

A Study on Energy-efficient Temperature Control

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Abstract—The top-heavy demographic of low birth-rate and longer lifespan is a growing social problem, and one of its expected effects will be a shortage of young workers and a growing reliance on a workforce of middle-aged and older people. However, the environment of today's industrial workplace is not particularly suited to middle-aged and older workers, one notable problem being temperature control. Higher temperatures can cause health problems such as heat stroke, and the number of cases increases sharply in people over 65. Moreover, in conditions above 33°C, older people can develop circulatory system disorders, and also have a higher chance of suffering a fatal heart attack. We therefore propose a new method for controlling temperature in the indoor workplace. In this study two different verification experiments were conducted, with the proposed temperature control method being tested in cargo containers and conventional houses. The method's effectiveness was apparent in measurements of temperature and electricity consumption.

Keywords—CO₂ reduction, Energy saving, Temperature control

I. INTRODUCTION

The aging of Japanese society has been progressing over the past several years, and the population of elderly people aged over 65 years of age now constitutes more than 20% of the overall population [1-3]. For this reason, the work force at production sites is becoming dependent on elderly workers, and the aging of the workers is becoming a great social problem. Furthermore, it is gradually becoming necessary to implement improvements in workplace environments with consideration for elderly workers [4-6]. The first points which are usually emphasized when considering indoor environments are the temperature and the humidity. Although a well-known health problem associated with rising temperatures is heat stroke, the surge in the number of instances varies depending on the age group. While the surge in the number of heat stroke instances in the age group of 15 to 64 occurs at 35°C, it occurs at 33°C for people aged over 65. Moreover, temperatures above 33°C induce circulatory system disorders in people aged over 65, and the death rate associated with heart attacks increases [7-9]. For this reason, the "Association for Preventive Medicine in Japan" recommends temperature and humidity measurements to be performed at indoor workplaces twice a month.

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Moreover, Global warming has recently become an international concern. Therefore, various organizations of Japan-domestic are making efforts to address global warming [10, 11].

Taking into account the above circumstances, the present research proposes a new temperature control method for indoor workplaces. If the temperature at indoor workplaces can be adjusted to the most comfortable level, the number of accidents during work can be decreased, and a pleasant work environment can be offered to elderly workers. Specifically, the proposed method prevents the temperature from rising by applying energy-efficient materials which reduce the emission of CO₂, without the need for air conditioning devices, and its effectiveness was verified experimentally. The proposed temperature control method uses a paint containing ceramic beads with insulating properties

II. VERIFICATION EXPERIMENT USING CARGO CONTAINERS

A. Experimental Setup

In the first verification experiment, the two containers (H: 2591mm, D: 2438mm, L: 3658mm) shown in Figure 1 were placed side by side. One container was coated with a paint containing ceramic beads (container A), the other was an uncoated, ordinary cargo container (container B). The effectiveness of the proposed temperature control method was verified by comparing temperature fluctuations in both containers during the summer. The experimental conditions are detailed in Table 1.



Fig. 1 Cargo containers

Table 1 Experimental conditions
(Verification Experiment using Cargo Containers)

CONTENT	DETAIL
Experimental location	Latitude 35.6 north and longitude 140.1 east
Measurement period	From September 19, 2006 to October 4, 2006
Evaluation index	Internal container temperatures
Measuring instrument machine	RSW-20s, ESPEC CORP.
Measurement interval	30 minutes

B. Results and Discussion

Figure 2 shows temperature fluctuations inside the containers and outside during the measurement period. It is clear from the figure that container A had a lower internal temperature than container B. There is also a visible correlation between outside temperature and internal container temperature, with temperature fluctuations inside the container following those outside. The average internal temperature in container A was 26.8°C, compared with 37.0°C in container B, showing that the proposed system was able to lower the temperature by 10.2°C. Moreover, the largest temperature difference, occurring on September 28, was 17.1°C. These results suggest that by using the proposed method, it may be possible to control temperature without the need for energy consumption.

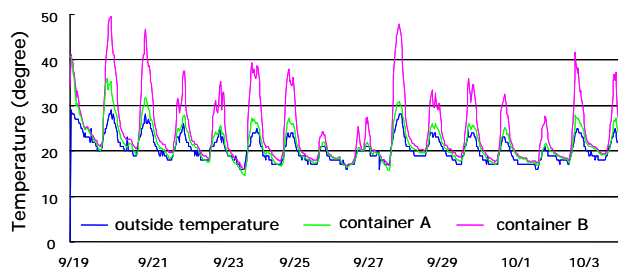


Fig. 2 Temperature fluctuations inside the containers and outside

III. VERIFICATION EXPERIMENT USING CONVENTIONAL HOUSES

A. Experimental Setup

Figure 3 is a photograph of the target buildings, these being two adjacent conventional houses of identical construction. The roof and external walls of one building were coated with paint containing ceramic beads (house A), and the other building was left as a normal, uncoated house (house B). The effectiveness of the proposed temperature control method was verified by comparing temperature fluctuations in both houses

during the summer. Comparison was also made of the amount of electricity consumed by each house's air-conditioning system to maintain a constant indoor temperature. The experimental conditions are detailed in Table 2.



