EVALUATION OF SUMMER INDOOR CLIMATE WITH AIR MOVEMENT

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ABSTRACT In order to design an environment-conscious house, it is desirable for summer indoor environment, to re-examine thermal conditions warmer than thermal comfort. The role of air movement is important, as it reduces the magnitude of discomfort. This paper discusses the comfort produced by air movement considering two main sensations; coolness and strength of movement, based on results obtained by a series of experiments carried out with five male and five female subjects. The secondary point to be discussed is the evaluation of humid hot environment considering the effects of air movement, where cooling power is positive and that of excessive strength is negative. The contributions of the sensations of warmth of the whole body and air movement to discomfort are tested based on results obtained by experiments conducted with six male and six female subjects.

1. INTRODUCTION

We have to change our life-style from the mode of the earth's environment. Energy usage is depend on our everyday life. It might include the concept of "comfort" as the goal of the indoor climate. In this study we made a series of experiments with human subjects intended to evaluate the summer indoor climate. The thermal conditions tested ranged from thermal neutrality to hot.

First we evaluated the effect of air current on people in thermal neutrality, considering two main sensations of air current; " coolness" and "strength", which can cause both comfort and discomfort. Secondary experiments discussed in this paper are the effects of an air current on people in warm conditions. In general, an air current is accepted as a comfortable stimulus, however excessive strength can produce discomfort.

We also examined the over all effects of sensations (whole body thermal sensation and that of air current) on feelings of comfortableness.

2. EXPERIMENTS ON THE EFFECTS OF AIR CURRENT ON PEOPLE IN THERMAL NEUTRALITY

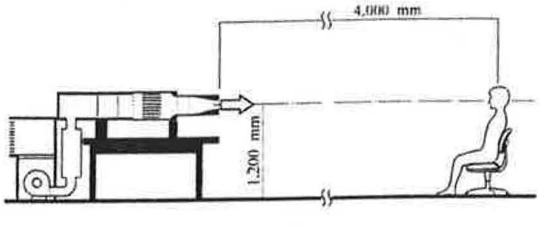

Figure 1 Setup for producing air current

The air current tested is illustrated in Figure 1. Air velocities tested ranged from 0.25m/s to 1.2m/s (0.25, 0.5, 0.65, 0.75, 0.9, 1.2m/s), and the room temperatures were 20, 23 and 26 ℃. Humidity was maintained at about 55 %. Five male and five female human subjects were instructed to wear a specific combination of clothing for each test temperature so that they could reach thermal neutrality.

The five subjects entered the testing room and stayed sedentary for 30 minutes under the condition of no air current. Then the subjects moved to a chair in front of a nozzle one by one, and sat receiving a current of air for 3 minutes. They were asked to report their whole body thermal sensations, and that of the air current: strength, coolness and comfortableness.

Figure 2 shows the relation between feelings of comfortableness and those of strength of air current. We find the peak comfort around the "neutral" strength sensation.

The regression line shown in the figure for data on the "strong" side only, is expressed as follows:

$$Yc(s) = -0.91\,Ys + 0.84 \quad \cdots (1)$$

Yc = sensation of comfortableness on air current [-]

Ys = sensation of strength of air current [-]

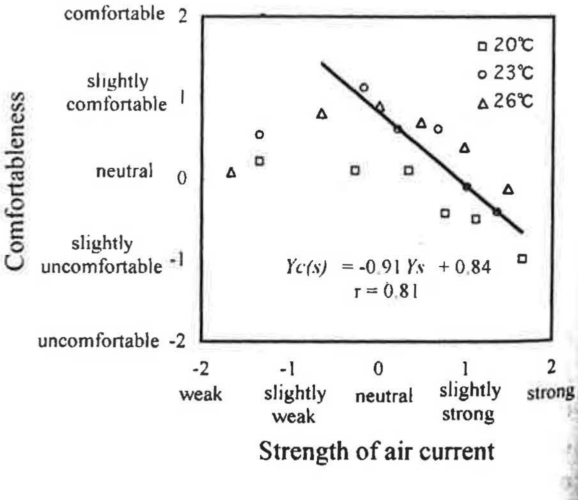

Figure 2 Comfortableness vs Strength of air current

The relationship between feelings of comfortableness and coolness of air current is shown in Figure 3. We see that the peak comfort lies around the middle between "neutral" and "slightly cool". The expression below represents the sensation of comfortableness as a function of the sensation of coolness:

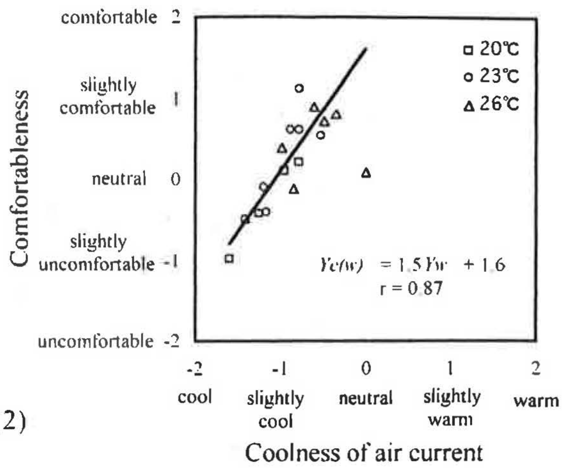

Figure 3 Comfortableness vs Coolness of air current

$$Yc(w) = -1.5Yw + 1.6 = -1.5(Yw+0.5) + 0.85 \cdots (2)$$

Yc = sensation of comfortableness on air current [-]

