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STUDY OF THE PERMISSIBLE "MINIMUM FRESH AIR SUPPLY" IN BUILDINGS

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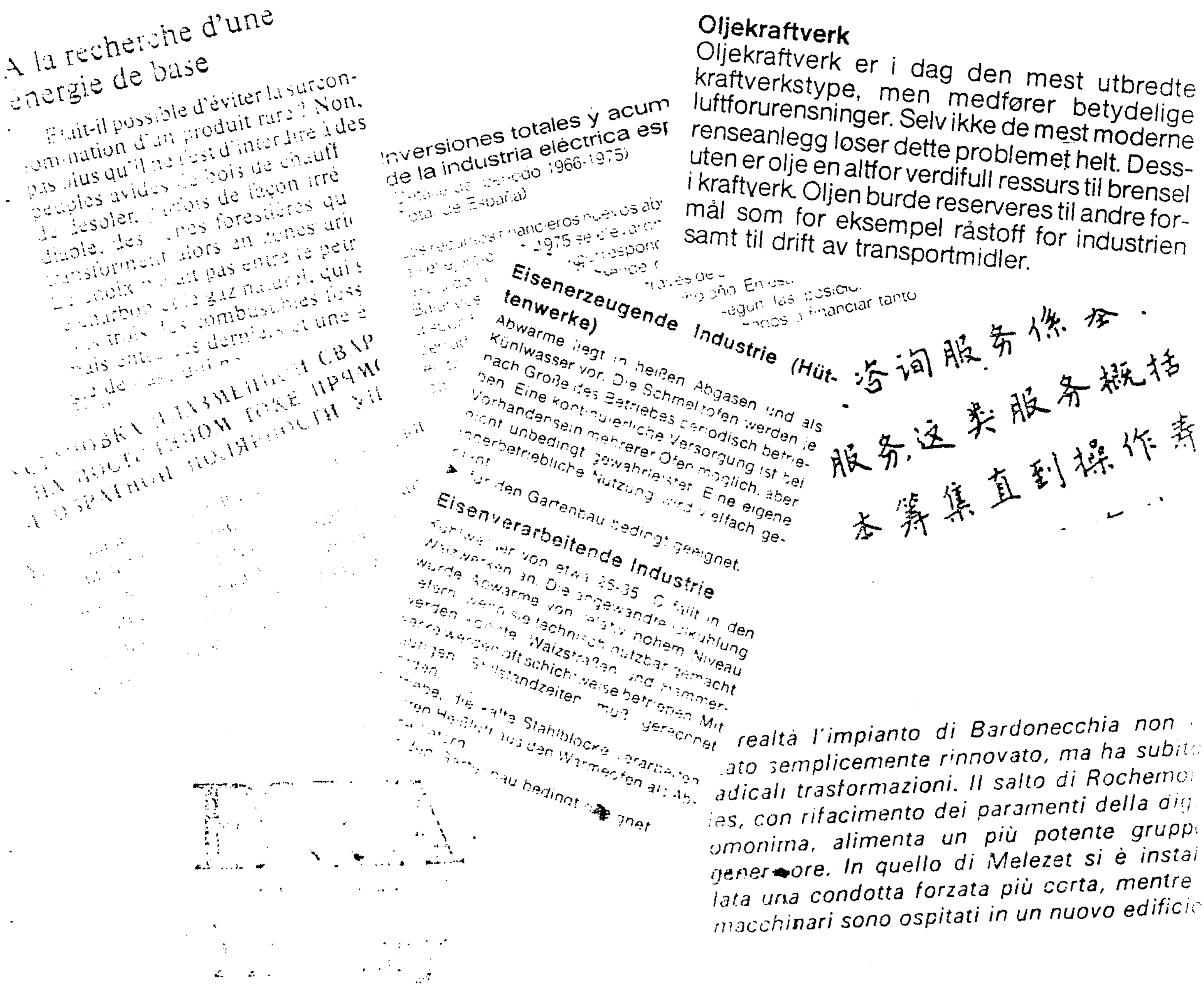

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Study of the permissible 'minimum fresh air supply per person' in buildings: Publication No 881 of IMG-TNO, Delft

by H B Bouwman

As the result of a commission from the Ministry of Housing and Planning to the ISSO within the context of the Steering Committee on Energy and Buildings a study entitled 'Norms for minimum fresh air supply' has been carried out. This article is a summary of the report entitled 'Study of the permissible minimum fresh air supply per person in buildings' produced for the purposes of the study by IMG-TNO for ISSO.

