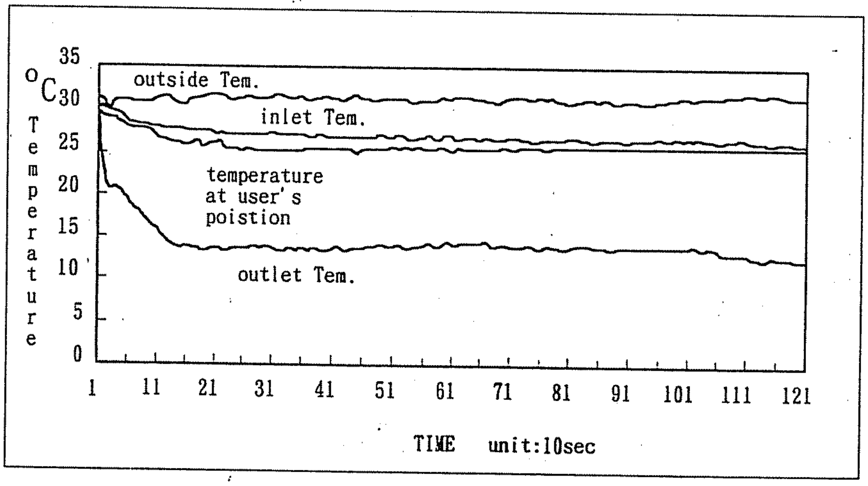


d. Time respone of fan speed changing

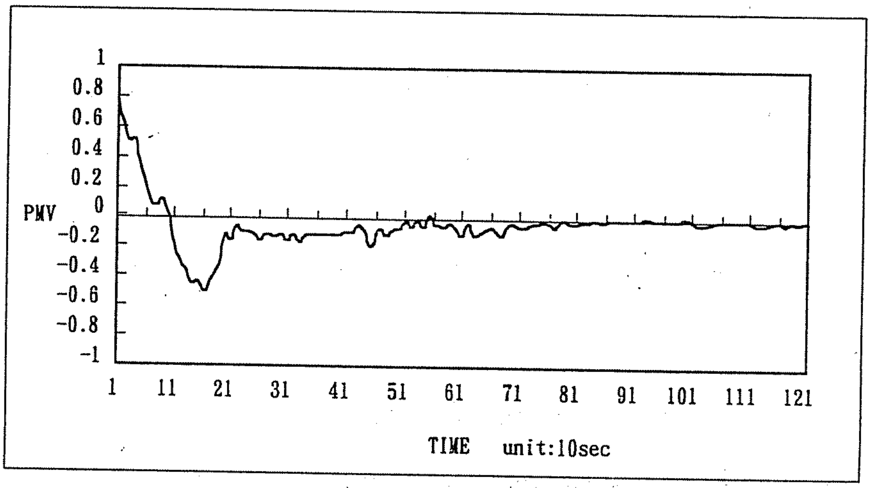


e. Time respone of power consumption

Fig. A-1 Time responses of system using PMV=0 criterion



a. Time respone of temperature



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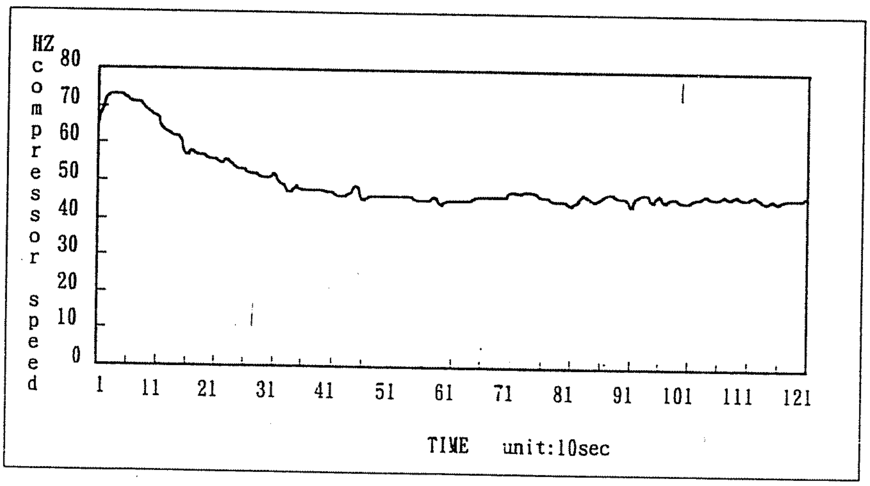
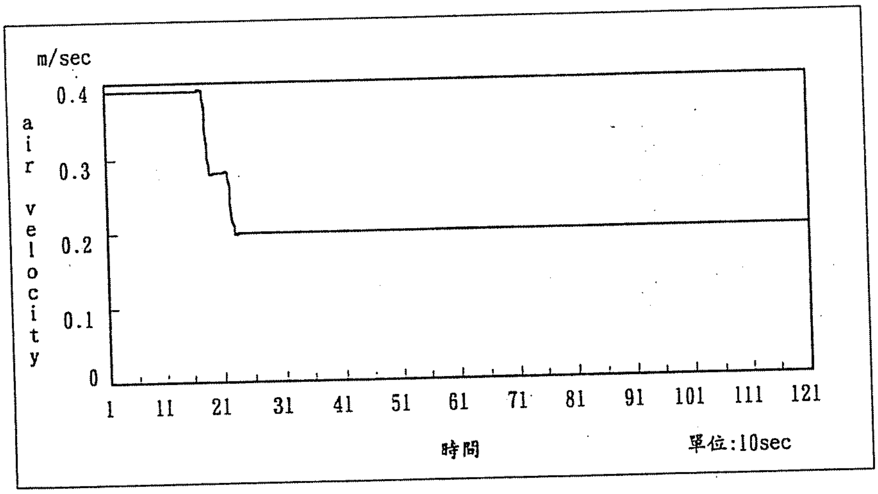
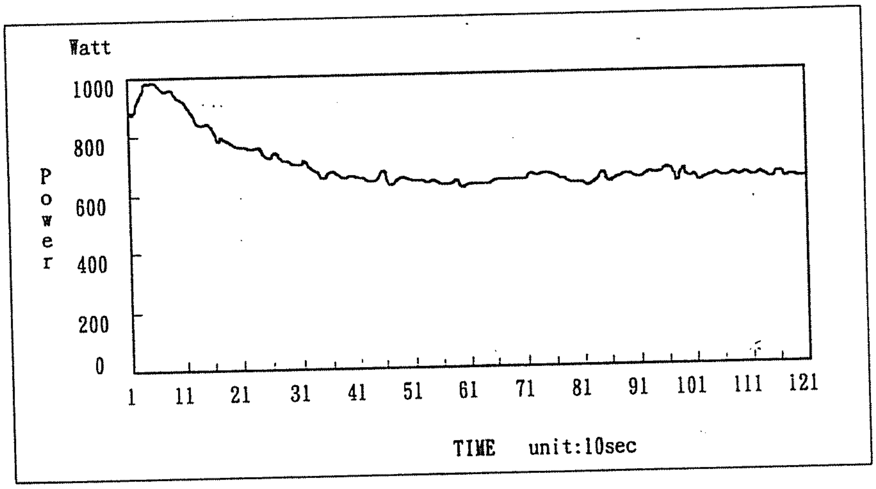