Yw = sensation of coolness of air current [-]

Based on the results described above, the comfortable feeling is assumed to be a function of the sensations of both the strength and coolness of the air current, when the whole body thermal sensation is neutral:

$$Yc = f(Yc(s), Yc(w)) \cdots (3)$$

After trial and error, we found the following expression to give a good correlation with comfortableness:

$$R = \sqrt{0.27\{Yc(s) - 0.85\}^2 + \{Yc(w) - 0.85\}^2} = \sqrt{0.22Ys^2 + 2.25(Yc + 0.5)^2} \cdots (4)$$

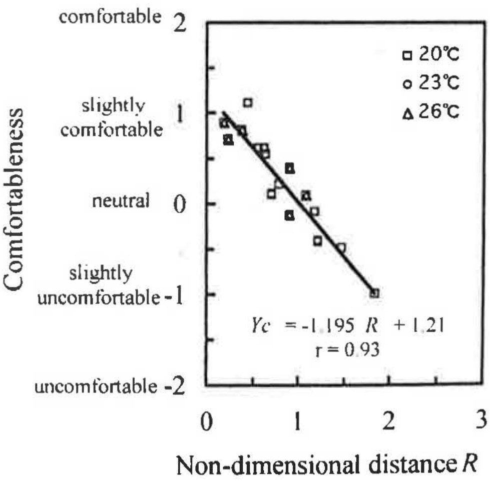

Figure 4 Comfortableness vs Non-dimensional distance *R*

Figure 4 shows a good relation between the non-dimensional distance R, and comfortable feeling Yc. This is expressed as follows:

$$Yc = -1.195\,R + 1.207 \cdots (5)$$

$$Yc = -1.80\sqrt{0.10Ys^2 + (Yc + 0.5)^2} + 1.207 \cdots (6)$$

In summary, a peak is found around 26 ℃ and 0.6 m/s.

3. EFFECT OF AIR CURRENT IN HUMID HOT ENVIRONMENT

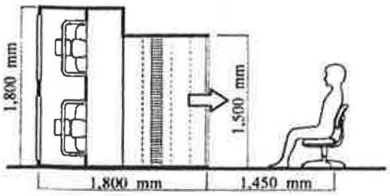

Figure 5 Setup for producing air current

Temperatures tested were from 28 to 34 ℃ and air velocities from 0.1 to 1.8 m/s, which simulated an air current coming from a window opening (Figure 5). Relative humidity was 80 %. The thermal resistance of clothing: short sleeves and short pants, was estimated at 0.3 clo. Six male and six female human subjects participated in the experiments.

The sensations asked to be reported included whole body thermal sensation, sweating, air current strength and general comfortableness of the thermal conditions.

The subjects stayed in an anteroom at 27 ℃ and 60 % humidity without any air current for 30 minutes, then entered the testing room and stayed there in a sedentary state receiving an air current from the front for 30 minutes. For the analysis, we used the reports at 30 minutes after the air current started.

Figure 6 shows the relationship between comfortableness and whole body thermal sensation. We found a good correlation between them. But examing this figure more precisely we see that the comfortableness varies with air velocity and an air velocity of 1.8 m/s was evaluated as lower than that of 0.6 m/s.

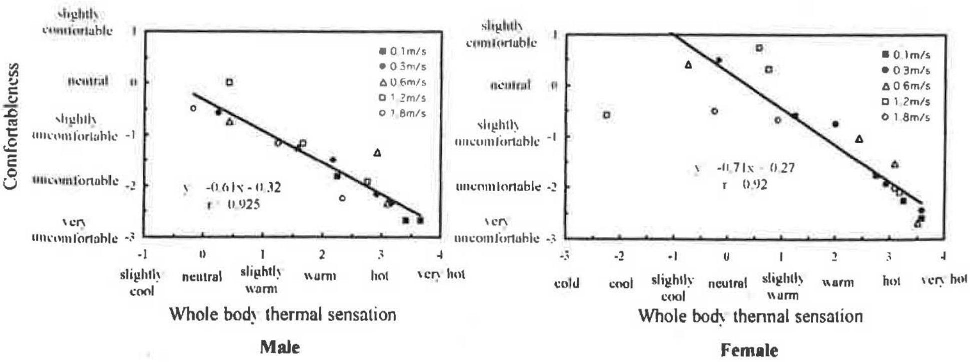

Figure 6 Comfortableness vs Whole body thermal sensation

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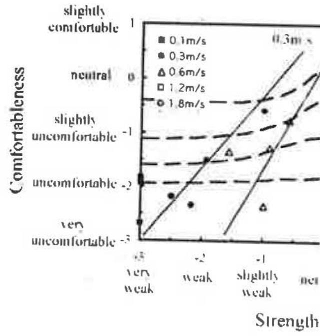

