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Proceedings of 7th Windsor Conference: ***The changing context of comfort in an unpredictable world*** Cumberland Lodge, Windsor, UK, 12-15 April 2010. London: Network for Comfort and Energy Use in Buildings, http://nceub.org.uk

Adaptive Effect to Thermal Comfort of Cool Chair in ZEB Office

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Abstract: This paper reports the operational status of the Cool Chair in the ZEB renewal office building during the autumn to the winter of 2010. Each worker has his or her own preferences for thermal environmental conditions and personal thermal comfort. Therefore, not every worker's preferences can be met by the conditions in the office building, and for many workers, their individual preferences of thermal comfort are not satisfied. To solve this problem, this study investigated the operational status of the Cool Chair, which has been developed since 2003. The airflow is blown from the armrests and the seat of the chair. The armrests are movable, and the flow, direction of the air from the armrests can be easily adjusted. Thirty-three chairs were introduced into office space on the third floor of the building, and the authors investigated the thermal environment conditions and use of the chairs.

Keywords: Chair, Environmental preference, Personal air-conditioning system, Isothermal airflow, Thermal comfort

1. Introduction

In the office space, each office worker has his or her own preferences for thermal environmental conditions and personal thermal comfort. Therefore, not every worker's preferences can be met by conditions in the office building; moreover, for many workers, their individual preferences of thermal comfort are not satisfied. In recent years, as a solution to such a problem, 'personal air conditioning' initiatives were introduced in offices to improve the thermal comfort of office workers. These efforts have attracted attention, because they have reduced complaints from office workers. By using a personal air-conditioning system or product, each worker could adjust the thermal environment to satisfy his or her desired preferences.

2. Function of the Cool Chair

To create a personal air-conditioning system, the authors enhanced an office chair with a thermal airflow generator that has an environment adjustment function. This chair, called the Cool Chair, is depicted in Fig.1. The Cool Chair has been developed since 2003. The airflow is blown from the armrests and the seat of the chair. The airflow from the seat inhale from the front of the seat and it is blown from above of the seat. Cool Chair has 3 fans. Fan of armrests draw 3.6 watts of power, and fan of seat of chair draws 1.4 watts of power. The armrests are movable, and the flow and direction of the air from the armrests can be easily adjusted. The Cool Chair airflow is isothermal with the indoor temperature. The armrest airflow can be adjusted using five settings. The combination of the air volume from the armrests and the seat can reach a maximum air volume of 40 m³/h. The Cool Chair has a sensor in the seat that automatically turns off the power when the user leaves the seat.

