OCCUPANT INTERACTION WITH VENTILATION SYSTEMS

7th AIC Conference, Stratford-upon-Avon, UK
29 September - 2 October 1986

PAPER 14

MEASUREMENT OF CARBON DIOXIDE OF THE INDOOR AIR TO CONTROL THE FRESH AIR SUPPLY

I.Fecker, H.U.Wanner

Institut für Hygiene und Arbeitsphysiologie
ETH-Zentrum
8092 Zürich
Switzerland

SUMMARY

In order to save energy, i.e. ventilation heat losses, the fresh air change rate should be adapted to the prevailing need. Even though it is a fact, that reducing the fresh air change rate will result in a ventilation heat gain, the fresh air flow rate should not be kept too low, so that pollutants, humidity and body odour can accumulate.
The results of measurements in a climatic chamber and in a lecture theatre show a significant relationship between the concentration of carbon dioxide and body odour of the indoor air under nonsmoking conditions.
The upper limit of carbon dioxide, where the indoor air quality is still acceptable to persons entering a room, is between 0.1 % and 0.15 % vol, whereas for occupants in the room this limit is higher because of adaptional effects.

1. INTRODUCTION

A new environmental problem has increased in the last ten years: in modern, energy efficient buildings some of the occupants show reactions similar to those known to be caused by formaldehyde, but even when the concentration of that pollutant is well below known reaction thresholds. These symptoms are explained as the net result of a summation or interaction of numerous subthreshold sensory stimuli. Many sensory systems may be involved, but the perceptual mechanisms are largely unknown [1].
Since many people spend an important part of their time in artificially ventilated or climated rooms, a healthy and comfortable indoor climate will attract more and more attention.
In other words: the temperature should be adapted to the activities of the occupants and humidity, pollutants and annoying odours must not accumulate [2].
The prevailing need of fresh air depends on the number of persons and on their activities in a certain space. Often, the fresh air supply is controlled by temperature; but does temperature really reflect the effective occupancy of a room ? The aim of this work is to point out the relationship between temperature, concentration of carbon dioxide and body odour of the indoor air, with the intention of working out a leading component

of the indoor air quality.
The natural concentration of carbon dioxide, an odour- and colourless non-toxic gas, in the athmosphere is about 0.035 % vol. Animals as well as human beings exhale carbon dioxide as combustion product of their biological metabolism; for man in sitting position the amount is around 20 l per hour [3].
If man is the only source of odours and pollutants in a room, the concentration of carbon dioxide seems to be suitable to control the fresh air supply.

2. METHOD

Measurements have been carried out in a climatic chamber and in a lecture theatre. The climatic chamber had a volume of 30 m^3. The volume of the lecture theatre was 950 m^3 and there was space for 160 students. The air inlet was situated at the ceiling and the air outlet on the floor.
Fresh air flow rate and humidity were always kept constant, while the temperature and the concentration of the indoor carbon dioxide were measured continuously. Discharge air was sucked off and offered to a test panel outside. They subjectively compared the perceived odour intensity with some pyridine reference odours, and they also answered some questions concerning the acceptance of the indoor air quality after 15, 60 and 90 minutes (lecture theatre), or after 30, 60, 90 and 120 minutes (climatic chamber). Together in time, the persons in the chamber replied to those questions, while the students in the lecture theatre did the questioning only at the end of the lectures.
All the measurements are summarized in tables 1 and 2.

