OCCUPANT INTERACTION WITH VENTILATION SYSTEMS

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INHABITANTS' BEHAVIOUR WITH RESPECT TO VENTILATION

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Synopsis

During winter periods in four types of newly built terraced dwellings and in apartments of a flatbuilding, the daily behaviour and motivations of the inhabitants with respect to airing and ventilation have been studied. In total the information was obtained from 279 households. A combination of verbal interviews, diaries and technical measurements are used as methods of investigation.
On basis of the findings, calculations can be made about air flows in occupied dwellings. The results of these calculations can be related to indoor climate problems with smoke, smell, damp, air flows and temperature. A large number of factors are found which determine the behaviour. Because most of the behavioural factors can hardly be influenced, it is recommended to look for better technological solutions.
Since it appeared that most problems of indoor climate are not caused by deviant patterns of behaviour, these technological solutions ought to be adapted to the standard behaviour patterns and wishes of the inhabitants.

Introduction

In order to assess the functioning in practice of several newly developed heating systems and/or building constructions to save energy, the daily behaviour and the opinions of the inhabitants of four types of terraced dwellings have been investigated during winter periods. One of the aspects which was studied was the behaviour with respect to airing and ventilation and the motivations which play a role to it.

The four types of these one family houses were situated in the locations Almere (44 dwellings), Oosterhout (36 dwellings), Zwolle (99 dwellings) and Huizen (31 dwellings).

As well as these studies in newly built terraced dwellings, a very comprehensive investigation has been performed in an apartment building in the city of Schiedam. The main purpose of this project was the assessment of the inhabitants' behaviour and motives with respect to ventilation and its relation to inner and outer climatic conditions.
Other purposes were a study of changes in behaviour as a result of information and instruction to the inhabitants and to make an estimation of the energy loss resulting from this behaviour.
The investigation concerned a total of 70 identical apartments and was performed from November 1984 to April 1986.

The above-mentioned projects were and are carried out by the Netherlands Institute of Preventive Health Care-TNO (NIPG-TNO), in close co-operation with the TNO Division of Technology for Society (MT-TNO), Department of Indoor Environment.
Some results which will be presented in this paper were already published in (1,2,3,4,5).

Methods of investigation

The information of the behaviour and opinion of the inhabitants has been obtained by extensive verbal interviews. In addition, in three of the five projects (Oosterhout, Huizen and Schiedam), the respondents were asked to fill in a prestructured 'diary' (logbook) during periods of one or two weeks. The diaries concern per hour information about presence at home, and the use of windows, ventilation provisions, doors inside, and heating systems. In Oosterhout and Huizen, the mean outside temperature was about +3°C during the daytime in the diary period.
In the project Schiedam the diaries are used in similar apartments during three periods, namely in winter 1985 (at 3°C), summer 1985 (at 18°C) and winter 1986 (at -2°C). Moreover, during the one-and-a-half-year period of investigation, the state of 1280 windows being open or closed has been continuously registered in a computer by means of the use of reed relays and magnets fixed to the window-frames.

Characteristics of the dwellings

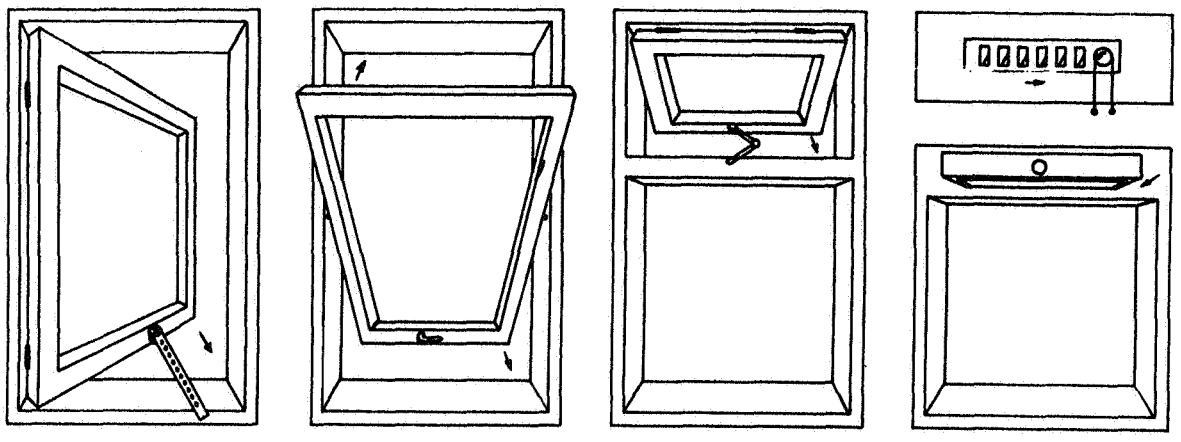
As stated above the investigation was made in four types of newly built terraced houses and in apartments of a nearly 20 year old flat-building. In table 1 some characteristics of the dwellings are given. Except for the project in Huizen all houses are rented and were built under the conditions of social housing programmes. In Huizen the electricity used to heat is produced by two windmills. Some of the dwellings in Huizen also have a facade to a common arcade.