c. Time respone of compressor speed

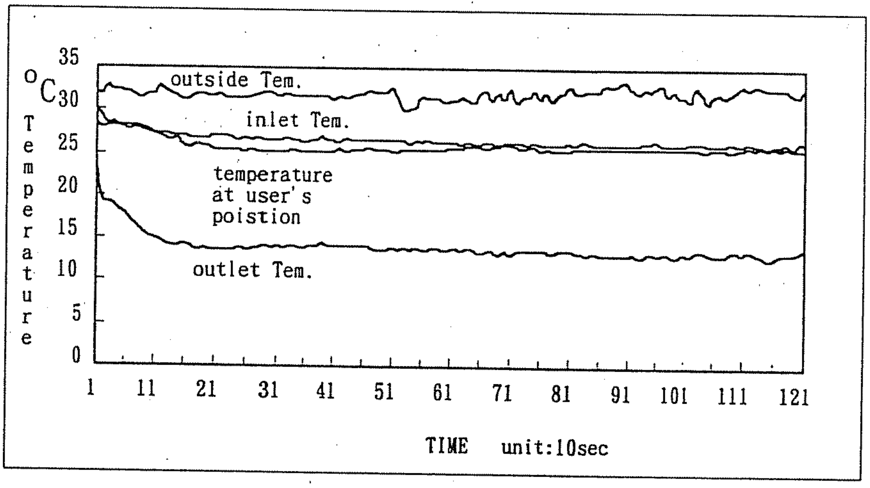


d. Time respone of fan speed changing

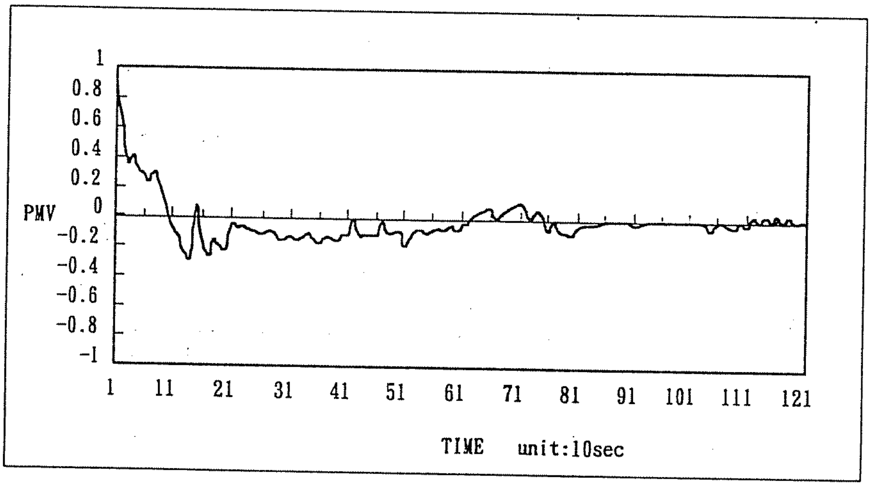


e. Time respone of power consumption

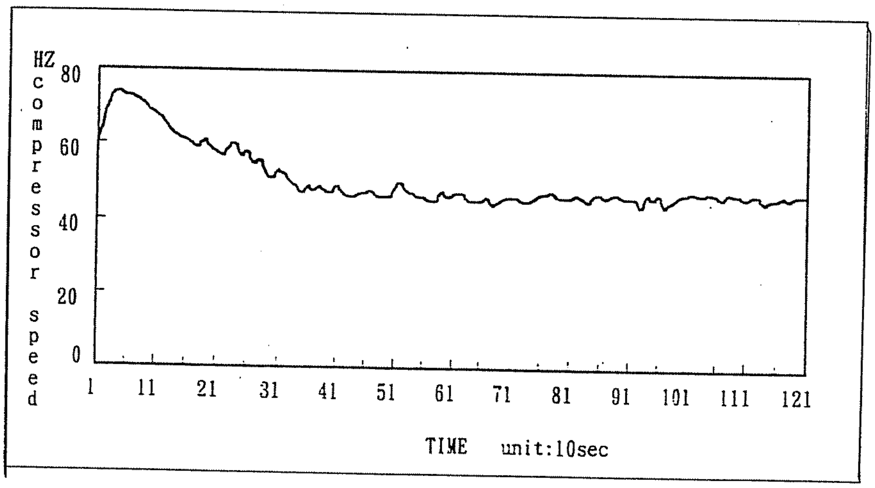
Fig. A-2 Time responses of system using PMV=-0.5 criterion



