EFFECTIVE VENTILATION

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Paper 17

RECIRCULATION OF AIR IN DWELLINGS

Differences in concentrations between rooms in dwellings due to the ventilation system.

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SUMMARY

The Dutch Standard NEN 1087 "Ventilation of dwellings", Requirements, is at this moment under review. A statement is made that outside air is required as fresh air for bedrooms. Bathroom, kitchen, W.C. and livingroom are allowed to be ventilated with air from other rooms.
During the last years air heating systems became more popular. These systems have in its most simple form recirculation of air from the livingroom to the bedrooms. The requirement of fresh outside air for bedrooms can only be reached with these systems when selective recirculation takes place.
During the reviewing process of the standard, TNO has carried out some studies to investigate the differences in concentrations of contaminants in dwellings due to different ventilation and heating systems. Measurements and calculations have been made in a lot of conditions to reconsider the requirement of pure outside air for bedrooms.
In this investigation the following aspects were studied;

* what pollutant is the most important with respect to recirculation,
* what concentrations may be expected under several weather conditions and living habits,
* what is the influence of staying different hours of time in different rooms (i.e. housewife versus baby) etcetera

Field measurements in two dwellings and calculations with the TNO Ventilation model (VENTCON) were compared.
The main conclusions of these studies are:

* Particles of sigaret smoke can be seen as the most important contaminant in houses specially considering childrens bedrooms.
* Leeward sided bedrooms can receive contaminated air from the living under certain weather conditions and living habits.
* Due to an effective window opening (large open casement windows) occupants can minimize these contaminant levels.
* There are no significant differences in doses (=concentration multiplied by occupation time) in houses with natural ventilation or mechanical exhaust and air heating systems who can be seen as balanced ventilation systems
* Babies are more exposed to contaminants from the living then housewives in both houses with natural ventilation or mechanical exhaust and houses with air heating systems
* There is a very good correlation between the measured and calculated concentrations of contaminants
* Simple measures in the air heating installation can give occupants the possibility to ventilate their house with outside air only, which can be a necessity in the case of sick or sensitive people.

1. INTRODUCTION

The Dutch Standard NEN 1087 "Ventilation of dwellings": Requirements [1] is at this moment under review. A requirement can be found about the quality of air. In fact a statement is made that outside air is required as fresh air for bedrooms. Bathroom, kitchen, W.C. and livingroom are allowed to be ventilated with air from other rooms.
During the last years air heating systems became more popular. These systems have in its most simple form recirculation of air from the livingroom to the bedrooms.
During the reviewing process of the standard, TNO has carried out some studies to investigate the differences in concentrations of contaminants in dwellings due to different ventilation and heating systems. The aim of the studies was to evaluate several heating/ventilation systems on pollutant levels in houses.

2. PILOT STUDY [2]

The first phase of this study was to determine which pollutant was the most important. No extensive literature research has been carried out. From [3], the situation with tabacco smoke produced in the living was taken as a reasonable reference situation for this studies. The tabacco smoke can be propagated to bedrooms due to recirculation of air and due to internal flows in the case of natural ventilation. In the bedrooms small children like babies can be sleeping for many hours without having the possibility to open ventilation-windows.
With the TNO ventilationmodel (VENTCON) a comparison on concentration levels of three different systems has been carried out. (see figure 1)