1. Introduction

The aim of the research was to examine whether it would be a responsible step to limit the minimum ventilation, for example to 25 m^3/h per person, with the aim of saving on the energy needed for the heating or cooling of the fresh outside air necessary for ventilation.

Fresh air supply to (and air removal from) a room where people spend time can be necessary for various reasons, namely

1) to prevent a shortage of oxygen
2) to counteract the CO_2 concentration rising too high as a result of the exhaled CO_2 from the people present
3) to keep the concentration of annoying and/or harmful substances from construction materials within permissible limits
4) to prevent an excessive degree of odour nuisance
5) to maintain the desired temperature, relative humidity and air movement

If (5) is satisfied, (3) is not always satisfied. If the ventilation satisfies (3) then it normally also satisfies (2). If (2) is satisfied then (1) can be left out of consideration.

Item (4) is the aspect which was the criterion for the research at hand: the minimum fresh air supply necessary to prevent odour nuisance. This can have its origin in materials coming from:

- construction materials such as wood, paint, glue, insulation
- furnishings and upholstery
- office equipment
- people: cosmetics, distinctive eating habits, limited personal hygiene, over-tiredness, sickness, etc.

The less fresh air is supplied the less rapidly are the smells removed and the CO_2 concentration from the people in the room also rises.

The difference between the CO_2 concentration in the room air above that in the outside air is called ΔCO_2. The value of this which occurs in a room can thus be seen as a measure of the degree to which the fresh air supplied is "burdened" by the presence of the people. Carbon dioxide itself, in the permissible concentrations, causes no odour or other nuisance.

The answer to the question of determining the air supply rate at which impermissible odour nuisance does not occur is therefore to an important extent given if it is known at what ΔCO_2 concentration impermissible odour nuisance still does not occur.

By way of example we quote two figures: in a normally ventilated room ΔCO_2 does not often get above 0.07-0.1%, ie 700-1000 ppm.

2. Odour concentration and odour nuisance

2.1 Odour concentration

Odour is difficult to establish even with the aid of instruments. The human nose can often be used as a detector. If someone perceives a strong odour in the air then he can still perceive the odour if the air is diluted a number of times with odour-free air.

The odour-containing air can be diluted to an adjustable extent, by means of an apparatus, with odour-free air and the mixture presented to a number - eg a panel of eight - people who are asked whether they can still distinguish it from odour-free air. In addition dilutions are also produced for which more than 50% of the persons can no longer perceive the odour. From the whole range of observations it is then possible to calculate at what dilution precisely 50% of the people should still perceive the odour in the diluted odorous air. The corresponding dilution factor (a number very seldom less than one) is by definition called the odour concentration. In the research under discussion the dilution principle described above was used to measure the odour concentration in an air sample drawn from the experimental rooms. These measurements were carried out using a "sniffer van" (Fig 6). The way it is used is described in more detail in the report.

We give some figures by way of example. In rooms where there is no smoking the odour concentration with moderate ventilation is of the order of 10. If there is a lot of smoking then it is of the order of 100. In the vicinity of odour-producing industries concentrations of the order of 10 to 100 or even 1000 occur in the open air.

2.2 Odour strength, nuisance and acceptance

Different odours, presented in the same concentration, can be experienced very differently. This depends, in addition to the magnitude of the concentration, also on the nature of the odour. Thus perfume can be experienced as pleasant at a low concentration but unbearable at a high concentration. On the other hand the smell of rotten eggs is unpleasant at all concentrations.

The odour strength experienced, called odour intensity, decreases with the dilution of a sample of odorous air but much more rapidly in the case of one smell than another. A measured odour concentration thus does not say anything about the degree of strength and odour nuisance which occurs.

The main question in this research was where the limit lies between acceptance or non-acceptance of an odour in an office or comparable building.

To establish the degree of odour nuisance and the degree of odour acceptance experimental subjects were used in this research. They were asked, using the scale in Fig 1, to assess the degree of nuisance and acceptance. The subjects were occupants and visitors. "Occupant" means someone who had already been continuously in the room for a substantial time (eg at least an hour). A "visitor" is someone who had been in the room for only a very short time (1-2 mins) and had not been there shortly beforehand.

3. Design of the research

In a number of buildings the occupancy level of a number of rooms was varied. The occupants were either men or a mixture of people among whom women were well represented. Some of the rooms were mechanically ventilated and the rest naturally. The ventilation was set at different values.