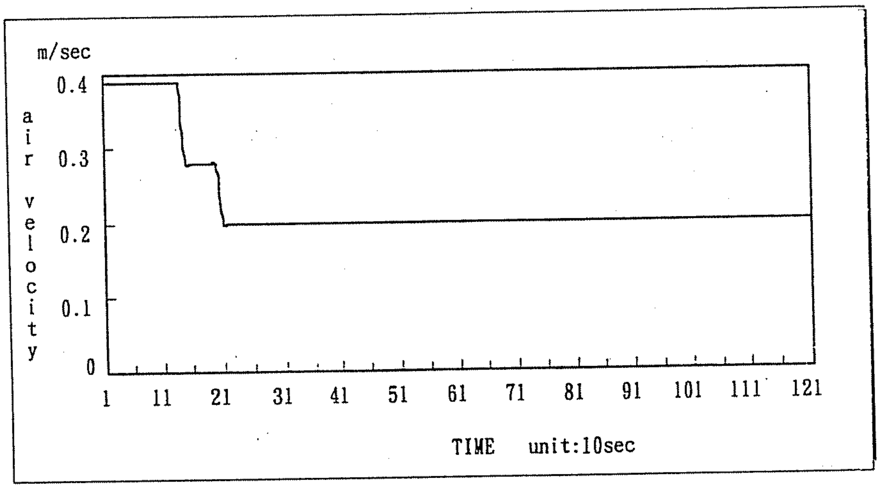
a. Time respone of temperature



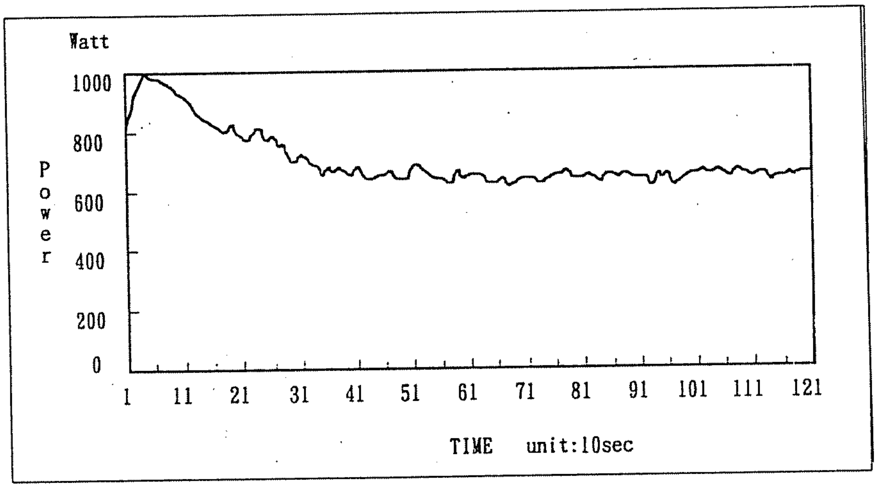
b. Time respone of PMV



c. Time respone of compressor speed

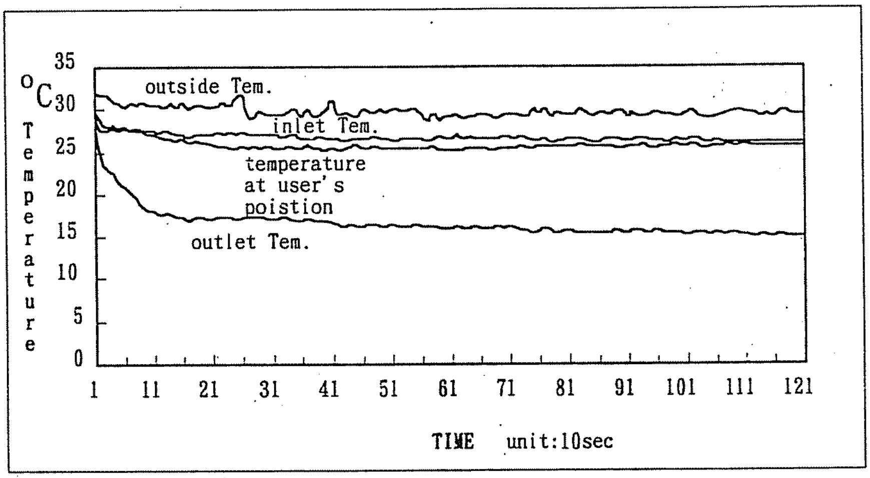