Figure 7

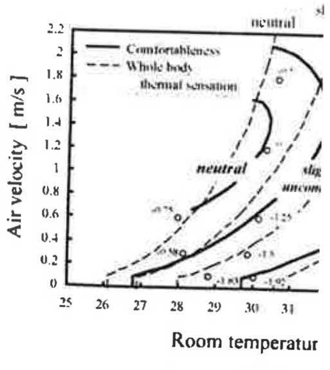

Figure 8 Comfortableness

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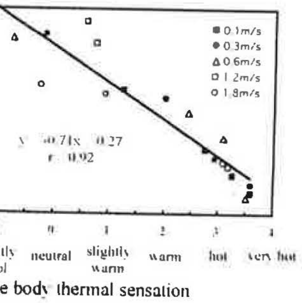

rmal sensation

Figure 7 represents the effect of the strength sensation on comfortableness. The comfort peak appears between "neutral" and "slightly strong", which corresponds to a velocity of around 1.2 m/s (provided the whole body thermal sensation is the same). An air velocity of 1.8 m/s seems to be too strong. From these results. we reconfirmed that the cooling power of an air current can reduce the thermal discomfort of a hot environment, however it can also produce its own discomfort due to the physical stimulus of the air current.

Figure 8 shows the contours of comfortableness in which the positive and negative effects of the air current in a warm environment are considered. It was found that the air velocity capable of improving a hot environment is less than about 1.2m/s.

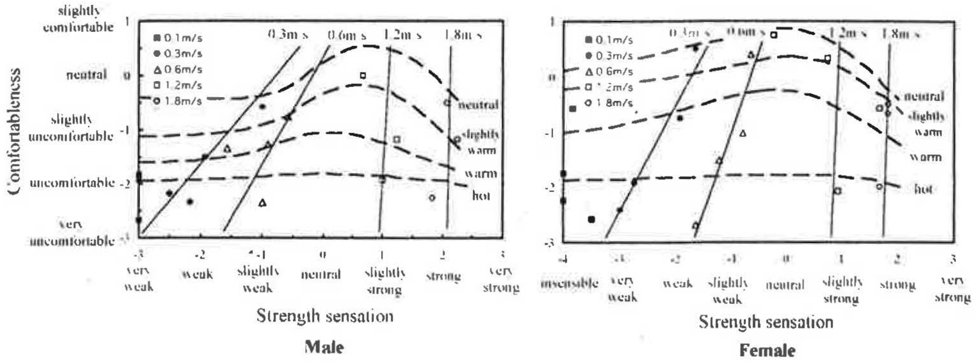

Figure 7 Comfortableness vs Strength sensation

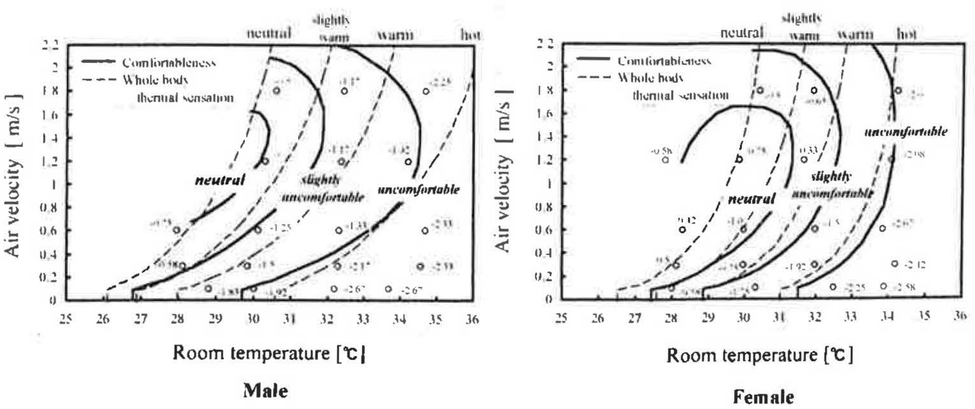

Figure 8 Comfortableness in relation to the positive and negative effect of air current

4. CONCLUSIONS

The sensation of comfortableness of an air current has been examined, when the whole body thermal sensation has been kept neutral. The most comfortable conditions have been found when the strength sensation of the air current is around "neutral" and the coolness between "neutral" and "slightly cool" ; that is 26 ℃ and 0.6 m/s respectively. A hot environment has been evaluated in which the comfortableness of people has been found to be a function of both whole body thermal sensation and air current sensation. An air velocity higher than 1.2 m/s produces a negative feeling due to excessive strength. The highest room temperature without losing comfortableness was found to be around 31 ℃ and 1.2 m/s.

ACKNOWLEDGMENT

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1. INTRODUCTION

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