In the rooms the air supply was measured in two different ways: by the helium tracer method and by the CO_2 output of the people present. The CO_2 concentration was measured both in the room and in the outside air. From these the ΔCO_2 value is known.

The odour concentration in the room was measured using a "sniffer van". The degree of odour acceptance was determined by asking the visitors to and occupants of the room. The occupants were generally asked twice at short intervals: the first time when they had spent some time in the room without a break and the second time when they had come back into the room after, on request, leaving it for 1-2 mins.

4. Processing of the data

The answers obtained from the questioning about odour nuisance are collected in the lower part of Fig 2. Each answer is indicated by a symbol whose location is determined by two co-ordinates:

- horizontally, the ΔCO_2 value in the room during the inquiry
- vertically, the odour nuisance experienced in accordance with the scale at the right of the diagram.

As observed earlier the ΔCO_2 value can be regarded as a measure of the burden placed on the air. From the shape of the symbols it can be seen whether the answers come from occupants or visitors, men or women, smokers or non-smokers. Answers from one experiment are joined by a vertical line. The large individual differences in the answers are striking. In one situation one comes across "odour not perceptible" beside "odour no longer acceptable".

More detailed information is also given in the diagram.

The answers are divided by the acceptance limit into the two groups 'acceptable' and 'not acceptable'. From this there follows for each ΔCO_2 value at which inquiries were made a 'not acceptable' percentage. Using a computer a probit curve is calculated which, on the basis of defined criteria, indicates as well as possible the relationship between the 'not acceptable' percentage and the ΔCO_2 value. This means, inter alia, that account is taken of the number of observations on which the percentages are based. The curve is S-shaped, as Fig 3 shows. This figure includes the answers 'acceptable' and 'not acceptable' from occupants and visitors from all the experiments.

The answers and the curve are also recorded in a diagram with a probability distribution along the vertical axis. The S-curve from Fig 3 becomes the straight line in Fig 4. Such diagrams can also be calculated and drawn for occupants and visitors separately (diagrams in the complete report).

If the answers obtained on the two smoking days are omitted the three diagrams can be recalculated and redrawn: of these only Fig 5 for occupants is included here.

5. Consideration of the results

Fig 5 shows that, if in the absence of smoking one is prepared to tolerate an average response from the occupants of not more than 5% of 'not acceptable', the ΔCO_2 value must not be more than 625 ppm. For a CO_2 output of 21-23 dm^3/h per person this means a minimum fresh air supply of 33.6-36.8 = ca 35 m^3/h per person. In the ISSO report the reliability which can be attached to this sort of number is examined. Moreover the 'not acceptable' percentage which can still be tolerated has an effect on the minimum fresh air supply per person.

In rooms with a great deal of space - ie of the order of more than 50 m^3 per person - the ΔCO_2 value of 625 ppm mentioned is not reached during short occupancy periods, ie of the order of 1-2 hours; in the case of short periods of occupancy with 50 m^3 of air per person a fresh air supply of 25 m^3/h per person can seem acceptable to 95% of the 'occupants'.

Energy saving in relation to ventilation can, of course, also be achieved via heat recovery from the exhaust air (and the recirculation of the air over activated charcoal). But even then it is important to have an insight into the minimum fresh air requirement.

Conclusions

See the summary at the beginning.

Postscript

The following have taken part in the research:

The Veluwe Waste Water Treatment Authority of Apeldoorn by making available the building and generous help from the Technical Service.

Managements and workers in the TNO Zuidpolder building complex in Delft.

The ca 25 persons who carried out their normal work in the various test rooms and were willing at the same time to act as experimental subjects.

The TNO Department of Social Technology (MT-TNO), Physical and Chemical Technology Section at Apeldoorn: for the odour concentration measurements C Roos (with the aid of a panel of existing workers from [secretarial] employment bureaux.

The TNO Institute for Mathematics, Information Processing and Statistics (IWIS) in The Hague:

- vv* (CO_2) calculations: H A Mol; statistics: P R Defize

The Institute for Environmental and Health Technology (IMG-TNO) at Delft:

[List of collaborators and their affiliations]

From the TNO CIVO Analysis Institute at Zeist Dr P J Groenen supplied data on the carbon dioxide concentration in cigarette smoke.