3. QUESTIONING AND ODOUR INTENSITY MEASUREMENT

The questions are listed in table 3. The first question "measures" the subjectively perceived odour intensity by category scaling. In a similar way, Yaglou already did that in 1936 [4].
The percentage of persons, who judge an odour as not acceptable, depends on the demands one makes on the comfort of indoor air quality (second question).
The annoyance reaction (third question) is composed of an impact of former experiences. It always has to be

seen in context of the immediate environment of the exposed person.
The last question was only asked the students in the lecture theatre. Amongst temperature, the subjective perception of temperature also depends on the clothing. However, that was not registered, but all the tests were carried out on cold winter days.
In the case of the lecture theatre measurements, bottles with different pyridine concentrations in water were used as reference odours; but they were produced by dynamic olfactometry for the climatic chamber experiments. The odour concentrations were: 0.67, 1.2, 2.2, 3.9 and 7.0 mg/m³ (lecture theatre) and 0.11, 0.19, 0.35, 0.62 and 1.1 mg/m³ pyridine (climatic chamber). Direct comparison of the two sets of odours showed, that the odours in bottles were subjectively valued six times less intense than the odours offered by dynamic olfactometry. In order to be able to compare the results of both of the places, the two sets of reference odours were standardized.

4. RESULTS

The answers of the students in the lecture theatre were subdivided into the following seven subgroups of different environmental conditions:

< 0.08 ≤ 21.0	0.08-0.15 ≤ 21.0	
< 0.08 21.1-22.0	0.08-0.15 21.1-22.0	> 0.15 21.1-22.0
	0.08-0.15 > 22.0	> 0.15 > 22.0

CO_2	% vol
T	°C

Because of the small number of persons in the climatic chamber, that classification could not be done there. Also the answers of the two test panels outside were only divided into soubgroups of different carbon dioxide concentrations.
Between the classifications "faint odour" and "distinct odour" on the *category scale* (figure 1), the percentage of the judgements "not acceptable" rose from 15 to 60%.

This limit was reached by the test panels outside the room at a carbon dioxide concentration of 0.08 % vol, while the occupants inside tolerated a concentration higher than 0.15 % vol.
The *annoyance scale* (figure 2) indicates a limit between 2 and 3 on the self-rating "thermometer". The persons outside reached that value at a carbon dioxide concentration of 0.08 % vol, the occupants in the lecture theatre at 0.15 % vol and the occupants of the climatic chamber at concentrations over 0.22 % vol.
At a certain carbon dioxide concentration, the students inside the lecture theatre judged the air quality as worse as higher the temperature was (figures 1 and 2).
The test panels outside perceived the strong odours of the indoor air subjectively more intense by the *reference odour method* than by *category scaling* (compare fig. 1 and 3). No reason was found to explain that result.
The *acceptability* of an odour (question 2) was interpreted together with the *odour intensity* (figure 1) and the *annoyance* by an odour (figure 2).
Within the indoor temperature conditions of the experiments in the lecture theatre, about 50 % of the occupants felt comfortable. The subjective *perception of temperature* showed some dependence on the indoor carbon dioxide concentration, as figure 4 shows.

5. CONCLUSIONS

The measurements in the climatic chamber and in the lecture theatre confirmed the expected relationship between the concentration of the carbon dioxide and the subjectively perceived body odour intensity. A Spearman rank order correlation coefficient of 0.66 between the odour intensity and the carbon dioxide concentration was found for the data of the climatic chamber, and one of 0.4 for those of the lecture theatre. These coefficients are the result of the correlations between the carbon dioxide concentration and the time on the one hand, and between the odour intensity and the time on the other hand. A correlaton between the carbon dioxide concentration and the odour intensity exists, if man is the only source of both of these pollutants and if the emission rate is constant over time; and so, the concentration of the indoor carbon dioxide can be seen as a good and useful indicator of the indoor air quality

under non smoking conditions.
As an upper limit of the indoor carbon dioxide concentration we would propose 0.15 % vol abs. (that is approximately adequate to 0.1 % vol rel. increase). At that concentration not more than 15 % of the occupants inside complained of an unpleasant odour. If the limit is set by newly entered persons, the concentration may be kept at 0.1 % vol abs., because of their higher sensibility of odour perceptions.
Carbon dioxide fails as a leading component during smoking occupancies. In that case, the concentration of carbon monoxide [5], or an air quality sensor may give better results.