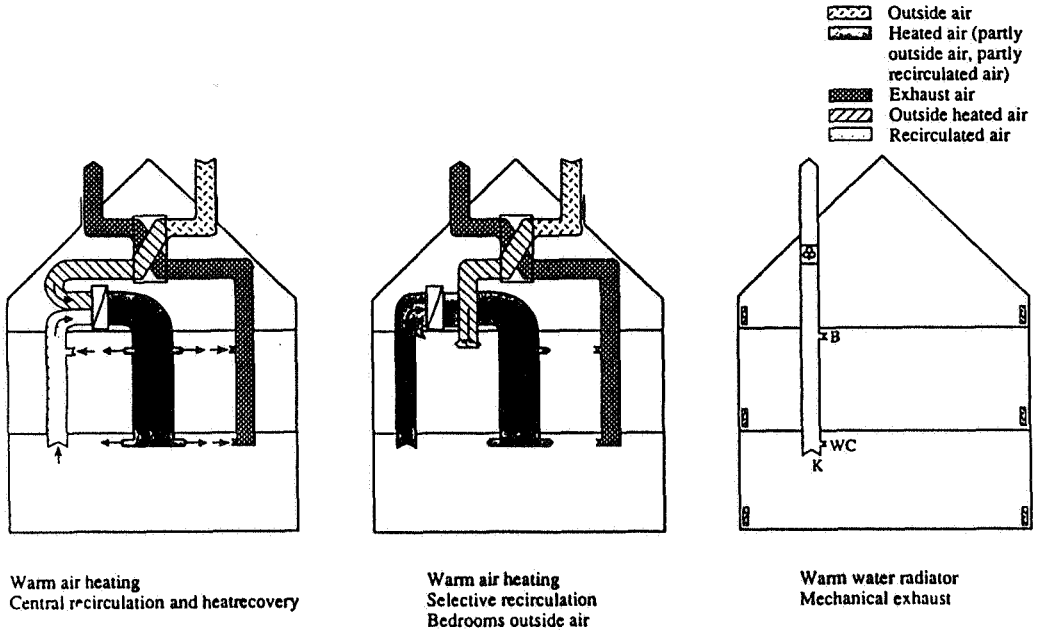

figure 1 The three different heating/ventilation systems

Thise study pilot was carried without taking into account the use of the ventilation provisions by the occupants.

The infiltration and mechanical ventilation levels and the particle concentrations in the rooms of the houses were calculated. The calculations have been made for a single family dwelling under a variety of weather conditions (see figure 2). On the basis of this results the time weighted average concentrations for five types of persons were determined. The five types of persons are defined as persons who are staying different hours in the several rooms of the house. The production of tabacco smoke was simulated in the living. The effects of sedimentation of the particles were neglected.
The results of this study are summerised in table 1.

TABLE 1 Time weighted average concentrations of particles $\mu g/m^3$

type of person	heating/ventilation system	
	warmwater radiator with mech. exhaust	airheating central recirculation
baby	12	16
child 2-6 y	33	20
child 6-13 y	13	9
housewife	45	23
man	26	13

From this figures can be seen that the particle concentrations due to smoking are for the different persons in the same order of magnitude. The concentrations are even a bit higher in the case of mechanical exhaust ventilation system.
Nevertheless some people argued that this results were only based on calculations.

3. MEASUREMENTS

Measurements were carried out in a single family house [4]. (see figure 2)