From the Plant Physiology Research Group of the Agricultural University of Wageningen Dr G A Pieters supplied the data on which the sub-paragraph 'Plants in the room' in the report is based.

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* Translator's note: Does not appear to correspond with any of the standard "vv" abbreviations.

Availability of the report

ISSO Research Report 1 "Research into minimum fresh air supply" which contains more than 100 pp can be ordered by remitting Dfl 75 (members of ACI or TVVL; non-members Dfl 100) which includes p&p to postal giro account 33 22 209 in the name of ISSO The Hague, stating the title and whether a member of ACI or TVVL.

FIGURES: For the sake of clarity captions which repeat information in the title of the figure are omitted

Figure 1. The odour (nuisance) scale used

5. Disgusting, nausea-inducing, etc
4. Objectionable, much too strong
3. No longer acceptable
- -
2. Still just acceptable
1. Clearly perceptible but not annoying
1/2. Just perceptible
0. Not perceptible

~~GEUR(HINDER)SCHAAL~~

5. Afkeerwekkend, misselijk makend, e.d.
4. Verwerpelijk, veel te sterk
3. Niet meer acceptabel
- - - - - - - - - - - - - - - - - -
2. Nog juist acceptabel
1. Duidelijk waarneembaar, maar niet hinderlijk
$\frac{1}{2}$. Juist waarneembaar
0. Niet waarneembaar

Figuur 1 De gebruikte geur(hinder)schaal

Figure 2. Odour concentration and individual odour nuisance response, plotted against ΔCO_2 and against the number of m^3/h of fresh air per person

Top diagram: RH axis: Odour concentration

h = men) occupants
d+h = men + women)
roken = smoking
na roken = after smoking
verflucht = smell of paint

Lower diagram: RH axis: Odour (nuisance) [for meaning of numbers see Figure 1]

x-axis: air supply needed per person for 8-hour occupancy and a CO_2 output of 0.021 m^3/h per person (units of m^3/h of fresh air per person)

Symbols

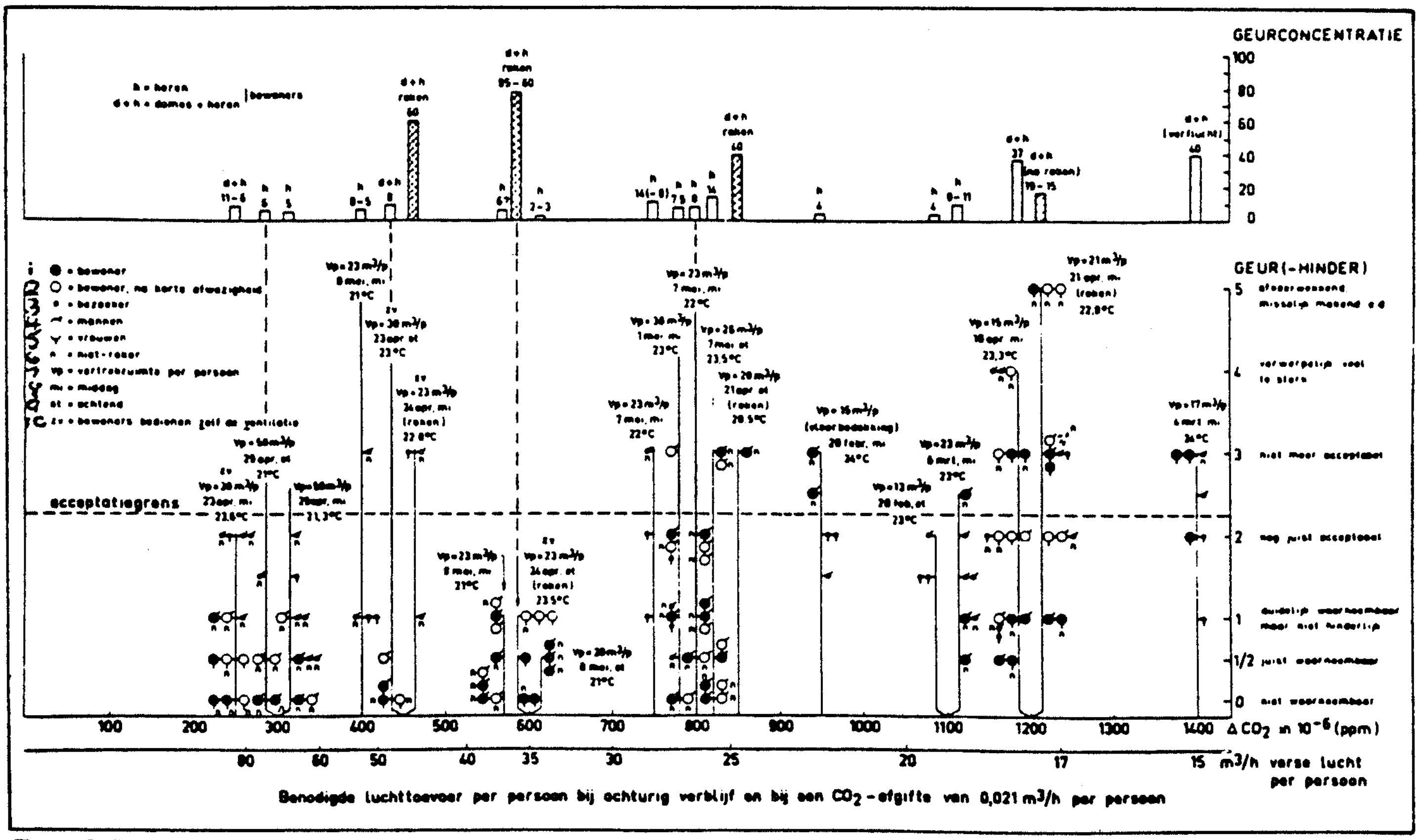
1. Occupant 2. Occupant after short absence 3. Visitor
4. Men 5. Women 6. Non-smoker 7. Room volume per person
8. Afternoon 9. Morning 10. Occupants operate ventilation themselves