6. REFERENCES

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ACKNOWLEDGEMENT

The study was made possible by the National Energy Research Foundation of Switzerland (NEFF).

fresh air a-c h^{-1}	$m^3/h*p$	CO_2 % vol start	end	N of pers. occup	panel	T °C start	end	CO_2 $l/h*p$
0.1	1.5	0.05	0.31	2	4	19.8	22.0	21.6
0.16	2.4	0.05	0.26	2	4	19.5	21.7	18.3
0.4	4.0	0.05	0.34	3	4	20.8	23.3	22.2
0.3	3.0	0.05	0.35	3	4	20.9	23.2	19.8
0.16	2.4	0.06	0.31	2	4	22.9	25.1	21.9
0.16	2.4	0.05	0.31	2	4	23.0	23.7	21.9
0.16	4.8	0.04	0.17	1	4	20.0	23.0	21.6
0.16	2.4	0.05	0.28	2	4	23.5	25.4	20.1
0.16	2.4	0.05	0.31	2	4	22.8	24.9	22.2

table 1
summary of the *climatic chamber* measurements

symbols

a-c: air change
occupants: persons inside
% answ.: % of the students in the lecture theatre who answered the questions
panel: test panel outside
h : hours
l : litres
p : persons
CO_2 (l/h*p): calculated values

fresh air		CO_2 % vol		occupants		T °C		pa-nel
a-c h^{-1}	m^3/h*p	start	end	N	% answ	start	end	
1.1	27	0.05	0.11	39	92	22.0	22.5	7
2.0	16	0.05	0.18	115	96	22.0	22.5	6
1.1	14	0.045	0.14	73	90	22.0	22.0	13
1.1	14	0.045	0.16	77	95	21.5	22.5	7
0.5	23	0.045	0.09	21	95	21.5	22.0	6
0.5	-	0.035	0.04	-	-	21.5	21.5	9
0.5	4.5	0.05	0.21	105	87	21.5	23.0	6
0.5	6.7	0.045	0.18	71	77	22.0	22.5	9
0.5	4.5	0.06	0.21	104	88	21.5	22.5	8
0.5	16	0.05	0.11	30	97	21.5	22.0	5
0.5	14	0.045	0.12	35	-	20.5	21.3	5
0.5	4.3	0.06	0.21	110	74	20.7	22.0	6
0.5	7.3	0.04	0.18	65	64	21.0	22.0	6
0.5	6.7	0.055	0.2	71	89	20.0	21.5	6
0.5	14	0.055	0.14	35	94	20.3	21.0	5
1.1	27	0.055	0.1	39	95	20.0	20.3	9
1.1	10	0.06	0.19	109	88	20.2	21.5	3
1.1	21	0.045	0.14	50	82	20.0	20.8	8
1.1	16	0.05	0.15	65	85	20.0	21.0	8
1.1	30	0.04	0.11	77	77	20.0	21.5	6
5.0	56	0.05	0.08	85	90	20.5	20.5	-
5.0	59	0.07	0.08	80	96	21.4	21.5	-

<u>**table 2**</u>
summary of the *lecture theatre* measurements
(*symbols:* see table 1)

1. Is there .... in this room ?

no odour	|_|	1
very faint odour	|_|	2
faint odour	|_|	3
distinct odour	|_|	4
strong odour	|_|	5
very strong odour	|_|	6
unbearable strong odour	|_|	7

2. The odour in this room is ....

acceptable.	|_|
not acceptable.	|_|
I am not sure	|_|

3. Mark the level of annoyance by an odour on this supposed self rating "thermometer"!

|_|	10	unbearable annoyance
|_|	9	
|_|	8	
|_|	7	
|_|	6	
|_|	5	
|_|	4	
|_|	3	
|_|	2	
|_|	1	
|_|	0	no annoyance