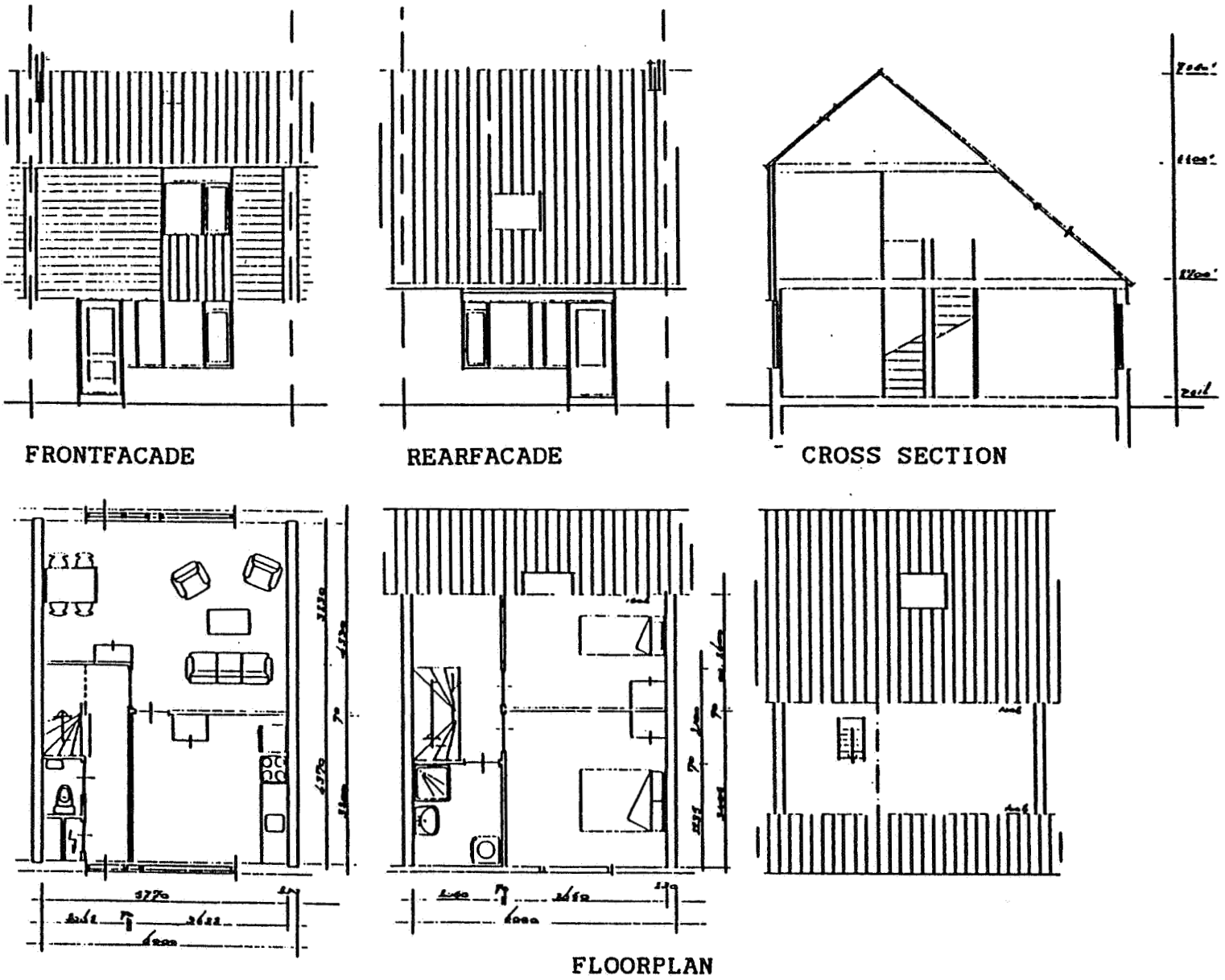

figure 2 The dwelling, groundplan, facades, cross section

Carbonmonoxide (CO) was used as a tracer and released in the livingroom. The measurements were carried out in an unoccupied dwelling with a airheating system. The effects of occupancy were simulated. For an impression of the concentration over time figure 3 and 4 is given.
The global results of this experiment are shown in table 2.