acceptatiegrens = acceptance limit

febr = February; mrt = March; apr = April; mei = May

roken = smoking

vloerbedekking = floorcovering

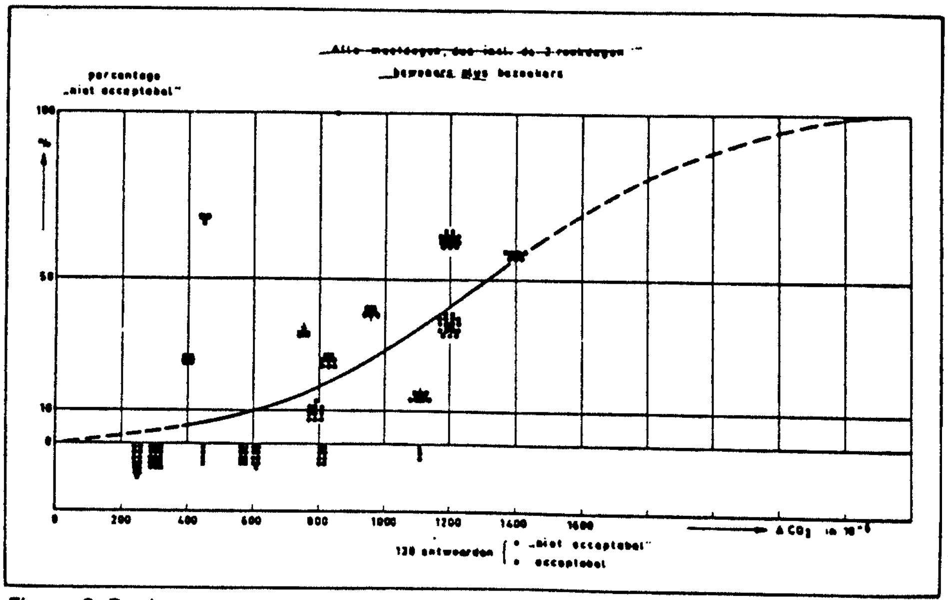


Figuur 2 De geurconcentratie en de individuele geurhinderrespons, uitgezet tegen ΔCO_2 en tegen het aantal m^3/h verse lucht per persoon

Figure 3. Dose-response relationship: 'not acceptable' percentage plotted against ΔCO_2 for occupants and visitors on all the days on which measurements were made, ie including the 2 smoking days