4. The temperature in this room is ....

too cold.	|_|
right.	|_|
too warm.	|_|

<u>table 3</u>
questions concerning the *indoor climate*

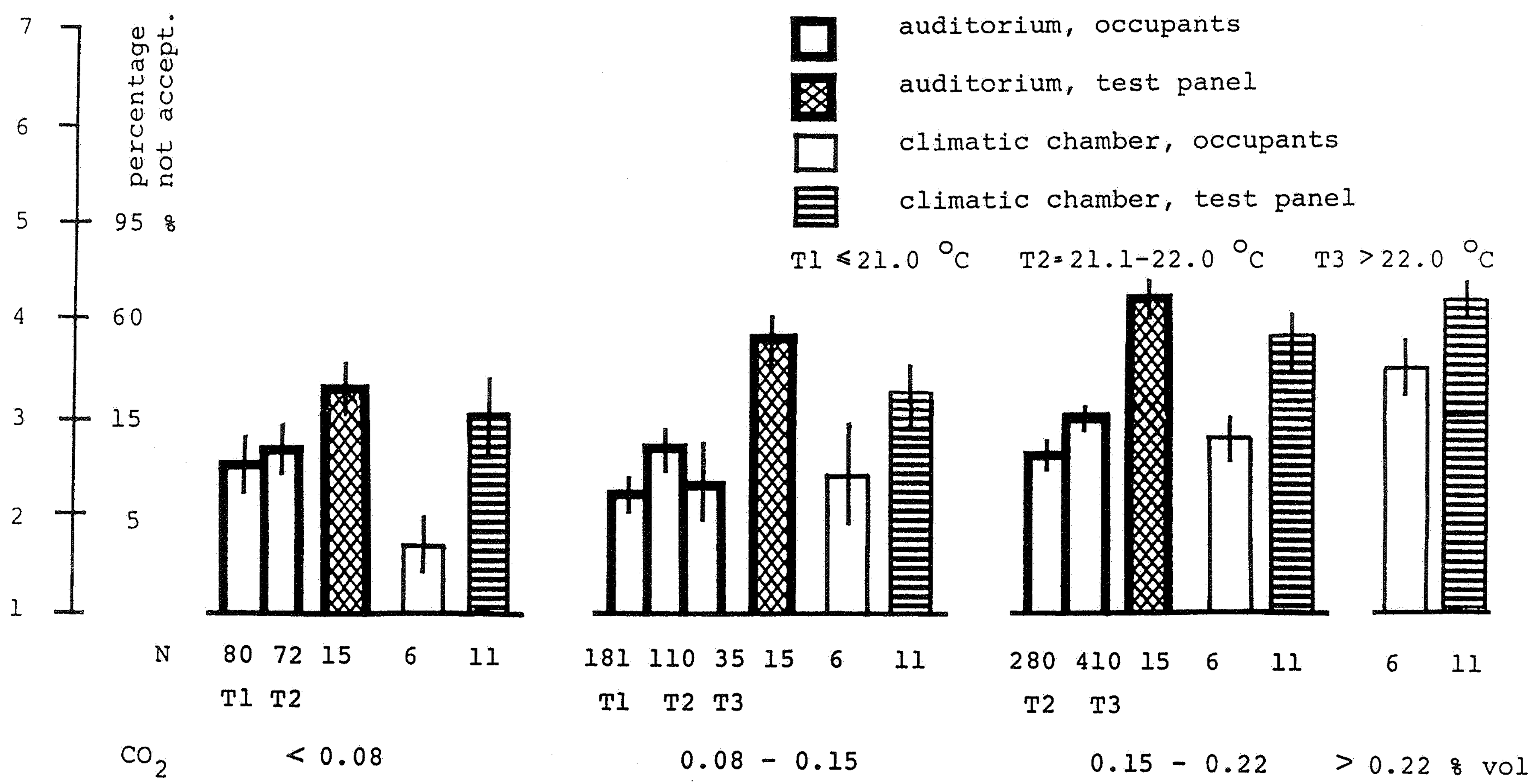

Figure 1: ODOUR INTENSITY (Category scale; see table 3, question 1)