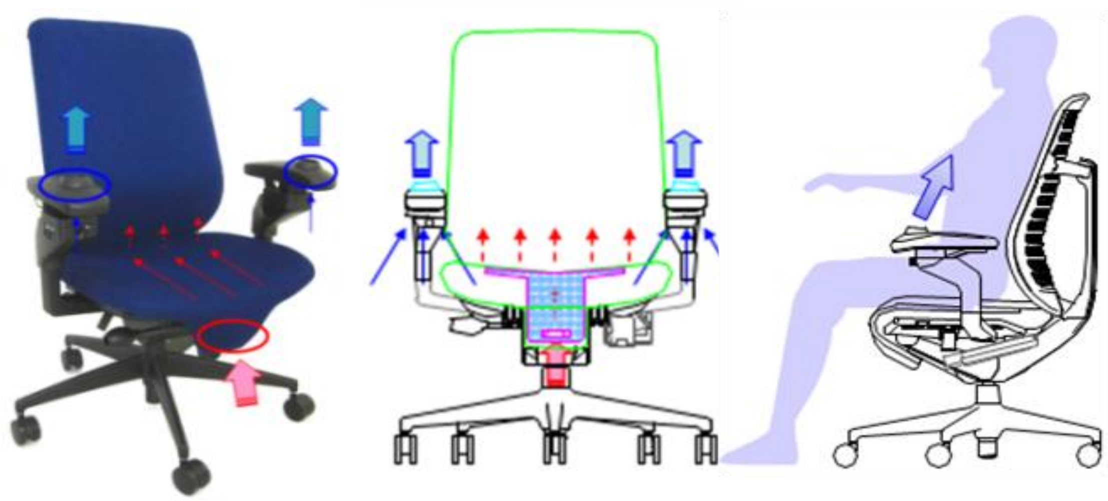


Fig.1. Enhancement of an Office Chair to Create the Cool Chair

Fig.2. The airflow in the seat

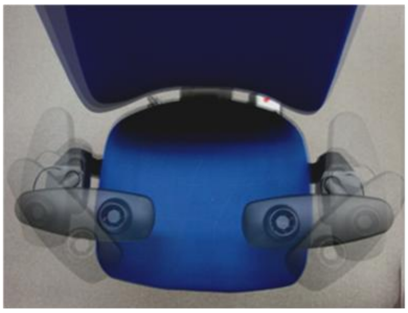


Fig.3. Armrest of Cool Chair

Fig.4. power on/off switch

Fig.5. Air volume control button

3. Measurement Method

This paper reports the operational status of the Cool Chair in the offices of a net-zero energy building (ZEB) during the autumn and winter of 2010. The survey was carried out in the third Tokyo Gas Kohoku NT ZEB renewal office building in Yokohama city in Kanagawa prefecture. Table.1 shows the building details and investigation period. Photographs of the building and the third-floor office space are shown in Figs.6 and 7, respectively. The investigation period was 6 weeks from 30 September 2010 to 14 December 2010. Thirty-six chairs were installed in the third-floor office. Table.2. shows the formulae used for computation (seating conditions, seated rate and usage rate of the chair), and Fig.8 shows the floor plan of the third-floor office space and the locations where Cool Chairs were installed. The authors investigated the thermal environment conditions, the usage rate of the chair and the amount of time users were seated. All the chairs were used by men. thermo-hygrometers used to investigate thermal environment conditions were installed at 100 mm and 600 mm heights. The authors set up a connector between the battery socket and the bodies and calculated the volume of air used by the Cool Chair by utilizing data about the current, which was recorded using a small current logger. Seating conditions were measured by temperature loggers that were set up under the seat of each chair. For this study, we asked 33 Cool Chair users and 35 standard office chair users to complete a questionnaire that asked users to assess their thermal sensation and thermal comfort and how they used their chairs. The rate of workers that were seated in this office was 25.4%; the workers in this office were often required to work outside of the office space during our investigation.

Table 1. Building details and investigation period

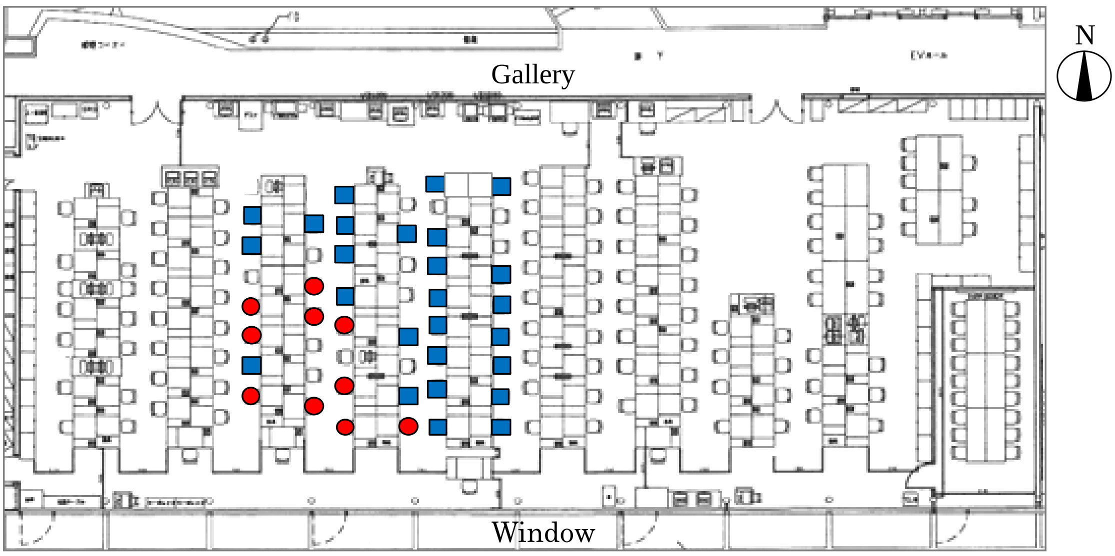
Office Building Name	Tokyo Gas Kohoku NT building(the earth port)					
location	Yokohama City of Kanagawa PREF.					
Scale of Building	4 floors above ground, penthouse 1 floor					
Investigation Period	Autumn			Winter		
	9/30-10/7	10/8-10/19	10/20-10/27	11/15-11/21	11/22-11/29	12/6-12/14
Questionnaire Period	—	—	—	○	—	○
A Number of Cool Chair User	33 males					

Fig.6. Photograph of the office building

Fig.7. Third-floor office space

Table 2. Formulae used to compute seating conditions, rate of being seated and usage rate of the chair

Seating Conditions	temperature of the seat of a chair : under 30°C	0.2°C /min and over
	temperature of the seat of a chair : 30°C and over	-0.5°C/min and over
Seating Rate	Seating Rate ＝ Seating Time / Working Hours	
Usage Rate of the Chair	Usage Rate of the Chair ＝ Used Time / Seating Time	



●:10 Cool Chairs of investigation object ■:Other chairs were introduced

Fig.8. Third-floor plan and locations where Cool Chairs and other chairs were introduced

4. Results

4-1. Seated Rate and Usage Rate of the Cool Chair

The Cool Chair was used in autumn and winter. Recently, the authors conducted a survey during summer. Fig.9 shows the monthly usage rate of the chairs. Cool Chairs were used from autumn to winter. However, the usage rate of the Cool Chair reduced 11.3 percent from October to November and 4.5 percent from November to December. During December, the chairs were seldom used. Fig.10 shows the hourly seated rate and usage rate of the chairs. As shown in this figure, the seated rate was 10–40 percent throughout the day. The results show that the seated rate was high at 8:00 a.m., 2:00 p.m. and 7:00 p.m. The authors speculate that these were the times when Cool Chair users came into the office. The usage rate gradually increased; starting from 7:00 a.m., the highest usage rate was at 12:00 noon, and the lowest usage rate was at 2:00 p.m.

