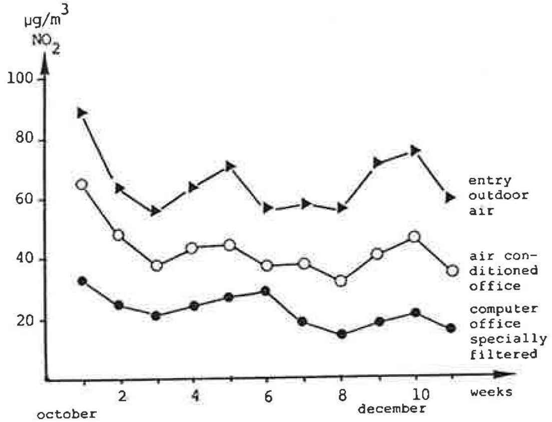


Fig. 1: Relation outdoor - indoor air in an air conditioned building in the town center.



# VENTILATION REQUIREMENTS IN BUILDING FOR CONTROL OF BODY ODOR

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## Abstract

We investigate the relationship between the indoor $CO_2$ level caused by sedentary occupants' expiration and subjective evaluation of body odor by visitors by means of the same method as Yaglou's, and try to estimate the ventilation criteria for sedentary persons. Subjective evaluations of body odor are carried out in an environmental chamber as model tests and in classrooms as field tests. The experiments are carried out with various combinations of temperature, humidity, occupancy density and occupants' sweating condition. From the results, we may conclude that the $CO_2$ level is a potential index of body odor and 80 % of visitors may be satisfied with indoor air quality, if $CO_2$ level be kept less than 0.1 % which is adopted as Japanese ventilation standards.

## Introduction

In Japanese Building Code, the minimum ventilation rate is 20 $m^3$/h per occupant in residential and office environments and 30 $m^3$/h per occupant in buildings with a floor space of over 3,000 $m^2$. These values corespond with about 0.13 % $CO_2$ and 0.10 % respectively as the accepted limit. The codes seem to be principally based on Yaglou's result on body odor and ventilation. Since oil shock in 1973, the interest in control of building ventilation has increased as a consequence of the new demands for energy saving. But we have not yet found the criteria for ventilation requirements in buildings.

The body odor is one of main contamination in the occupant space. The fresh air should be fully supplied to maintain body odor at a satisfactory level. Recentry the studies on body odor is investigated to decide the minimum entilation requirement[2),3),5)] In Japan, those studies were conducted by Asano[1)], Minamino[4)] and et.al.. Also we have made the same studies on body odor in these recent years. the experiments will be only briefly described here.

## Method

### Facilities

A series of experiments are conducted in a 20 $m^3$ environmental chamber. The walls of chamber are finished with aluminium foil. The ventilation air is directed into the chamber both from the plenum chamber and from outdoor by the exhaust fan. The chamber process temperature and humidity control. The room air is mixed fully by fan in the chamber. Also, to compare with the model tests in an environmental chamber, a series of the field tests is conducted inclassrooms for university students and general publics during nonsmoking occupancy.

Occupancy Odor

Experiments are designed to evaluate ventilation requirement in offices during sedentary activity for the control of occupancy odor as perceived by visitors. The investigateions of occupancy odor are performed under the following four conditions.

a) The environmental conditions are about 20 , moderate humidity (RH: 30-65 %), and four occupancy densities (5, 7.5, 10 and 15 $m^3$/person). The experiments are performed 3 times for each condition.

b) The environmental conditions are about 20 , high humidity (RH: 80%), and occupancy densities (5 and 10 $m^3$/person). The experiments are made 3 times for each condition.

c) The environmental conditions are about 30 , moderate humidity (RH: 50-70 %), and occupancy densities (5 and 10 $m^3$/person). The experiments are made 2 times for each condition.

d) The environmental conditions are about 20 , moderate humidity (RH: 40-65 %). The occupants are a little sweating by ropeskipping (RMR=20) during about 2 minutes before entering in the chamber. The occupancy densities are 5 and 10 $m^3$/person. The experiments are performed 3 times for each condition.