LH axis: 'not acceptable' percentage

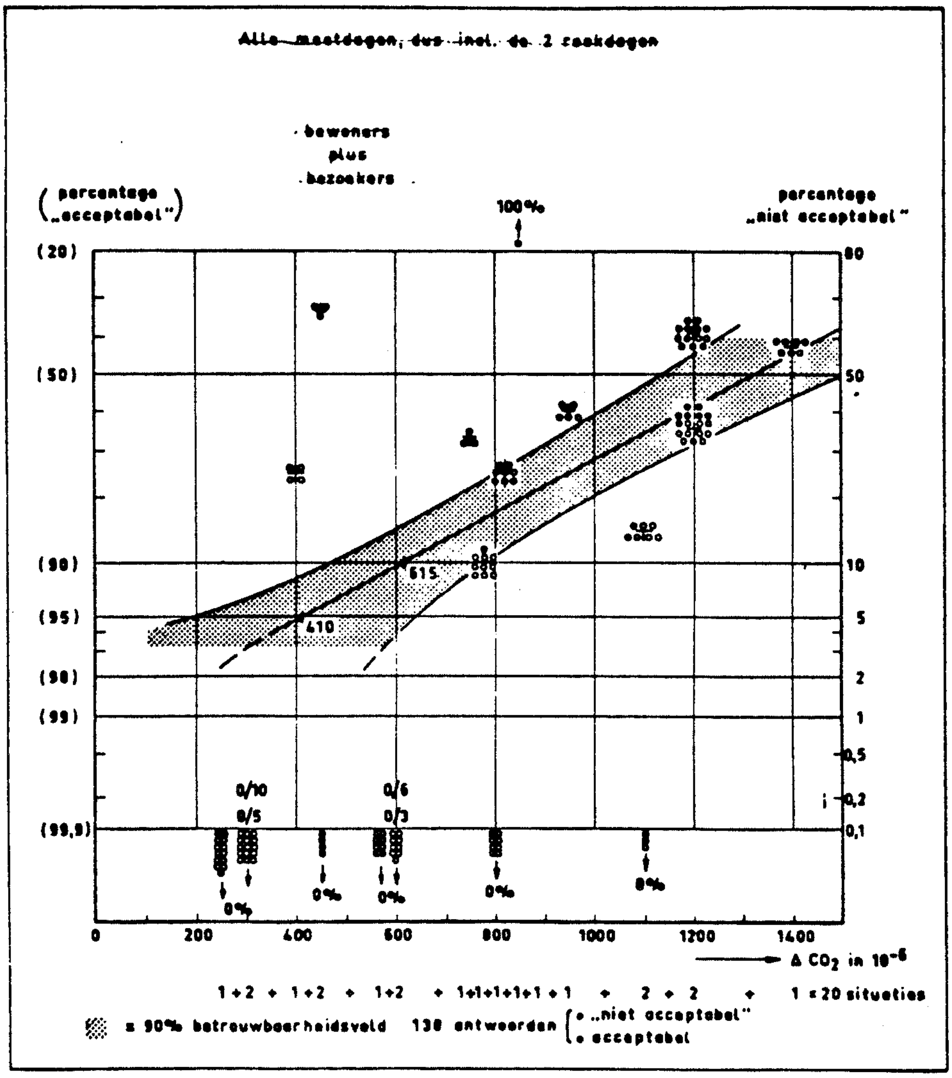
Bottom caption: 138 answers ('not acceptable / (acceptable



Figuur 3 Dosis-responsrelatie: percentage 'niet-acceptabel' uitgezet tegen ΔCO_2 voor bewoners en bezoekers op alle meetdagen, dus inclusief de twee rookdagen