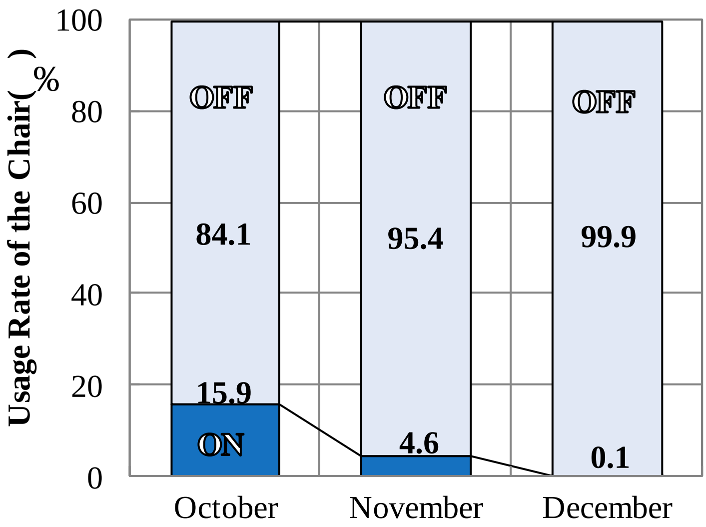


Fig.9. Monthly Usage Rate of the Chair

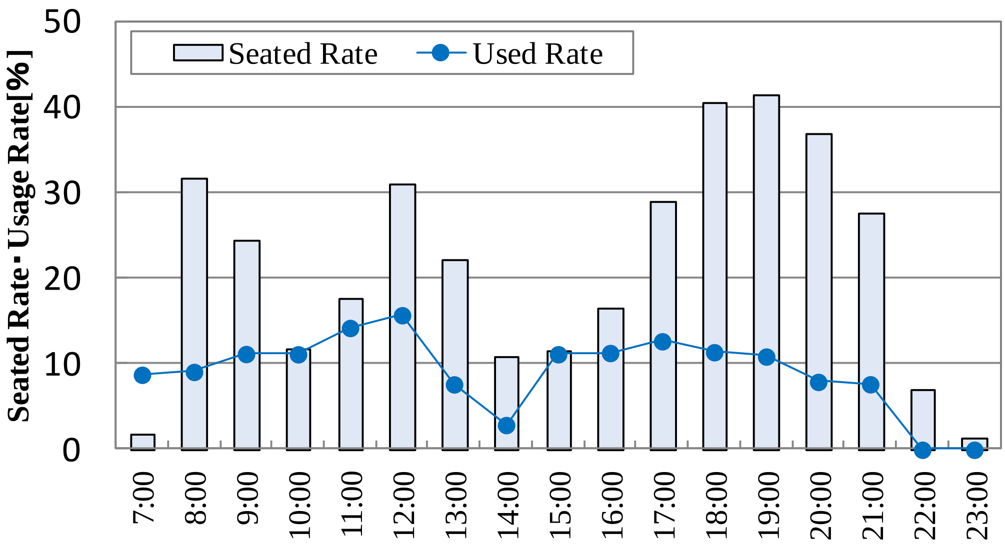


Fig.10. Seated Rate and Usage Rate of the Chair

Fig.11 shows the usage rate of the Cool Chair and the sitting time in late October when the Cool Chairs were used more often. As shown in the figure, typically, the amount of time that office workers remained seated was 1–5 min. As the sitting time increased, the usage rate tended to decrease. Also, the duration of sitting did not extend beyond 60 min. In most cases, the Cool Chair was used from 31 to 35 min; the Cool Chair was not used over 40 min at a time.