Each run take over a 2-hour period of occupancy. Temperature, relative humidity and carbon dioxide concentration are monitored continuously. And the odor assessments are made by a few visitors (odor panel) who entered the chamber only shortly from a fresh plenum chamber at every 15 minutes. The assessments are the intensity and the discomfort of occupancy odor. The intensity of odor are measured on a scale running ; 1.definite, 2.moderate, 3.strong, 4.very strong, and the acceptance of discomfort are measured on a scale running ; 1.slightly uncomfortable, 2.uncomfortable, 3.very comfortable.

Both occupants and panels took a bath and changed their clothes on the previous day of the experiment, and kept from smoking, drinking, taking scented foods and using toiletries on the day of experiments.

Also, in the field tests, the odor is emitted from occupants attending normal lessons in the classroom which seats about 30 persons for the university students and seats about 100 persons for the general publics. Those experiments are performed 7 times for the university students and 2 times for the general publics.

## Results and Discussion

The effect of occupancy densities on odor intensity

Figure 1 shows the relationship between the indoor $CO_2$ level and the body odor intensity at four kinds of occupancy densities for the (a) condition. These curves are the average values obtained from the assessments of a few panel at each occupancy density. Odor level depended entirely on ventilation rate per person irrespective of the occupancy densities, like those of Leaderer and Cabin, but unlike Yaglou's.

The effect of environmental conditions on odor intensity

Figure 2 shows the relationship between the indoor $CO_2$ level and the odor intensity judged by panels under the foregoing four conditions. The straight lines on Fig.2 represent the regression fits of each condition to



Eq.1.

$$I = k_1 \log S - k_2$$

where; I : the odor intensity judged by panel
S : the indoor $CO_2$ level (ppm)
$k_1, k_2$: empirical constants

The results of the regression analysis on the four conditions are summaried in Table 1.

Table 1 Empirical parameter obtained by regression analysis for each condition

| Condition | $k_1$ | $k_2$ | r | |
|---|---|---|---|---|
| a | 4.20 | 11.9 | 0.94 | 0.29 |
| b | 4.28 | 11.4 | 0.94 | 0.36 |
| c | 4.22 | 11.6 | 0.97 | 0.26 |
| d | 4.58 | 12.6 | 0.97 | 0.28 |

Where; r : correlation coefficient
: standard deviation

1. From the results for the (a) and (b) conditions, this suggests that a significant influence of air humidity on the olfactory judgements of body odor is proved. The reason seems to be considered whether the emission rate of body odor from occupants increase or whether the actual olfactory stimulus of body odor by panel increase.

2. From the results for the (a) and (b) conditions, this suggests that a significant influence of air temperature on perceived odor intensity is observed, so that a little sweating seems to occur when air temperature is about 30 .

3. For the (a), (b) and (c) conditions, the occupants keep very clean personal hygiene. But a part of the occupants in the actual rooms do not always keep clean hygiene. So the experiments for the (d) condition are conducted for the occupants who generate a little sweating by ropeskipping before just entering in the chamber. Significant difference between the odor intensity in the (a) and (d) conditions with the same $CO_2$ level is found. These difference seems to have been caused by occupants' sweating before entering the chamber in the (d) condition.

4. The results of the field tests conducted in the classrooms are plotted in Fig.2 to compare with the results of the environmental chamber. The obtained values in the classrooms seems to be rather resemble closely that for the moderate condition than that for the conditions of high temperature, high humidity and occupants' sweating.

The relationship between the intensity and the discomfort of body odor

Figure 3 shows their relationship under the four conditions. The straight lines on Fig.3 represent the regression fits of each condition. No significant difference between their relationship for every condition is found. That is, the discomfort of odor may be provided for a given odor intensity under every environmental condition.

From the previously experiments, it is proved that the indoor $CO_2$ level can determine approximately the intensity and the discomfort of body odor. But the criteria for odor acceptability can not be immediately determined from those results. ASHRAE Standards takes as subjective evaluation that the air can be considered acceptably free of annoying contaminant, if 80 % of a panel of at least 20 untrained observers deems the air to be not objectionable under occupancy.