KRAMMER WARMWATER RADIATOR HEATING 8 april 1987

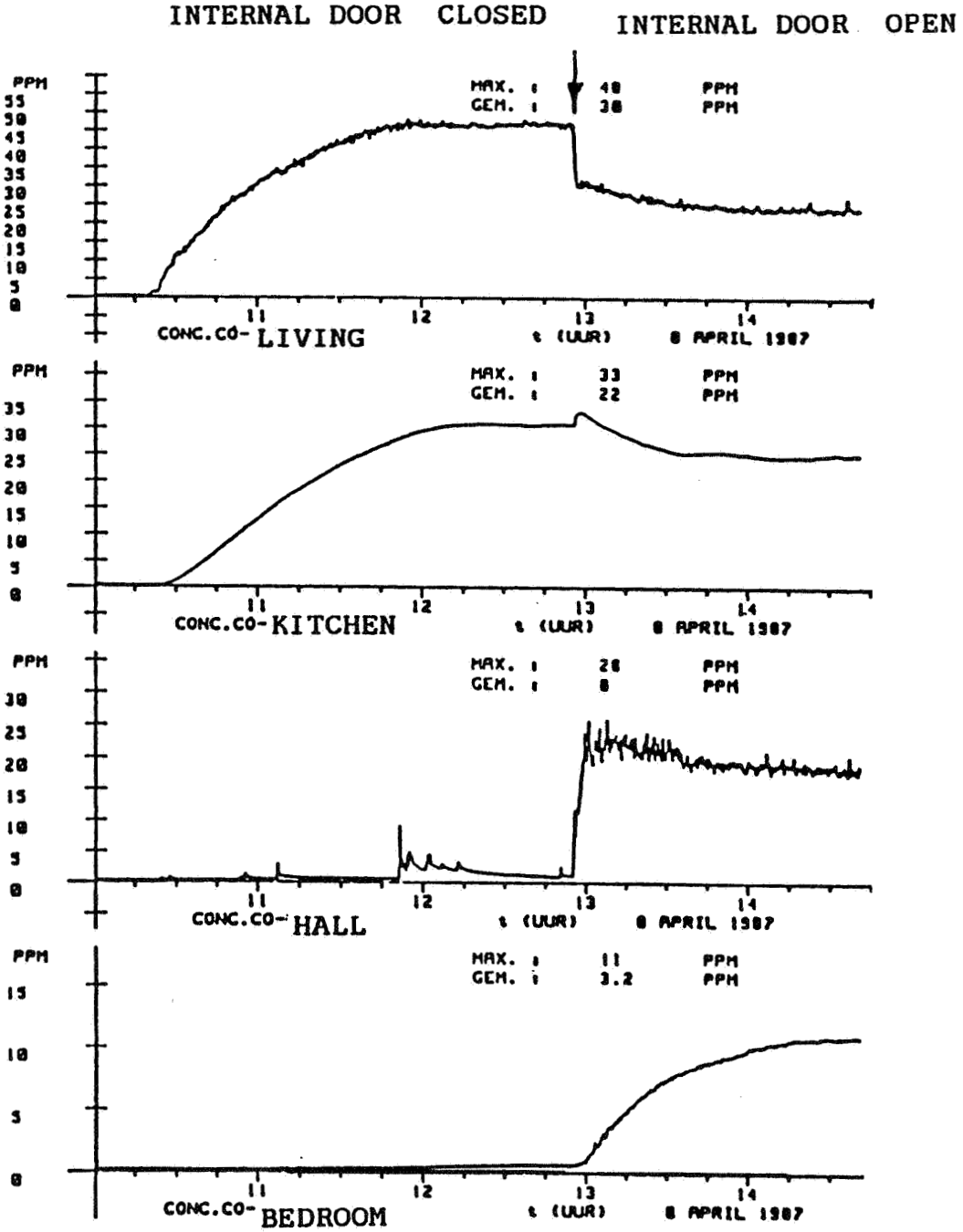

figure 3 Concentrations measured in several rooms
Warmwater radiator heating system with mechanical exhaust. Door of living closed en open.