In Almere and Zwolle a part of the dwellings are provided with a warm air heating system, a system which requires a mechanical balanced ventilation and restricted airing behaviour by the occupants themselves.

If mechanical ventilation is installed, in principle the 'slow speed' state of the ventilator is usually adjusted to an air flow of about 150 m^3 per hour. In air heated dwellings a warm air flow can be increased to 225 m^3 per hour.

Four types of windows or ventilation provisions can be distinguished: casement windows (in the Netherlands usually hinging to the outside), pivot windows (with a horizontal axel in the middle), fanlights and ventilation grids (see figure 1).

Figure 1. Types of windows or ventilation provisions



casement window | pivot window | fanlight | ventilation grids

Although in Oosterhout, in Schiedam and partly in Zwolle and Huizen the dwellings were designed with a 'closed' kitchen, only in Oosterhout a moderate part of these kitchens (36%) were really kept closed by a door.

In a small number of dwellings measurements were taken of their airtightness. In the dwellings in Oosterhout the mean airtightness is worst. It appeared that the variance in airtightness between identical dwellings can be considerable.

With all ventilation provisions and windows closed, the air leakage of Dutch terraced dwellings varies from about 130 m^3 per hour in "airtight" dwellings to circa 325 m^3 per hour in "normal" terraced dwellings (at a windspeed of 5 m/s and Δt (inside-outside temp.) of 13°C) (6). The airtightness of flatbuildings varies between 45 to 130 m^3 per hour respectively. The dwellings of the projects here concerned tend to be fairly "airtight".

Table 1. Characteristics of the dwellings per location

	Volume	n bedrooms	mech. vent.	'open' kitch.	type of windows	airtightness (q_{50} m^3/s)	number of dwellings
Almere (rad)	300	4	yes	yes	C,F,G	0,41	31
Almere (air)	300	4	yes	yes	C,F,G	0,41	12
Oosterhout (rad)	275	3	no	no	C,P,G	0,90	36
Zwolle (rad)	225	2	yes	80% y	P,G,C	0,25	31
Zwolle (air)	225	2	yes	60% y	P,C	0,25	68
Huizen (arc,coll)	300	4	yes	yes	P,G	0,24	9
Huizen (coll)	300	3	yes	77% y	P,G,C	0,35	22
Schiedam(flat,coll)	250	3	no	no	C,F	0,27	70

rad = radiator heated
air = warm air heated
arc = front to an arcade
flat = apartment in flatbuilding
coll = collective radiator heating

C = casement window
P = pivot window
F = fanlight
G = ventilations grids

Characteristics of the occupants

Those adults were selected as respondents, who usually are at home mostly (predominantly women). Assistance by other occupants in answering the questions was allowed.

In table 2 a number of socio-demographic and other characteristics of the occupants are given per project.

Table 2. Characteristics of the occupants per location

	n occupants (mean)	% >28h/w nobody at home	% ≧1 occupant ≧ 50 year	% smoking 5 cigarettes	% thin clothing prefered	number of dwellings
Almere (rad)	2,9	10	10	61	29	31
Almere (air)	3,2	17	8	50	30	12
Oosterhout (rad)	2,9	31	17	42	35	36
Zwolle (rad)	1,8	61	6	61	26	31
Zwolle (air)	1,8	50	7	46	22	68
Huizen (arc)	2,7	33	0	44	0	9
Huizen	3,0	36	0	55	0	22
Schiedam	2,6	14	46	47	30	70

From these characteristics the main difference between the projects is that the number of older occupants is relatively high in Schiedam. In Zwolle the households are smaller (35% consist of one person) and the occupants spend less time at home than in the other locations.