The proportion of discomfort votes cast in each category as a function of $CO_2$ level is obtained from the experimental result. For example, that for (a) condition is shown in Fig.4. Then $CO_2$ level of category boundary of (1) and (2) for every condition is shown in Fig.5. The discomfort category (1) should be taken as acceptable air quality, because the category (1) is corresponded to the odor intensity 2,4. If the relationship between the indoor $CO_2$ level and the sensational intensity or the discomfort of body odor in the ordinary room may be extended its width between (a) and (d) conditions, the indoor air quality on occupancy decided from 1000 ppm $CO_2$ in Japan, is seemed to be accepted from about 80 % of visitors.

## Conclusions

1. The indoor $CO_2$ level produced by the occupants seems to lead to approximately the same body odor level irrespective of occupancy density.
2. The relationship between the indoor $CO_2$ level and the odor intensity could be represented by Weber-Fechner's low.
3. The discomfort of body odor could be provided for a given odor intensity level irrespective of how the environmental conditions of the chamber possessed.
4. 80 % of visitors may be satisfied with indoor air quality on occupancy, if $CO_2$ level be kept less than 0.1 %.

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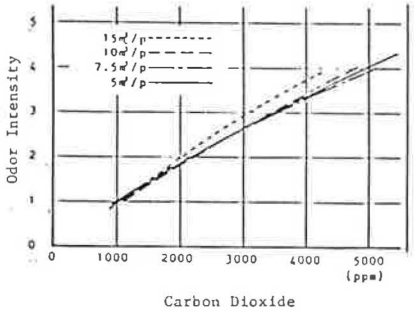


Fig.1 Odor intensity in relation to $CO_2$ level and occupancy density.

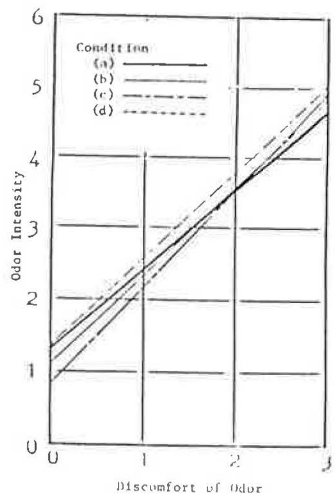


Fig.3 Discomfort of body odor as a function of odor intensity for every condition.

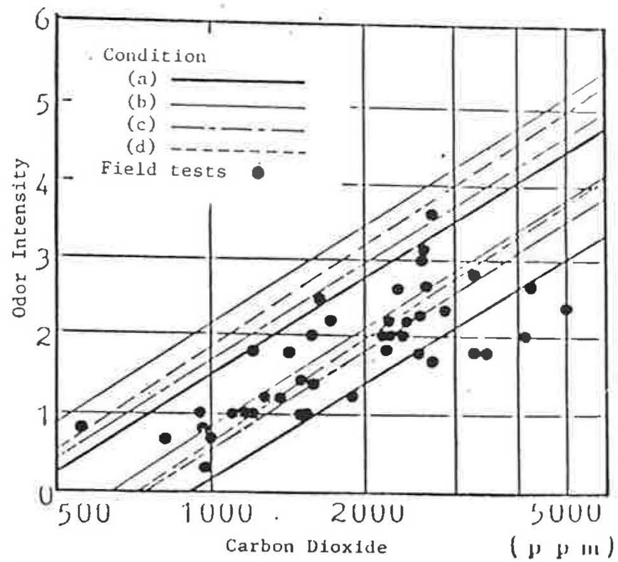


Fig.2 Odor Intensity as a function of $CO_2$ level for every condition.