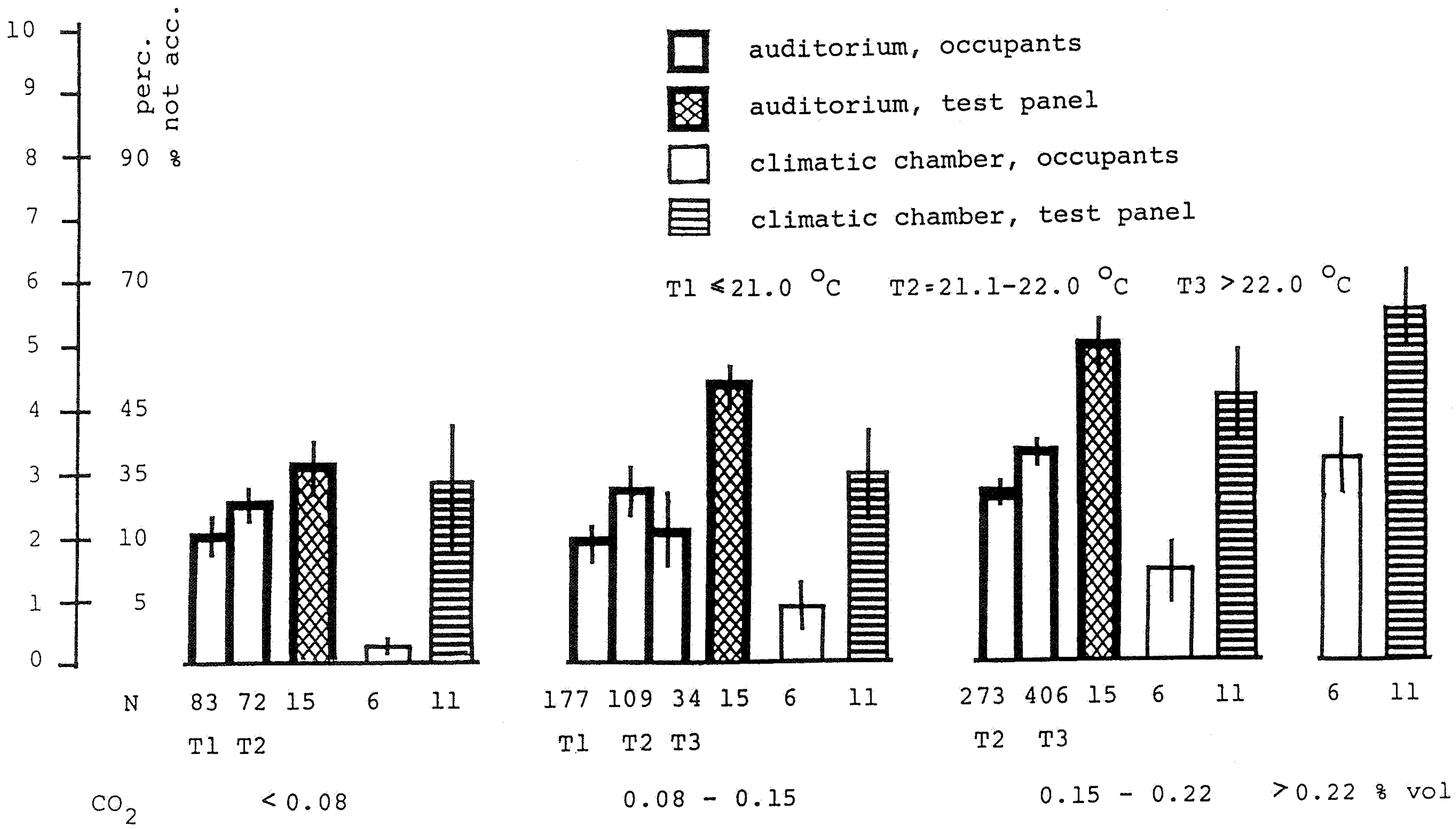

Figure 2: ANNOYANCE BY ODOURS (See table 3, question 3)