Where it is asked it also appeared that the washing machine is used about 1.5 times the number of occupants per dwelling and that on an average the shower is used circa 8 minutes per day per person.

From the verbal interviews some characteristics are known about the state of the 'indoor climate' in the distinguished projects. (table 3)

It appeared that the mean value of preferred inside temperature of the livingroom is 20,4° C and that only a restricted number of respondents (about 15%) prefer a warm (≧ 18° C) bedroom.

Table 3. Indoor climate per type of dwelling.

	LIVINGROOM								
	temperature ° C		% problems with					% prefered BED ROOM temp. > 17°C	N
	prefered	measured	too cold	conden-sation	draught	cig.-smoke	*cooking smell		
Almere (rad)	20,1	20,7	6	26	42	42	52	19	31
Almere (air)	20,6	19,7	25	33	67	100	67	33	12
Oosterhout	19,5	~19 (17,5/24h)	25	19	83	47	3	11	36
Zwolle (rad)	20,2	19,2**	25	13	68	9	35	10	31
Zwolle (air)	20,5	20,6**	21	6	12	16	28	12	68
Huizen (arc)	20,9	21,1	22	0	11	50	44	44	9
Huizen	20,3	20,3	27	9	36	8	33	27	22
Schiedam	21,0	20,1**	11	31	50	24	9	7	70
weighted mean values	20,4	20,1						14	279

* If ≧ 5 cigarettes smoked per day.

** Measured at a maximum outside temperature of ≦-5° C

Table 3 also shows problems with condensation draught, cooking smells and cigarette smoke that are in a substantial number of the dwellings. In nearly all projects the heating of the dwelling gave reasons for dissatisfaction too. Especially in Zwolle and Huizen technical problems arose with the heating system, while in air heated dwellings the (cold) air flows often caused complaints.

It is important to emphasize that problems with draught are not necessarily related to airtightness of dwellings. In airtight dwellings draught often is caused by relatively small "leaks" like ventilation grids (in Zwolle) or key-holes and letter-boxes (in Almere).

Results

In the projects mentioned above the occupants were questioned about how they ventilate and air their dwellings.
To ventilate is defined as to provide continuously a certain rate of refreshment of the indoor air by means of the use of ventilation grids, fanlights, leaving a window ajar or the inside door(s) of the living-room opened.
It is calculated that at a windspeed of 5 m/s and a temperature difference of 15 degrees the ventilating air flow will vary between 2-10 m^3 per hour (grids) to 50 m^3 per hour (fanlights) approximately (7). An open door inside the dwelling will generate air flows of approximately 300 m^3/h if the temperature difference between the hall is 1 degree to 600 m^3/h if this difference is 4°.

Airing is the opening of windows more than ajar during a certain period. This results in an air flow between 36 - 360 m^3 per hour depending on the width of opening.

The living-room

In table 4 the mean number of hours per day is shown in which the occupants in the different projects usually ventilate and air their living-room in an average winter period, with normal Dutch climatological conditions.

On the basis of the assumed air flows given in table 4, a rough estimation can be made about mean air exchange in the living-rooms of the distinguished projects. In these flows the rate of airtightness of the construction of the dwellings (see table 1) is not included.
The Dutch ventilation standard is based on an air exchange of 25 m^3 per hour (or 7 dm^3 per second) per person.

It will be clear that the presence of mechanical ventilation highly influences the existing air flow in the livingrooms.

Table 4. Airing and ventilating in the livingrooms

proj. nr.	location	hours per day: outward airing	outward ventil.	mech. ventil.	inward (door)	estimated mean air flow in m^3 per hour: from outside	from inside by door
1a	Almere (rad)	0,7	4,0	24	6,4	88	80
1b	Almere (air)	0,8	2,9	24	0,5	182***	10
2	Oosterhout	0,5	7,1*	0	4	7	83
3a	Zwolle (rad)	0,8	24,4*	24	3,2	92	40
3b	Zwolle (air)	0,0	0,5**	24	4,5	171***	56
4a	Huizen (arc)	0,4	55*	24	3,2	83	40
4b	Huizen	0,3	27*	24	7,5	80	94
5	Schiedam (W'85)	0,7	1,5	0	17,5	8,3	219
assumed air flows in m^3/h (per proj.nr.)		200	2(4a,b) 10(2,3a) 40 (1a,b,3b, 5)	75 (1a,3a, 4a,b) 170*** (1b,3b)	300 500 (1b,2)		

* Sumtotal of the use of more than one ventilation grid.
** No ventilation grids present
*** Partly recirculation of air

The mean total air exchange is lowest in the dwellings in Oosterhout. It is the very project where a substantially higher number of the respondents mention problems with the supply of fresh air, namely 36%.