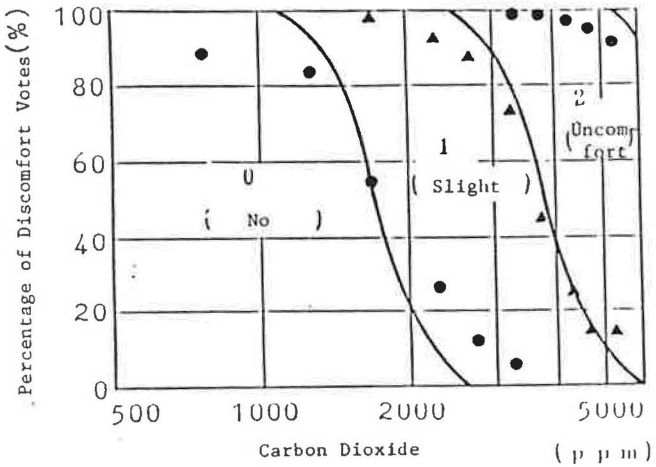


Fig.4 Percentage of discomfort votes as a function of $CO_2$ level for (a) condition.

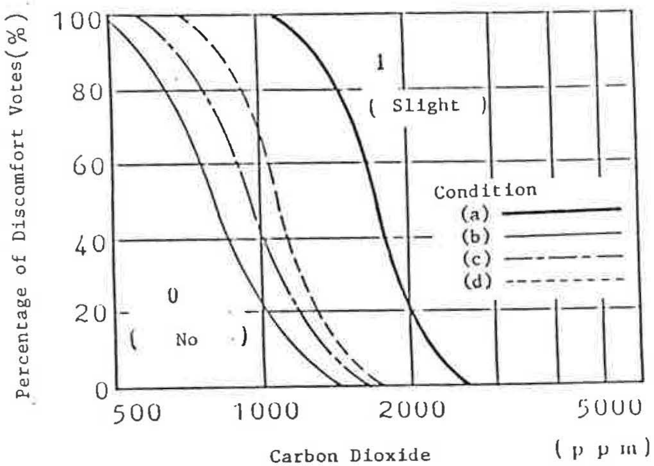


Fig.5 $CO_2$ level of discomfort category boundary (1) and (2) for every condition.



# DEVELOPMENT OF A DESICCANT BASED AIR CONDITIONER WITH INDOOR POLLUTION CONTROL CAPABILITIES

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## Abstract

Application of heating, ventilation, and refrigeration systems to control living and working conditions has enhanced comfort conditions and has measurably increased productivity. Recent energy conservation measures have made buildings "tighter" and have exacerbated concerns about potential indoor air pollution. This paper reviews the development effort of a desiccant based air conditioner. The gas-fired desiccant dehumidifier (along with particulate filtration) may not only provide improved thermal comfort, but also superior indoor air quality (IAQ) control. It is concluded that the desiccant based system is economically viable and shows excellent promise for enhanced comfort conditioning and air quality control.

## Background

The World Health Organization defines IAQ as control of a person's wellness regarding health as well as mental and social well-being. Surveys [3] indicate that poor IAQ will hamper performance in the working environment. Concerns regarding control of IAQ in private homes are emerging now also. Additionally, the control of humidity to impose thermal comfort is very important especially in warm and moist climates, like the south and southeastern United Sates around the Golf of Mexico.

In Miami, Florida, the cooling season averages 5136 hours for a typical residence. An analysis in [1] shows that 91% of that time the indoor conditions will be outside the comfort zone (25.6 oC, 58% r.h.) as defined by American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE). The humidity distribution in Figure 1 further indicates that for over 440 hours per year the relative humidity will exceed 70% - the level at which mold and mildew form. This will be the case if a vapor compression system conditions the residence at a set point of 25.6 $^{o}C$. Designing a structure to be energy conserving aggravates the problem by increasing the number of hours exceeding 70% r.h. to over 660 for the cooling season [1].

Most cooling systems - whether gas or electric - actually provide two types of cooling: sensible cooling, or temperature reduction, and latent cooling, or dehumidification. In a desiccant-based cooling system, the latent cooling load is met by means of a desiccant, or drying agent, that removes moisture from the air via absorption or adsorption. The desiccant is regenerated by the application of a heat source that releases the