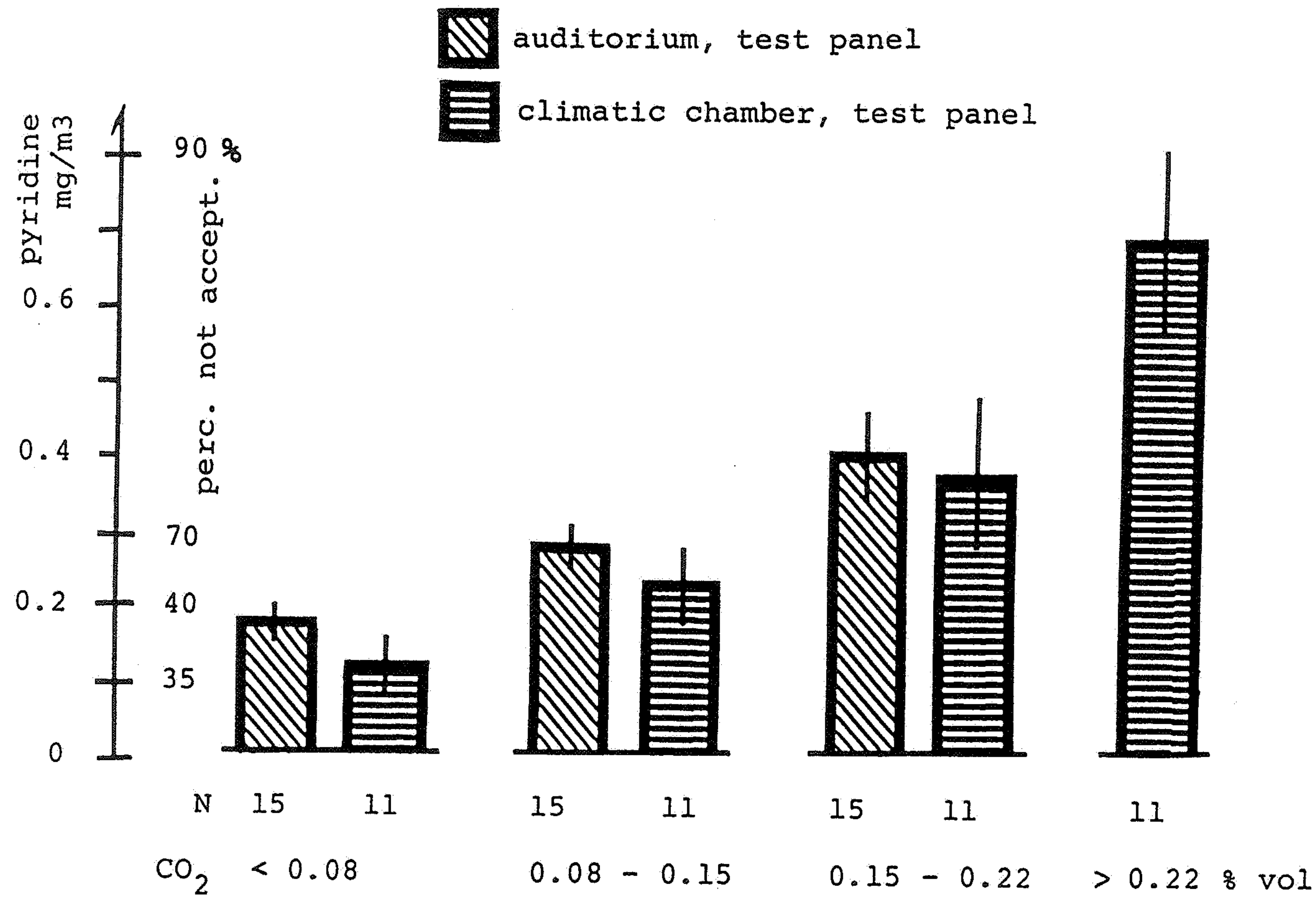

Figure 3: ODOUR INTENSITY (Reference odours)