In its first column table 5 gives the percentages of living-rooms in which the ventilation provisions (except from the mechanical ventilation) never or seldom (less than one hour per day) are used during winter time.
In the second column the percentages of livingrooms are presented in which the airing is extensive (more than one hour per day, with an estimated air flow of ≧300 m^3 per hour or ≧ 84 dm^3 per second). In most cases the indoor air quality was mentioned as a reason for extensive airing.

Table 5 Minimal and maximal use of the provisions in the livingroom.

	N	minimal use		extensive use	
	total	%	(N)	%	(N)
Almere (rad)	31	29	(9)	23	(7)
Almere (air)	12	25	(3)	17	(2)
Oosterhout	36	31	(11)	3	(1)
Zwolle (rad)	31	13	(4)	6	(2)
Zwolle (air)	68	96	(65)*	0	(0)
Huizen (arc)	9	11	(1)	0	(0)
Huizen	22	27	(6)	0	(0)
Schiedam	70	36	(25)	11	(8)

* no ventilation grids installed.

In Oosterhout and Schiedam, where the indoor air quality is most critical in theory, because of the lack of mechanical ventilation, a high proportion of the 'non-ventilators' have usually opened the inside door during a long time. In Schiedam this is the case with 24 of the 25 dwellings; in Oosterhout in 8 of the 11 dwellings.

The bedrooms

The time windows are opened in the bedrooms is dependent on the use of these rooms. The approximate relation between the main (parents') bedroom, the bedrooms of the children and bedrooms not used to sleep is 6:3:2.
It is found that on average at 'normal' winter conditions in approximately 60% of the bedrooms of the parents a window is opened during the night. Even on extremely cold nights (-8° C) a window or fanlight is opened in 12% of the main bedrooms.

The mean time per day in which the windows in the bedrooms used to sleep are opened in the different projects is given in table 6. From information about how wide the windows were opened and the type of windows a rough estimation has been made about the percentage bedrooms in which the air flow is more than 125 m^3 per hour.

Table 6. Use of the windows in bedrooms

	hours per day	% air flow > 125 m^3/h	total number of bedrooms
Almere (rad)	5,8	59	95
Almere (air)	1,4	36	25
Oosterhout	6	53	70
Zwolle (rad)	6,9	5	39
Zwolle (air)	5	20	76
Huizen	3,4	8	39
Schiedam (w. '85)	4,3 + 9,8*	75	123

* windows = 4,3 hours
fanlights= 9,8 hours

The length of time the bedroom windows are opened is also related to the functioning of the heating system, which resulted in too warm bedrooms in Oosterhout and Schiedam and too cold bedrooms in Huizen en Zwolle*.

* In (8) it is calculated that in the case of Oosterhout, where the ducts of the radiator heating system horizontally run through a bedroom, a window must be opened 6 hours to cool the bedroom from 18° C to 15° C at an outside temperature of 5° C.

The kitchen

As already indicated in table 1, in the dwellings in Oosterhout and Schiedam mechanical ventilation is lacking. (In 21 kitchens in Oosterhout and 17 kitchens in Schiedam the occupants used a ventilationhood, but these did not significantly lead to a better judgement about the indoor air quality). Moreover in these projects the kitchens are not designed as a part of the living-room although the door from these kitchens to the hall of the dwellings predominantly is opened: in 64% of the cases in Oosterhout and 93% of the cases in Schiedam. In Schiedam a gas geiser to produce hot water was installed in the kitchen. On average, airing took place 45 minutes per day in Oosterhout (by means of a door to the garden) and about 20 minutes in Schiedam (by means of a casement window). Moreover in Schiedam a fanlight was opened 3 hours per day. In Oosterhout a small ventilation grid had been installed. On average this was opened 6,7 hours per day.