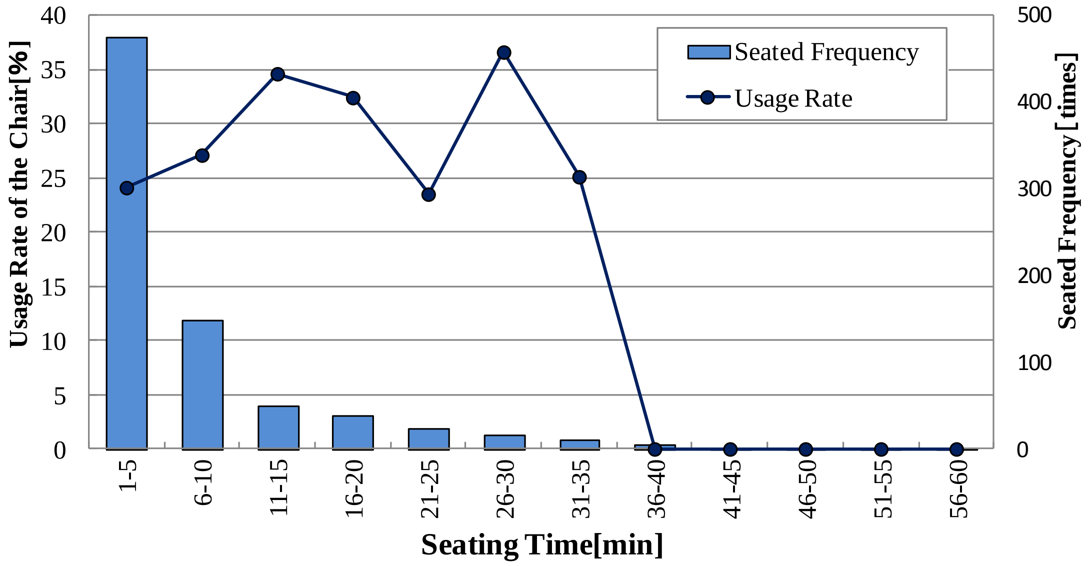


Fig.11. Usage Rate and Sitting Time in Late October when the Cool Chairs were Most Often Used

4-2. Outdoor Temperature and Usage Rate of the Chair

Fig.12 shows relationship between outdoor temperature, indoor temperature and the usage rate of the Cool Chairs. Room temperature is almost constant during the measurement period. However, the ambient temperature and the daily usage rate of the chair tend to gradually decrease from October to December.

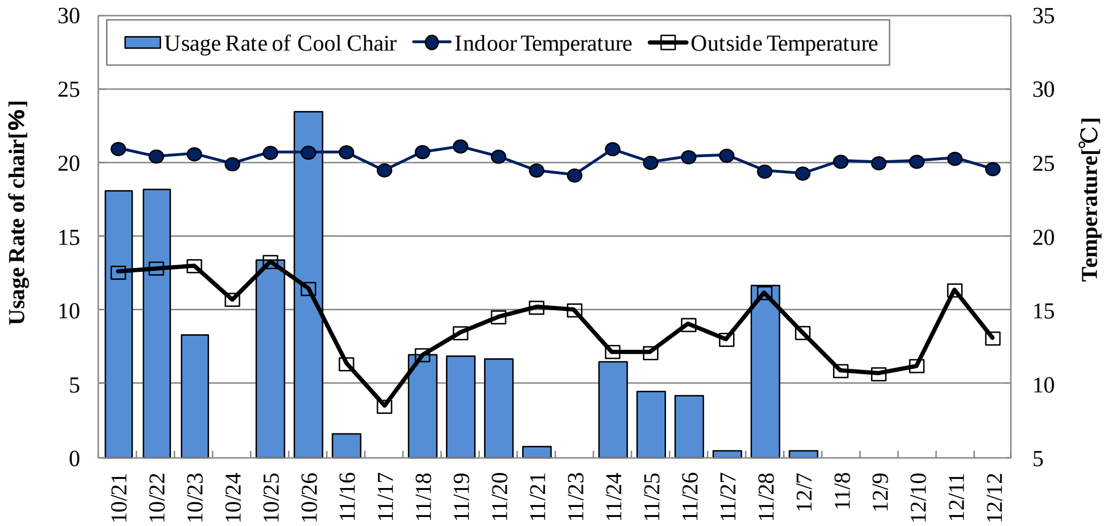


Fig.12. Outdoor Temperature, Indoor Temperature and Usage Rate of the Cool Chair.

Fig.13 shows outdoor temperature and usage rates, and Fig.14 shows the situations for which the workers used the Cool Chair. When the outdoor temperature increased, usage rate of the Cool Chair increased. As shown in Figs. 13 and 14, the usage rate of the Cool Chair can be assumed to be correlated to the outdoor temperature more than the room temperature. In addition, as shown in Fig.14, most office workers indicated that they used the Cool Chair after they came into the office. From these results, Usage rate of Cool Chair is ascribable to environmental history and action history.