d. Time respone of fan speed changing

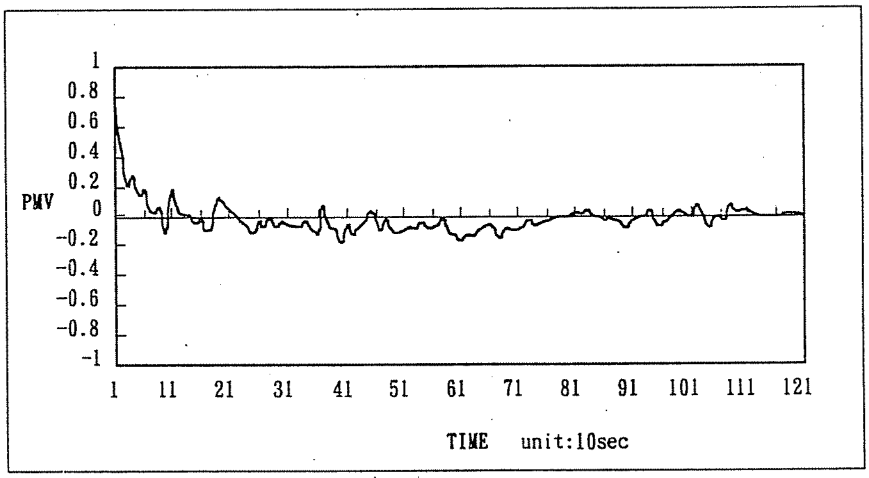


e. Time respone of power consumption

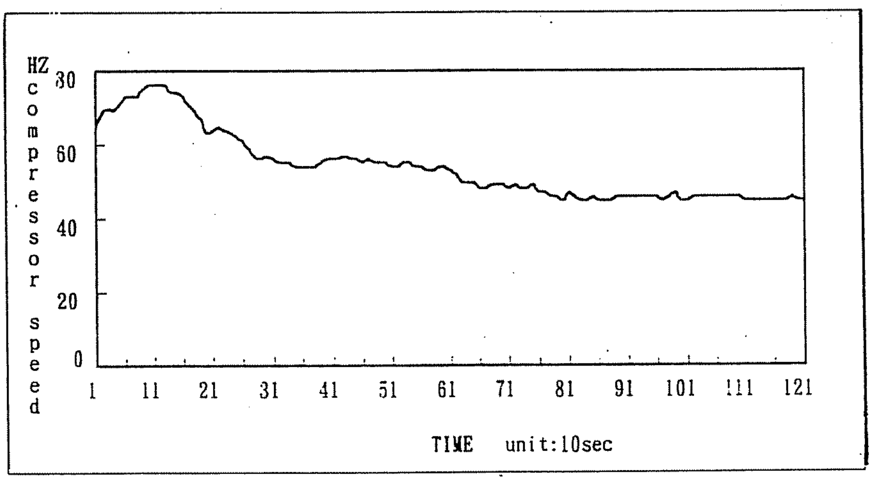
Fig. A-3 Time responses of system using PMV=-0.25 criterion