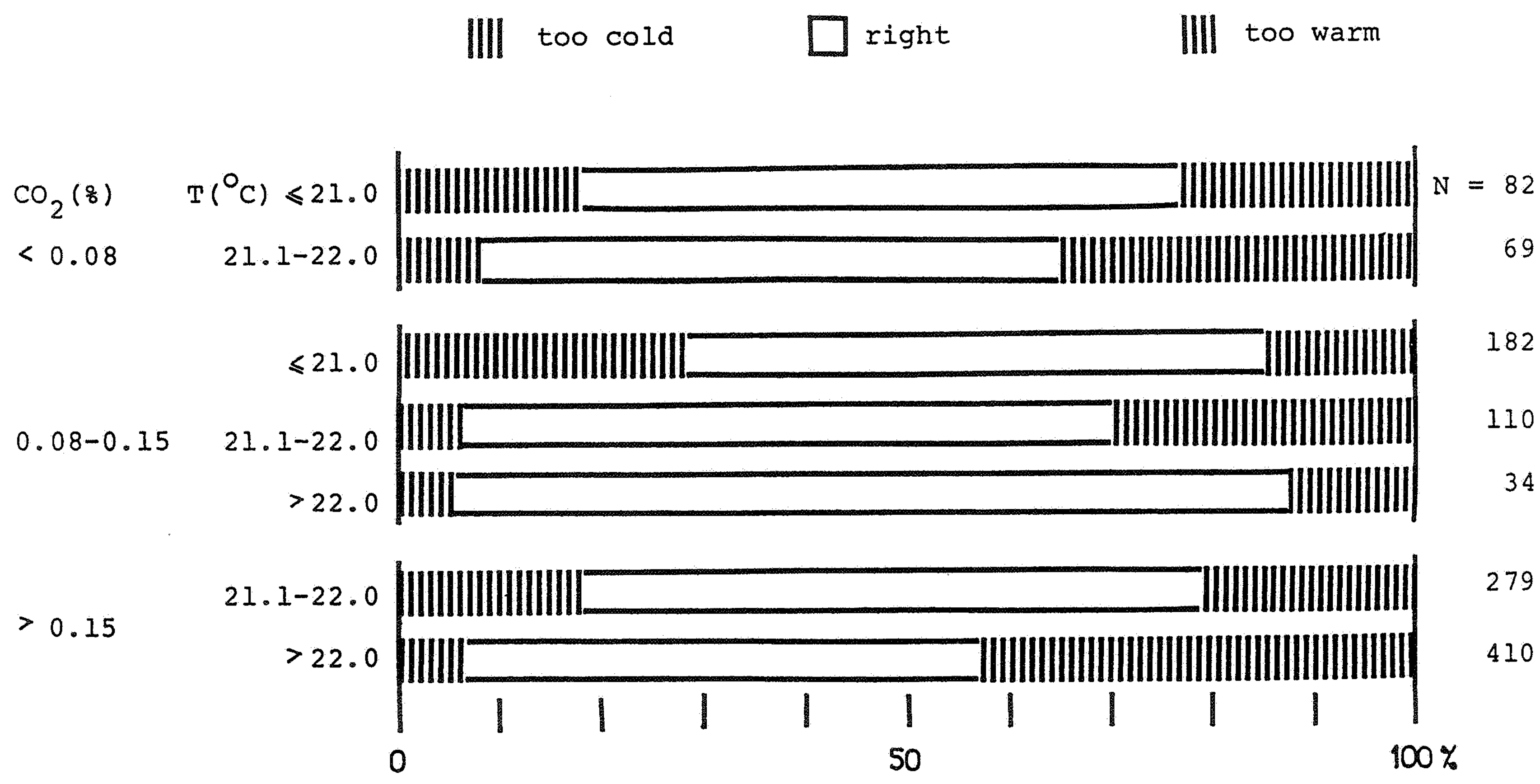

Figure 4: SUBJECTIVE PERCEPTION OF TEMPERATURE (see table 3, question 4)