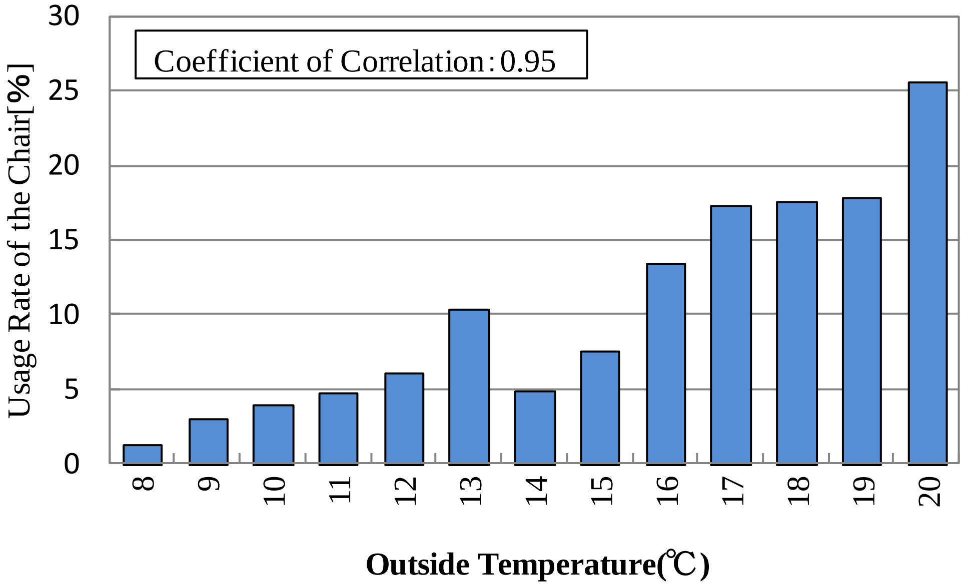


Fig.13. Outdoor Temperature and Usage Rate

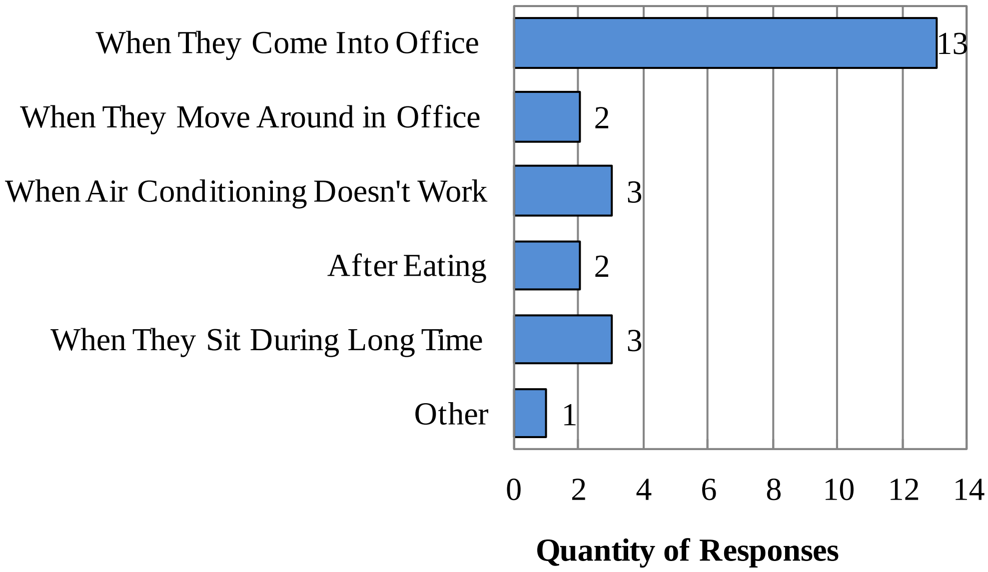


Fig.14. Situations for which the Cool Chair Was Used

4-3. Air volume used by the Cool Chair

Fig.15 compares each seated time of the usage rates of the Cool Chair and air volume. As shown in Figure 15, the usage rate of the Cool Chair decreased gradually, and the Cool Chair was not used after 32 min. The Cool Chair's air volume tended to increase after 25 min, and in general, the Cool Chair's air volume was approximately 30 m^3/h. Thus, when the Cool Chair was used concurrently with standard seating, the Cool Chairs tended not to be used after approximately 30 min.

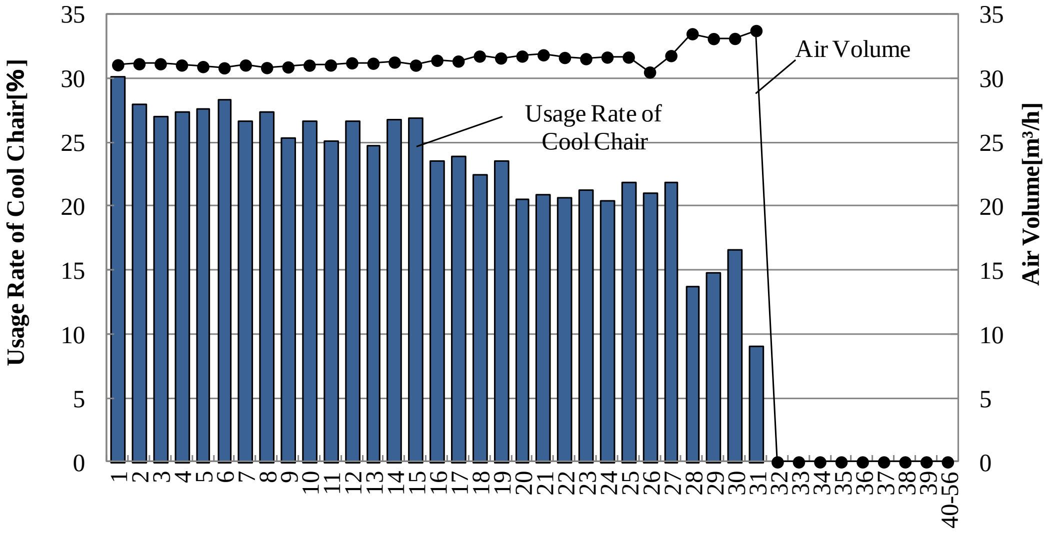


Fig.15. Each Seated Time of Usage Rates of the Cool Chair Compared to Air Volume

Fig.16 shows the frequency of usage at different levels of air volume from early October to late December. The office workers most often combined the air flow from the armrests and the seat using the follow method: ‘armrest air volume of least (main1) + seat air volume (seat).’ Their highest usage was air blasting from the seat. Most office workers were accustomed to lowering the heat from the seat of chair. The results show that the maximum air volume had not been used much in autumn and winter of the investigation. The office workers often combined the airflow from the seat and the armrests.