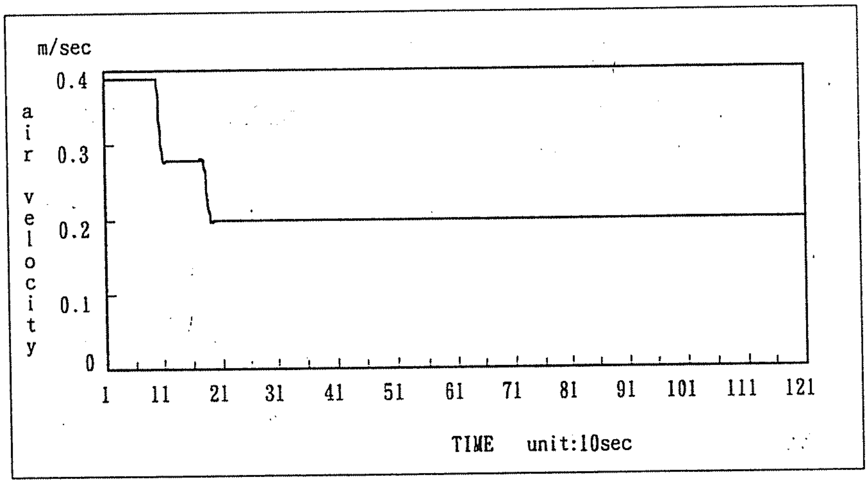
a. Time respone of temperature



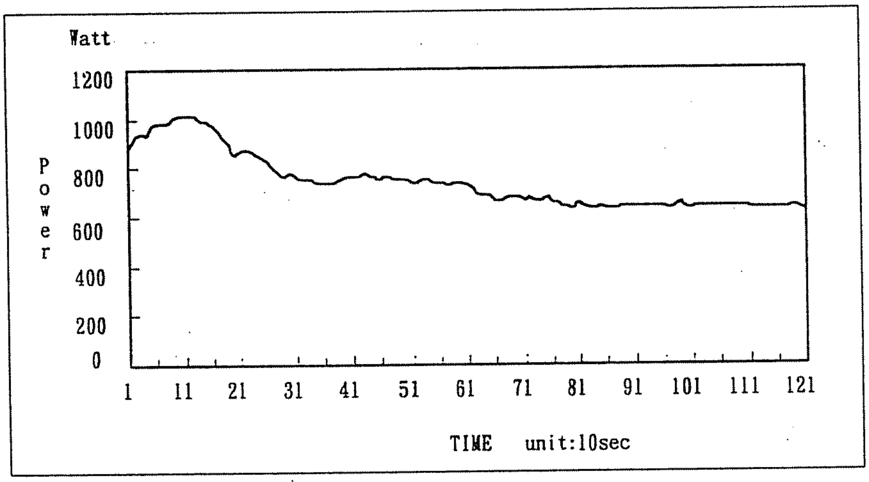
b. Time respone of PMV



c. Time respone of compressor speed

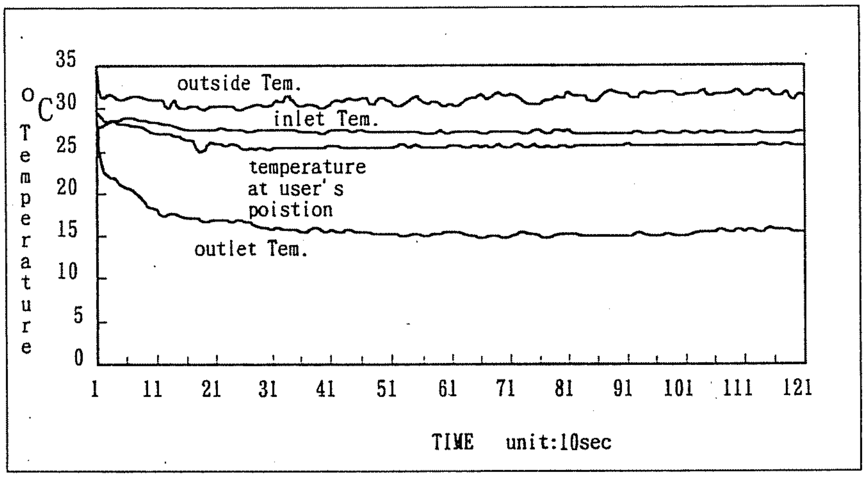


d. Time respone of fan speed changing

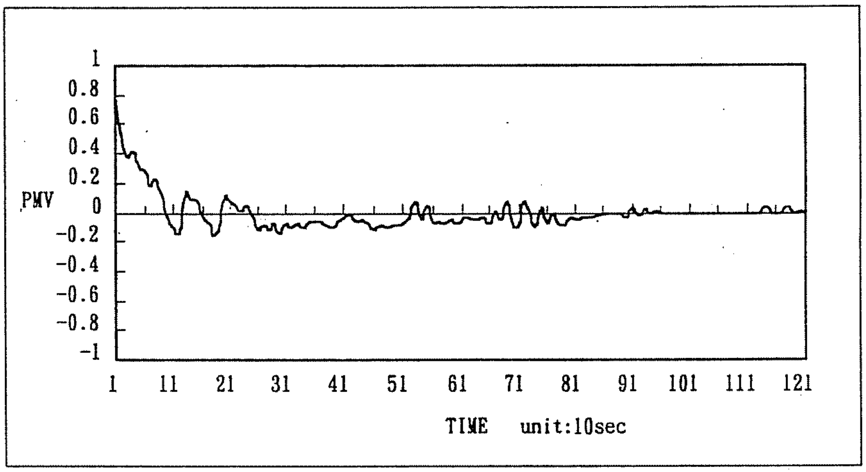


e. Time respone of power consumption

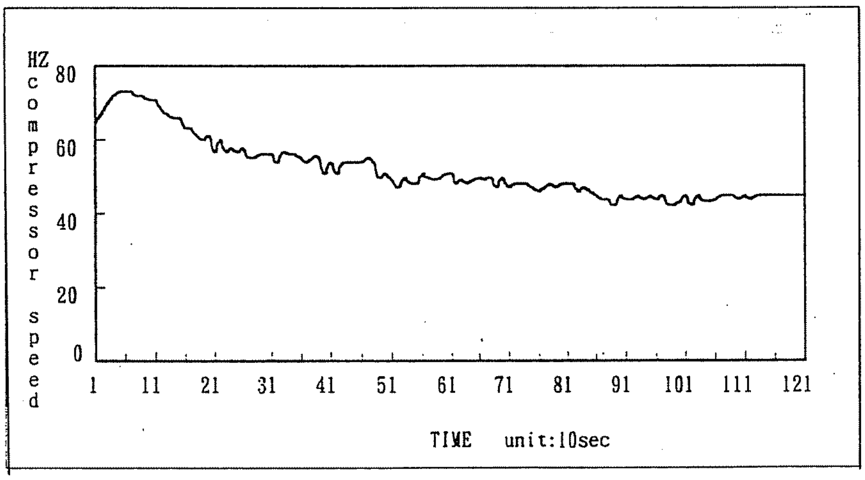
Fig. A-4 Time responses of system using PMV=-0.1 criterion