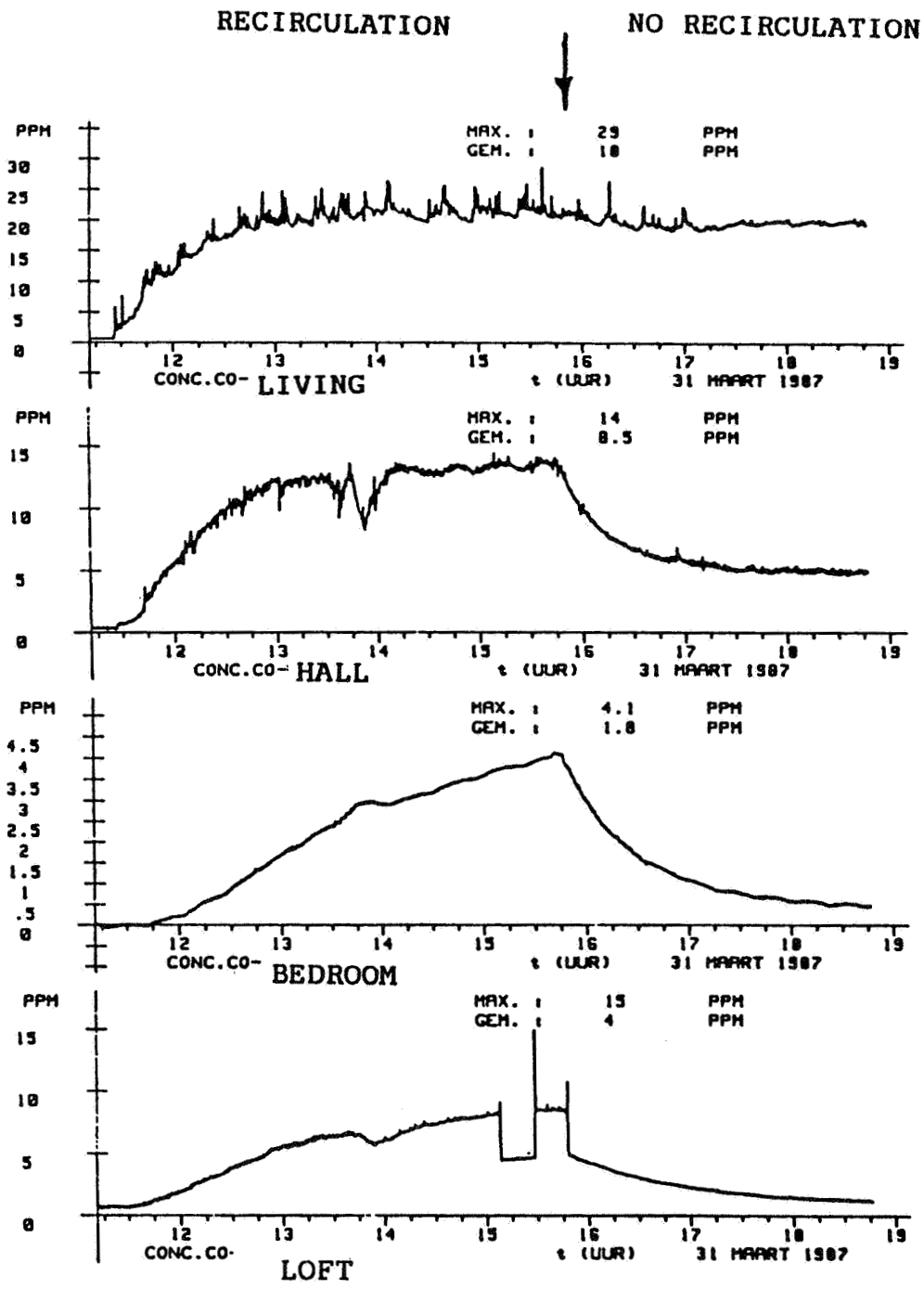

figure 4 Concentrations measured in several rooms
Warm air heating system with and without recirculation

TABLE 2 Airflow from the living to the bedrooms in %

heating/ventilation system	position of internal doors closed	open
warm airheating selective recirculation	< detectable	< detectable
warm airheating central recirculation	15	25 - 30
warmwater radiator mechanical exhaust	0 - 5	30 - 50

From these one can conclude;

* No transport of contaminants take place in the situation with selective recirculation.
* The propagation of contaminants from the livingroom to other rooms depends on the position of the internal doors.
  Under the circumstances with the doors closed the warmwater radiator system with mechanical exhaust, leads to lower concentrations in the bedrooms than the warm air/central recirculation-system.
  In the case the internal doors are open, the situation is the opposite.

4. VALIDATION OF THE MODEL

Because some measured data was available, finally some validation exercises have been undertaken.
With the MT ventilation model (VENTCON) some measured situations are simulated. The results are shown in figure 5.