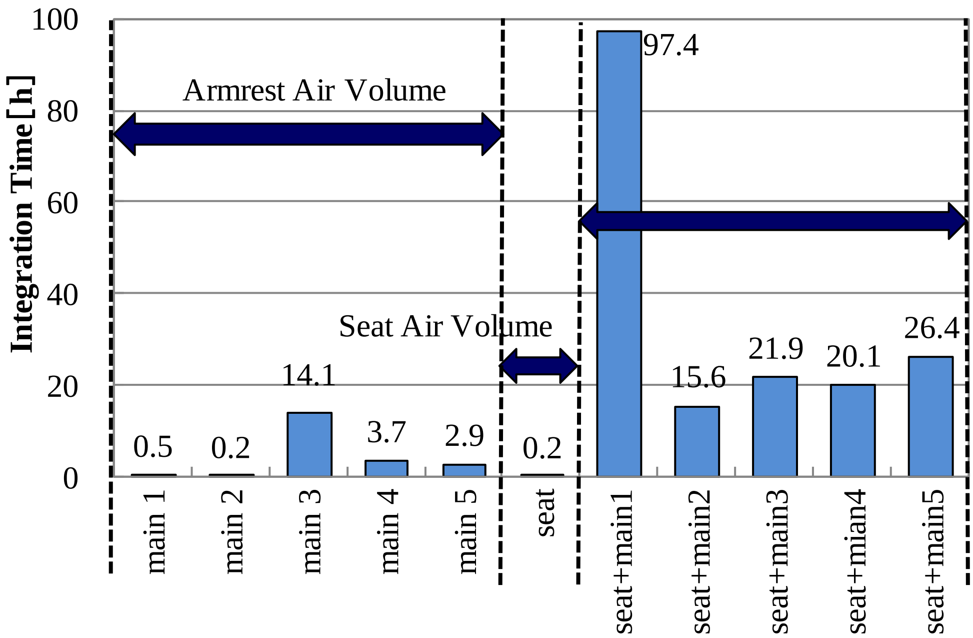


Fig.16. Frequency of Usage of Each Level of Air Volume

Fig.17 shows the location at which the users aimed the airflow from the Cool Chair. The target locations that received the maximum air were first the arm and then the face. Next, most of the Cool Chair users aimed the airflow at locations with exposed skin. Fig.18 shows the perception of air volume. Most workers responded ‘neutral’, but next highest responses were ‘slightly light’. As previously shown, the maximum volume of air that appeared to be ‘light’ was blowing at 40 m^3/h.