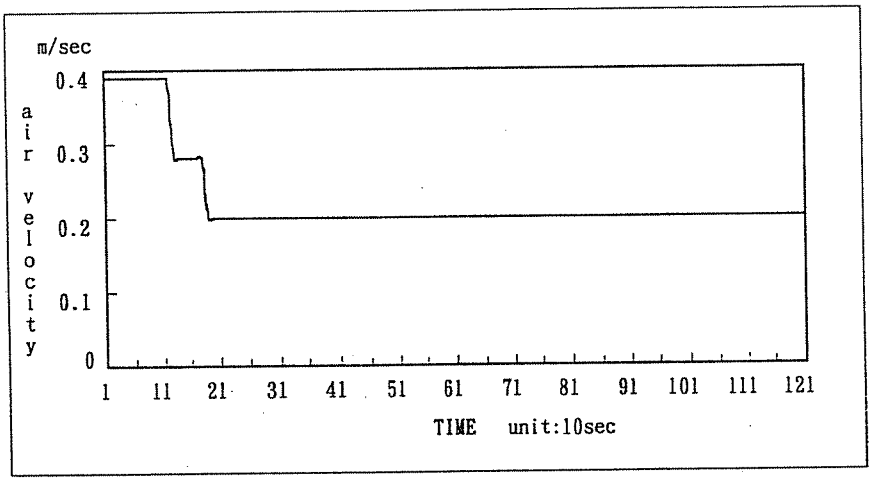
a. Time respone of temperature



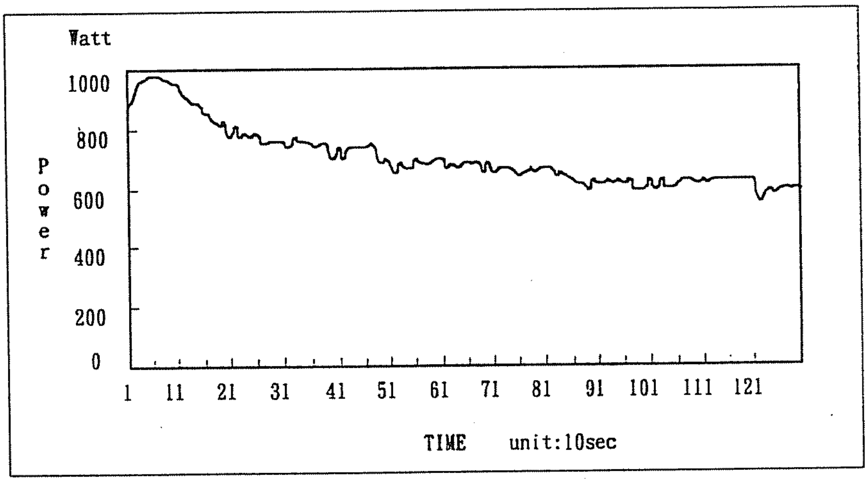
b. Time respone of PMV



c. Time respone of compressor speed

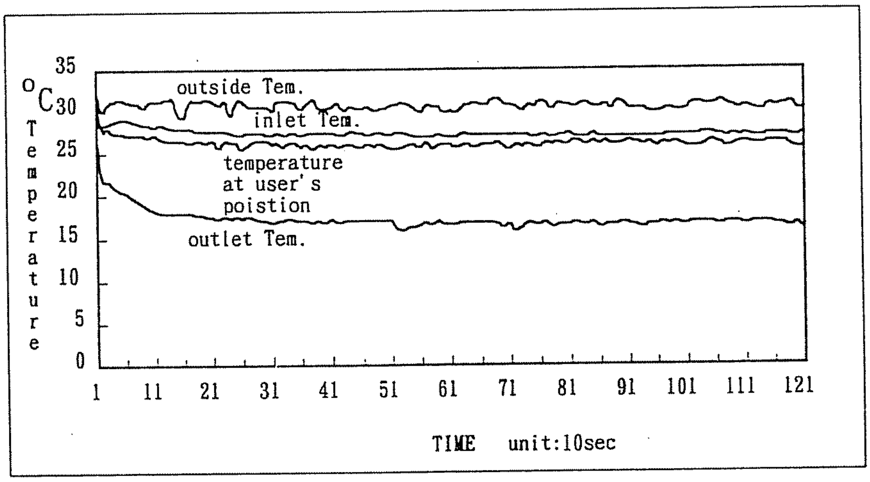


d. Time respone of fan speed changing

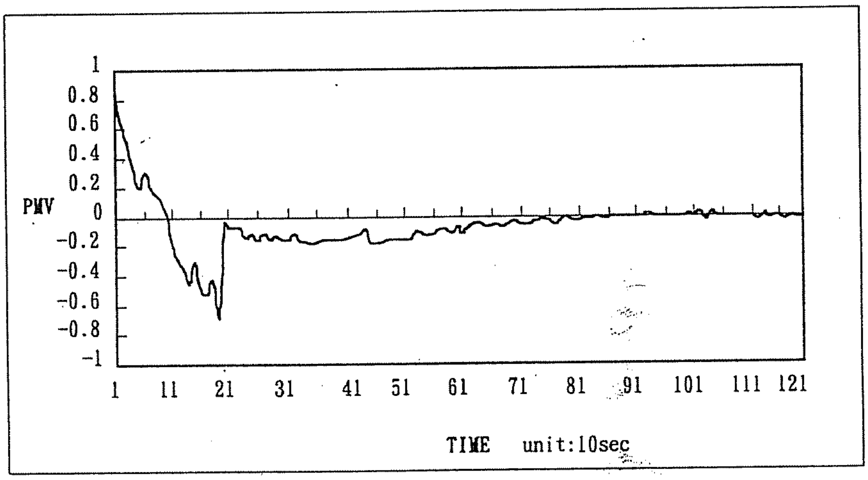


e. Time respone of power consumption

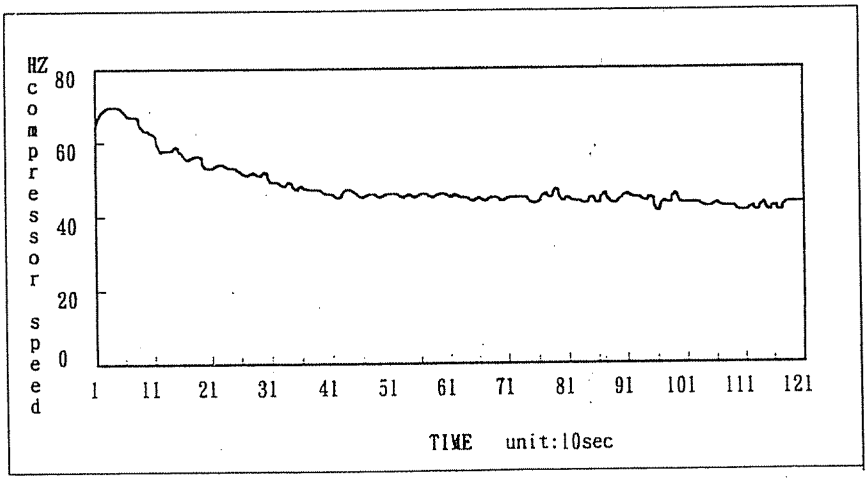
Fig. A-5 Time responses of system using equal absolute PMV criterion