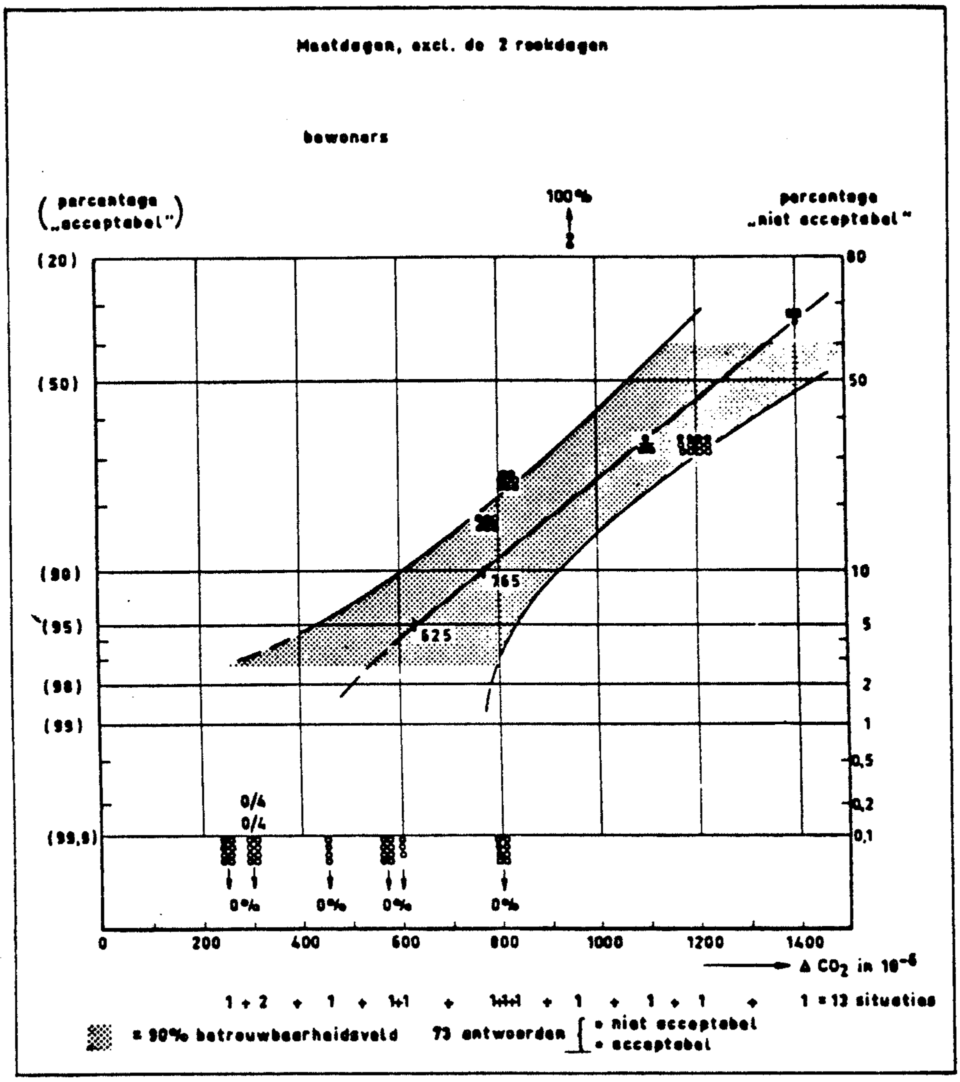
__Figure 4__. Dose-response relationship: 'not acceptable' percentage plotted against ΔCO_2 with a probability distribution along the vertical axis. Occupants and visitors on all days on which measurements were made.

LH axis: 'acceptable' percentage
RH axis: 'not acceptable' percentage
Bottom captions: betrouwbaarheidsveld = confidence range
138 etc - as Figure 3
situaties = situations



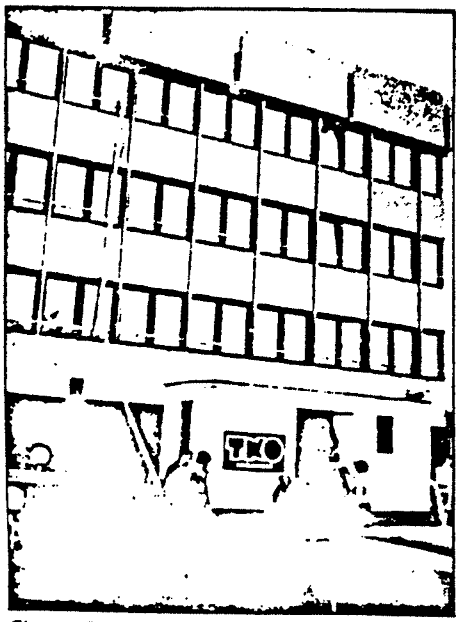
Figuur 4 Dosis-responsrelatie: percentage 'niet-acceptabel' uitgezet tegen ΔCO_2 in een diagram met waarschijnlijkheidsverdeling langs de verticale as
Bewoners en bezoekers op alle meetdagen

Figure 5. Dose-response relationship: 'not acceptable' percentage plotted against ΔCO_2. Occupants on the days when measurements were made except for the two smoking days. Captions as Figure 4.



Figuur 5 Dosis-responsrelatie: percentage 'niet-acceptabel' uitgezet tegen ΔCO_2
Bewoners op de meetdagen met uitzondering van de twee rookdagen

Figure 6. The panel to determine the odour concentration enters the "sniffer van" at one of the buildings



Figuur 6 Het forum voor de bepaling van de geurconcentratie betreedt de snuifkar bij een der gebouwen