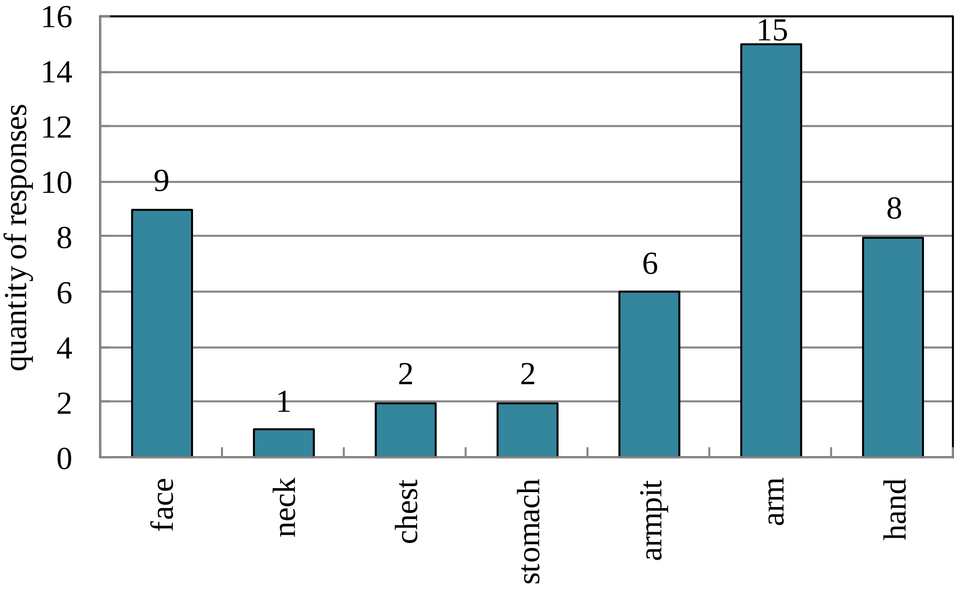


Fig.17. Locations Where Users Aimed the Cool Chair’s Airflow

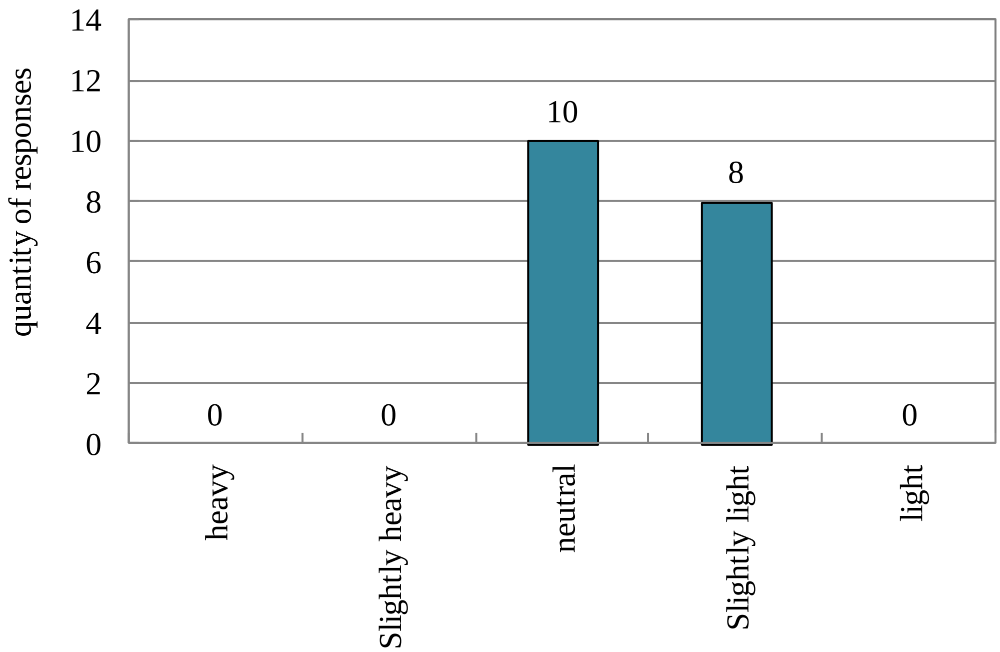


Fig.18. Perception of Air Volume

4-4. Thermal Sensation Responses and Comfort Sensation Responses

Figs.19 and 20 show the workers responses to questions about thermal sensation and comfort sensation. These responses were given by Cool Chair users and standard office chair users. Respondents to the survey were all males. The standard office chair users expressed a wide range of opinion about thermal sensation, selecting from 'very hot' to 'very cold'. In contrast, the Cool Chair users' thought that their thermal sensations were neutral. As shown in Fig.20, the Cool Chair users and standard office chair users expressed the same opinion about the maximum level of comfort sensation. However, the minimum value was considered higher by users of the Cool Chairs, because a higher proportion of those users felt comfortable with that environment. For this reason, the workers responded more positively when they used the Cool Chair than when using the standard office chair.