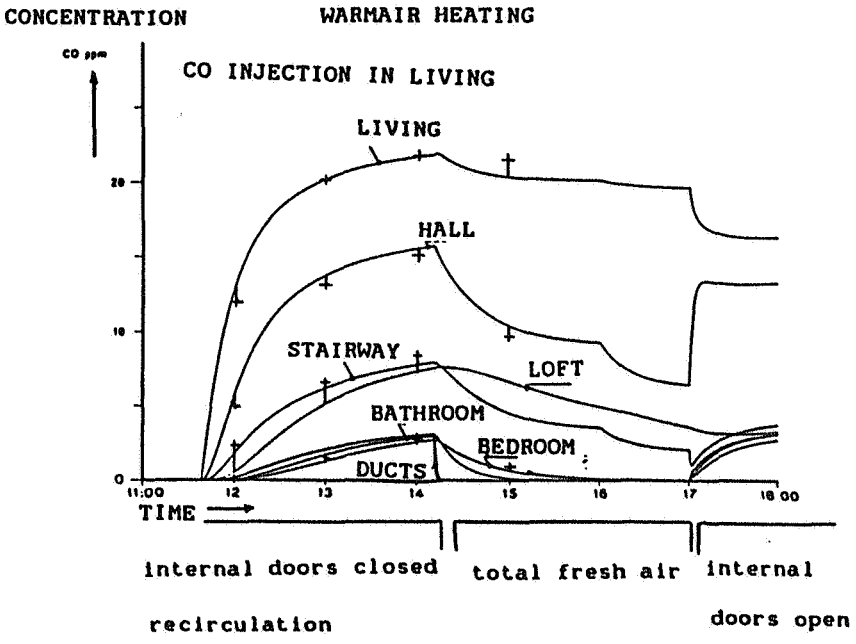

figure 5 Comparison between measured and calculated concentrations

5. CONCLUSIONS

The concentration levels in bedrooms of contaminants produced in the living are highly dependent on the use of internal doors.

Different heating/ventilation systems can produce the same levels of concentrations throughout the house.

The exposed doses of people in the house are dependent on their time of occupation in different rooms.

A warm air heating system with selective recirculation does not cause any transport of contaminants from the living to the bedrooms.

Models can predict concentrations levels to evaluate indoor air quality problems.

There is no evidence that the heating/ventilation system is the dominating factor in the propagation of contaminants through the dwelling.

6. REFERENCES

[1] NEN 1087 (Dutch standard)
Ventilation in dwellings, Requirements
NNI, Rijswijk, 1975

[2] Knoll,B.
Toelaatbaarheid van het recirculeren van lucht uit de woonkamer naar de slaapkamers.
IMG-TNO, Delft ,1985

[3] Trepte,L.
IEA Annex IX
Minimum ventilation rates
Dornier, Friedrichshafen, 1983

[4] Phaff,J.C
Recirculatie in woningen
MT-TNO, Delft, 1987

Discussion

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R. Anderson (Solar Energy Research Institute, USA) On the basis of your work, would you say that the mixing produced by occupant behaviour and natural convection is of the same order of magnitude as the mixiing produced by the ventilation system?

W. De Gids (TNO Division of Technology for Society, Holland) Our findings so far suggest that this is true.

J. Uyttenbroeck (Belgian Building Research Institute) (a) What is the meaning of open and closed indoor doors? (b) Is it possible to obtain the desired comfort level in a living room with the doors open?

W. De Gids (TNO Division of Technology for Society, Holland) "Closed door" means that although the door is shut air can still pass around it via the gaps that remain. (b) No, and particularly not with a radiator system.

P. Levin (Royal Institute of Technology, Stockholm, Sweden) (a) For the "exhaust ventilation" system what provisions were made for supply of air? (b) Could the leaks be assumed to be evenly distributed, to avoid short circuiting? (c) What is the level of airtightness of the building?

W. De Gids (TNO Division of Technology for Society, Holland) Provision for supply air followed the Dutch standard which stipulates openings of 100 to 140 cm2 for bedrooms. (b) The air leakage is not evenly distributed, although there is no evidence that there is much difference between facades. Roof and floors are more airtight than walls. (c) We based our calculations on an airtightness n50 of 10 to 12. Our field measurements showed that some houses are much tighter than this, with n50 of 1 to 4.

D. Harrje (Princeton University, USA) (a) It is very important to determine where the occupants are at various times during the day, and how pollutant exposure can be minimised. (b) Since warm air systems tend to spread the pollutant load, why aren't we seeing a more uniform distribution with doors open than when closed?

W. De Gids (TNO Division of Technology for Society, Holland) (a) Yes, the time:dose relationship determines the overall exposure. We have yet to study individual exposure profiles. (b) Not all rooms have balanced flows and equivalent dilution from system air.