Fig. 3 Target Buildings

Table II Experimental conditions
(Verification Experiment using Conventional houses)

CONTENT	DETAIL
Experimental location	Latitude 34.1 north and longitude 136.2 east
Measurement period	From August 25, 2007 to September 17, 2007
Evaluation indices	Indoor temperature fluctuations Amount of electricity consumption
Measuring instrument machine	RSW-20s, ESPEC CORP. 3169, HIOKI E.E. CORP.
Measurement interval	5 minutes (RSW-20s) 10 minutes (3169)

B. Results and Discussion

Figure 4 shows temperature fluctuations inside the houses and outside for one week after measurement began. It is clear from the figure that house A had a lower indoor temperature than house B. The same trend was also seen in the measurement days not shown in Figure 4. The average indoor temperature in house A was 28.8°C, compared with 30.5°C in house B, showing that the proposed system was able to lower the temperature by 1.7°C. The largest temperature difference was 2.4°C, occurring on September 17. The difference between the results of the house and container experiments can be attributed to the use of insulating materials in the construction of the houses. In other words, the proposed method is effective even in buildings constructed with insulating materials.

Figure 5 shows a snapshot of electricity consumption measurements during air-conditioning usage times. It is clear from the figure that electricity consumption in house A is lower

than in house B. Also, because the air-conditioning temperature was set to 26.0°C in the experiment, the air-conditioning system switched off when the indoor temperature fell below 26.0°C. In the figure, this state is indicated by an electricity value of 0. Table 3 shows electricity consumption on each day of measurement. Electricity consumption in house A was 3.7kWh/day, compared with 4.6kWh/day in house B, showing that the proposed system was able to reduce electricity consumption by 20%.

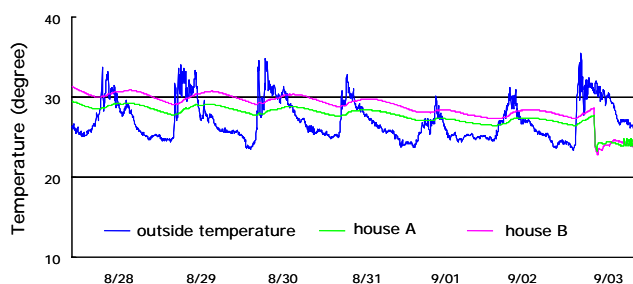


Fig. 4 Temperature fluctuations inside the houses and outside

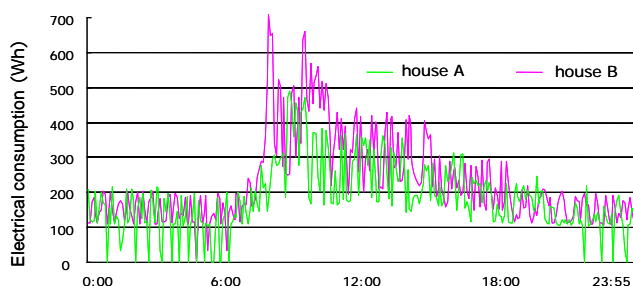


Figure 5 Electricity consumption measurements during air-conditioning usage times

Table III Electricity consumption on each day of measurement (Wh, °C)

DATE	HOUS E A	HOUS E B	A / B (ratio)	PEAK OUTSIDE TEMPERATUR E
Aug. 26	2.73	3.45	0.79	36.8
Aug. 27	4.98	6.62	0.75	35.6
Aug. 28	3.85	4.85	0.79	37.4
Sep. 4	3.77	4.56	0.83	34.7
Sep. 5	3.14	3.48	0.90	33.7
Average	3.694	4.592	0.804	35.64

The results of these experiments demonstrate the effectiveness of the proposed method of temperature control using paint containing ceramic beads with insulating properties.

By applying this technology to the workplace it may be possible to create an indoor working environment suited to older workers, but this is a subject for future research.

IV. LABORATORY FOR RESOURCE AND ENVIRONMENTAL DEVELOPMENT

The effect of paints containing ceramic beads became clear by the experiment. Then, two laboratories were constructed as shown in figure 6. A left laboratory is called as "Lab. A" which is painted in the paints containing ceramic beads. On the other hand, a right laboratory is called as "Lab. B" which is painted in the paints containing silicon and acrylic. In other words, "Lab. A" means the building of effective environmental measures. "Lab. B" means conventional building. The comparative study of two laboratories is scheduled to be executed in the future.



(Left side: Lab. A, Right side: Lab. B)

Fig. 6 Snap shot of laboratories for resource and environmental development

V. CONCLUSION

In this study two different verification experiments were conducted, with the proposed temperature control method being tested in cargo containers and conventional houses. The obtained results can be summarized as follows.

- In an environment whose ambient temperature is 24.6°C on the average, the temperature inside a cargo container where the proposed system was used was 10.2°C lower in comparison with an ordinary container.
- In an environment whose ambient temperature is above 33.1°C, for any arbitrary setting of the room temperature inside an ordinary house, the proposed system can reduce the energy consumption by 20% as compared to an air conditioner.

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