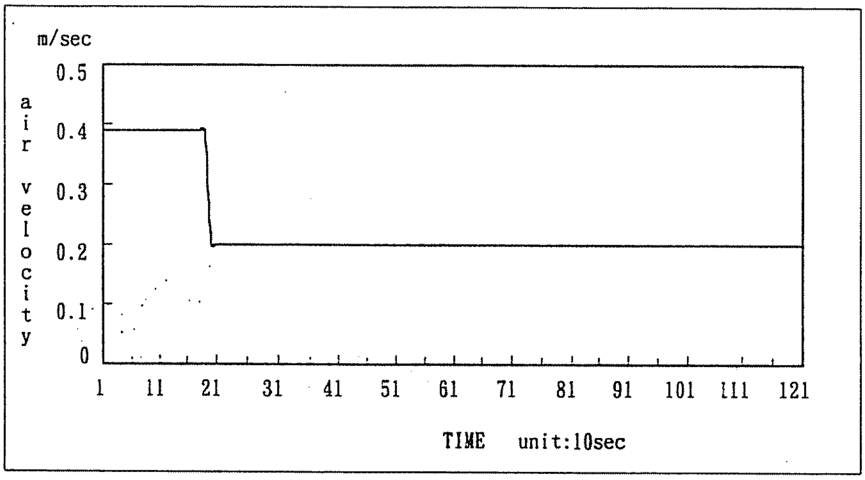
a. Time respone of temperature



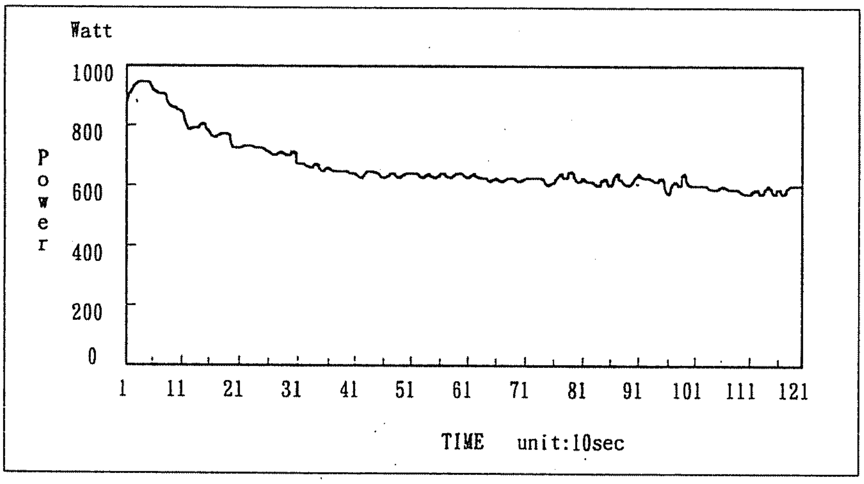
b. Time respone of PMV



c. Time respone of compressor speed

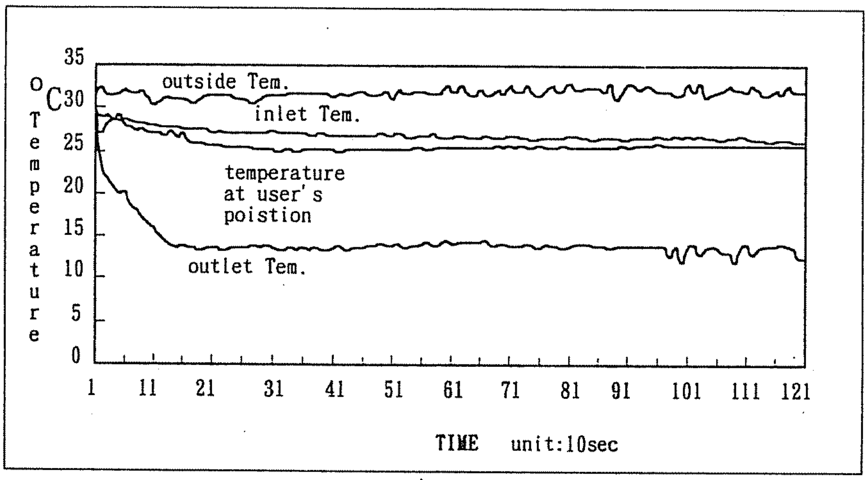


d. Time respone of fan speed changing

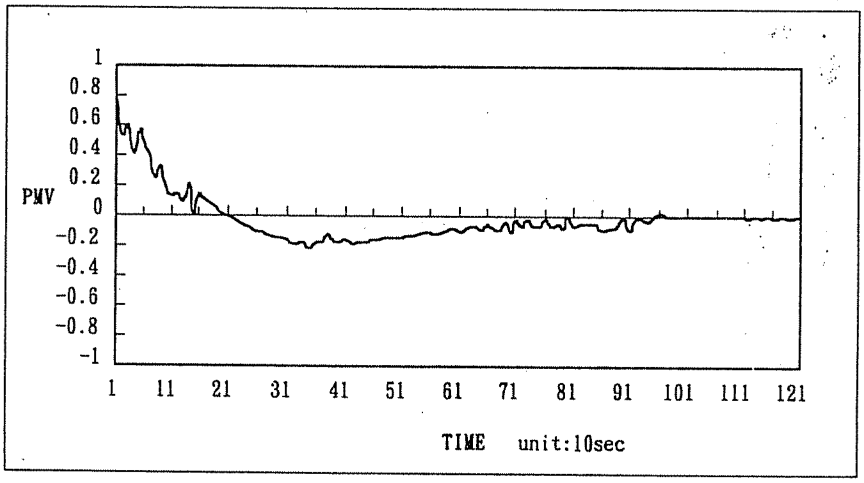


e. Time respone of power consumption

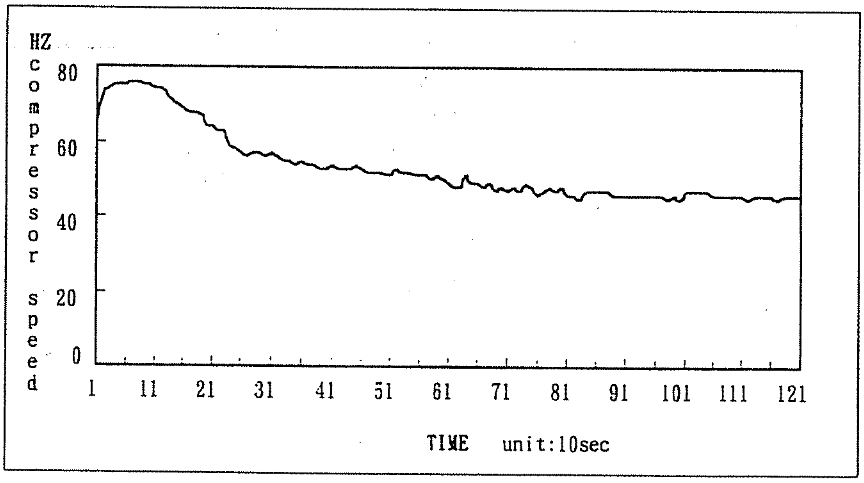
Fig. A-6 Time responses of system using designated temperature criterion



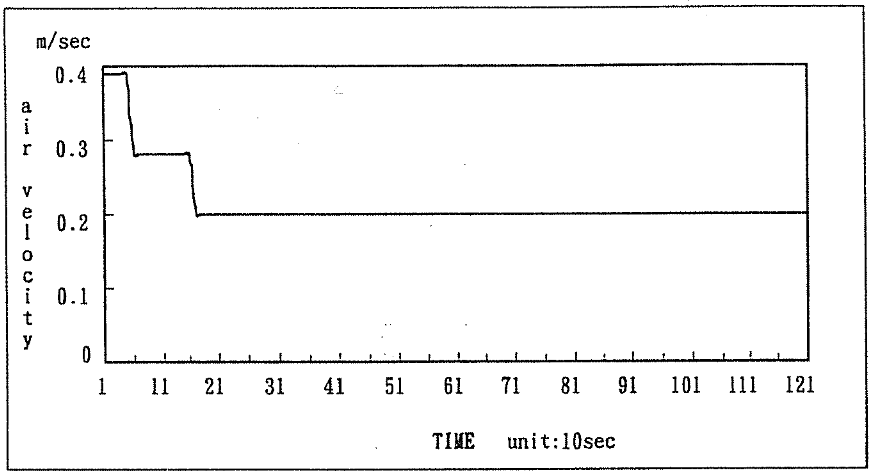
a. Time respone of temperature



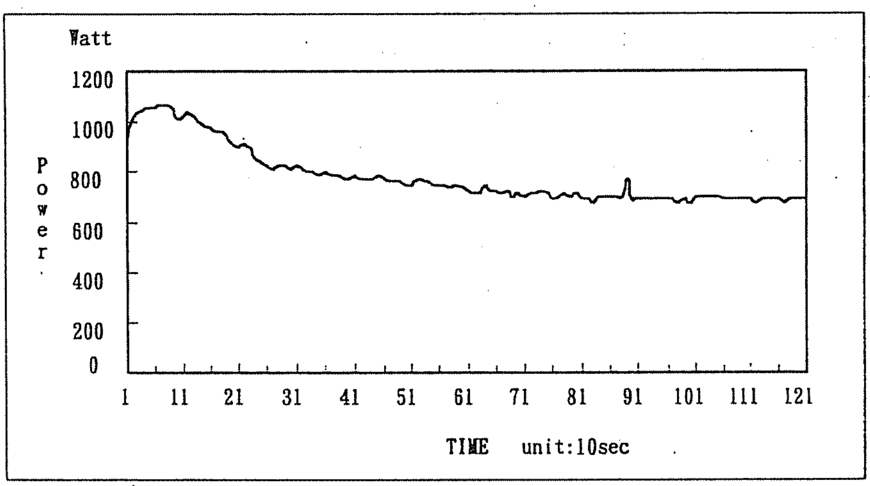
b. Time respone of PMV



c. Time respone of compressor speed



d. Time respone of fan speed changing



e. Time respone of power consumption

Fig. A-7 Time responses of system using air temperature error criterion

省能量之冷房舒適度控制

林柳絮 *

摘 要

目前窗型變頻式冷氣機，多爲三段風扇轉速、溫度控制。在前人的研究中多半以固定風速（低風速）下作舒適度的控制，或在穩定狀態下作舒適度與能源效率的最佳化控制。截至目前爲止，並未有上述之窗型變頻式冷氣，考慮動態過程中，不同風速下，以舒適度爲控制對像，並兼顧能源消耗的研究。故本研究採用模糊邏輯（ Fuzzy Logic ）推論之溫度控制器，配合三種風速（高、中、低）下舒適度－溫度線圖（ PMV vs Temperature diagram ）分析，提出七種不同風速切換方式。並進行實際測試，觀察動態過程中不同風速（高、中、低）切換方式對舒適度、能量消耗、與反應速率之影響以尋求較佳風速（高、中、低）切換方式。

關鍵詞：舒適度，能源效率，模糊控制，最佳化

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