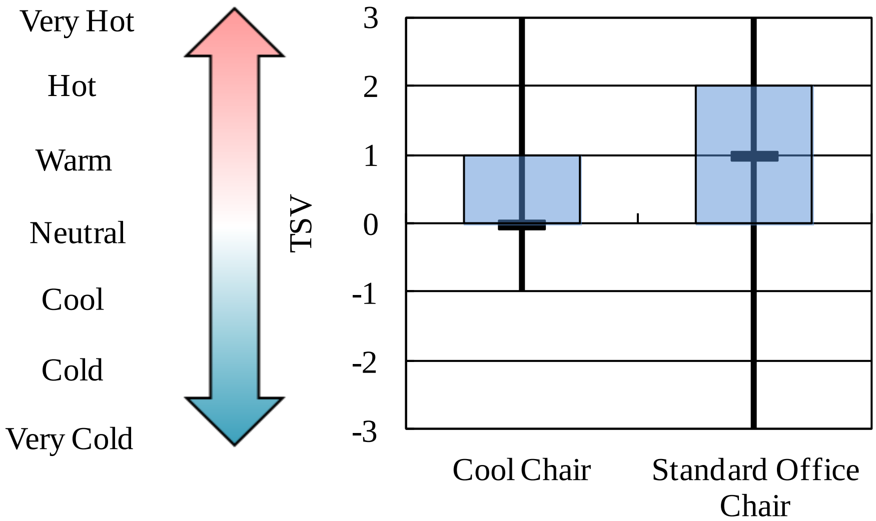


Fig.19. Responses Concerning Thermal Sensation

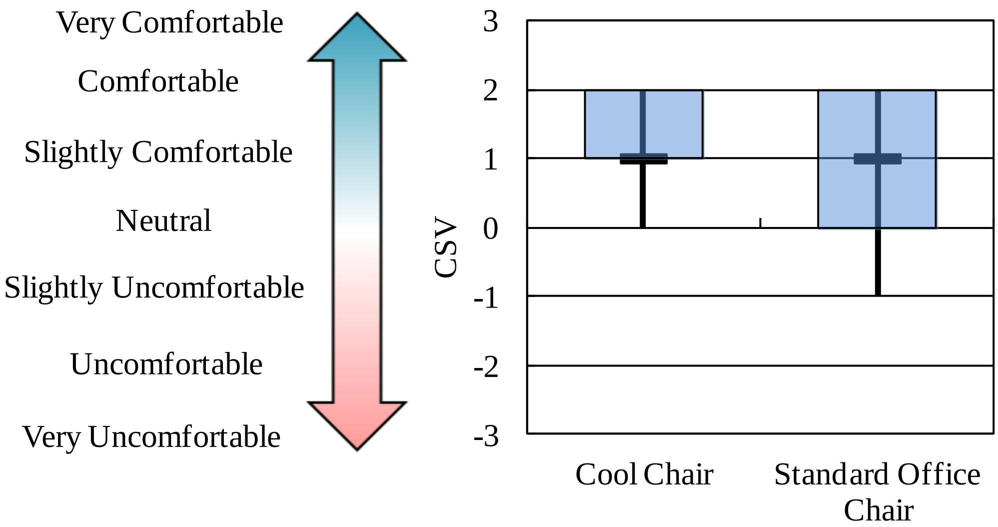


Fig.20. Responses Concerning Comfort Sensation

Fig.21 shows the relationship of the frequency of usage and comfort sensation. Office workers who frequently used the Cool Chair tended to be more comfortable than those who used the Cool Chair less frequently. Office workers in the perimeter zone tended to high frequency of usage. These results show that office workers exhibit a greater latitude in behavioural adaptation when they use the Cool Chair, and the author understand that they can gain more a comfortable feeling by using Cool Chair.

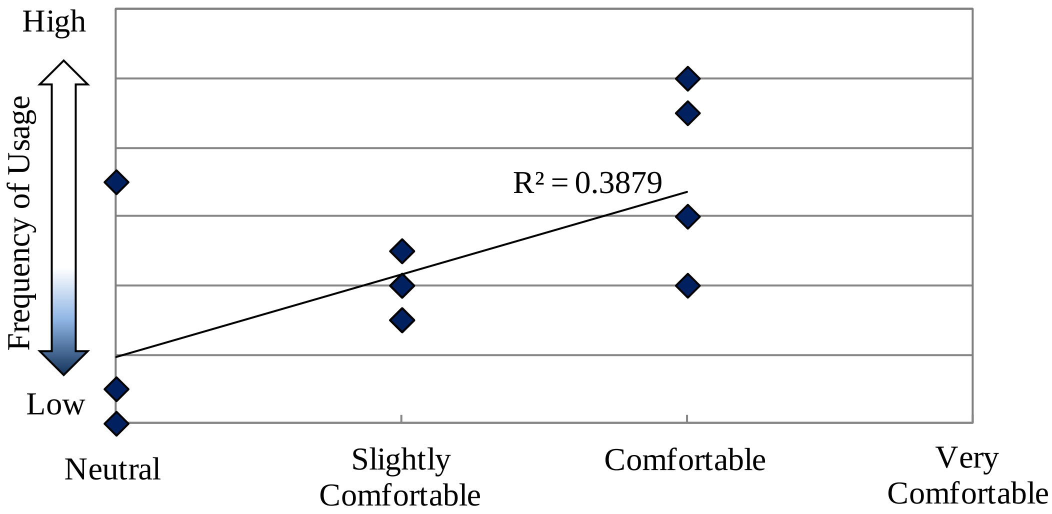


Fig.21. Relationship of Frequency of Usage and Comfort Sensation

5. Conclusions

The following are the results of our detailed investigation. First, the workers tended to use the Cool Chair the most when they returned to the office. Also, the usage rate increased with the ambient temperature. Therefore, the Cool Chair usage rate was assumed to be due to the weather outside. Second, the workers who used the Cool Chair felt more comfortable than those who used the standard office chair. Finally, the Cool Chair usage rate differed by office worker. The more frequently a worker used the Cool Chair, the more he expressed a feeling of comfort. Based on these results, we will increase the number of office workers who will be offered the choice to sit in a Cool Chair. The authors predict that these office workers will actively use the Cool Chair to become thermally comfortable. Overall, the office workers were positive about having the capability of personal air conditioning.

6. References

[1] Washinosu, K., et al. (2011), Application of ‘Cool Chair’ for ZEB renewal office building. Part 1: Specification of prototype ‘Cool Chair’. Summaries of Technical Papers of the Annual Meeting of Air-Conditioning and Sanitary Engineers, Japan, 14 - 16 September 2011 (in Japanese).

[2] Suzuki, I., et al. (2011), Application of ‘Cool Chair’ for ZEB renewal office building. Part 2: Operational status in actual offices during autumn. Summaries of Technical Papers of the Annual Meeting of Air-Conditioning and Sanitary Engineers, Japan, 14 - 16 September 2011 (in Japanese).