Assuming the way of airing and use of the kitchen, an estimation can be made that the mean air flow directly from outside is less than 25 m^3/h per day in about 50% of the kitchens in Schiedam.

With respect to dwellings with an "open" kitchen as part of the living-room, it is already stated (table 3) that in spite of mechanical ventilation provisions, in a high percentage of these dwellings problems exist with cooking smells.

Motives to air or ventilate

In answer to the "open" questions why people ventilate or air as they do, a need for fresh air is mostly mentioned. Especially the bedrooms are preferred to be "fresh". (What is meant by "fresh" probably is a combination of temperature, smell and amount of dust).

Other spontaneous mentioned reasons to ventilate or air are to get rid of cigarette smoke and, depending on the project, vapour and condensation problems and cooking smells. Household activities like vacuum cleaning and "airing" blankets are mentioned as reasons too.
In table 3 information has already been given about the problems with indoor climate factors and the (low) percentage of dwellings where a "warm" bedroom is preferred. (It's notable that a high proportion of respondents could not give a preferred bedroom temperature, but answered "fresh" only).
Especially in Almere the respondents complained about condensation on the (single glazed) bedroom windows and a way to get rid of it was to keep the windows opened. The condensation was partly caused by dampness from the bathroom, which was situated in the middle of the dwelling. The same type of location of the bathroom also plays a role where there are problems with condensation in Schiedam.
A part of the spontaneous answers given on the question why airing or ventilating or the method used referred to comfort and convenience. A door to a balcony or garden is preferred to a window.

Few respondents referred to the dense insulation of their dwellings.

The main reasons not to ventilate or air are sufficient indoor climate, air quality and draught. (Table 3 showed that in nearly all projects, including the most insulated dwellings, a high percentage of the occupants experience problems with draught). Especially the air flow through ventilation grids seems to produce annoyance. As reason not to air, the presence of plants, domestic animals and small children ought not to be neglected. Plants must be kept free from lice; canaries or parrots free from cold. The territory of children, cats, dogs and hamsters needs to be controlled. It appeared that the use of doors inside the dwelling is highly determined by them, together with arguments like habit and convenience.
Where mechanical ventilation is installed (in "open" kitchens),

sometimes complaints are expressed about noise annoyance. In another study (9) it is found that an emmission level of noise from a ventilator of 30 dB(A)L_{eq} in a living room, generates annoyance in 25% of the households.
In 5 of the 36 dwellings in Oosterhout traffic noise influenced the use of the windows in the bedrooms at night (in the other locations the outside noise levels were too low to influence the behaviour).
Finally, only a few respondents explicitly pointed out burglary as a factor to close windows.

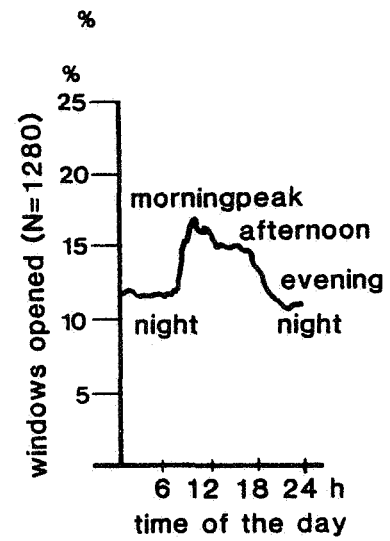
Correlated factors

The type of windows and the handiness to use and to wedge them influence the behaviour. Pivot windows tend to be less wide opened. From the Oosterhout project it is known that the use of casement windows is influenced by the direction of the wind, resulting in one hour difference in use on average per day. The same tendency is found in Schiedam.

Apart from architectural characteristics of the dwellings and applied technical provision, a number of behaviouristic aspects of the occupants can be correlated with the length of time in which airing and ventilating take place.
A comparison between dwellings in which the occupants were not at home less than one hour per day on average, with dwellings in which nobody was at home more than four hours per day indicated that, taking all provisions together, no clear difference is found in the mean time the windows were used per day. Only the (bedroom) windows were less wide opened. However, on the basis of the information from the diaries it was clearly found that in the periods of the day nobody was at home and if the windows are not easy to open from the outside, they were kept opened much shorter than on average: for instance in Schiedam in winter 1985: 0,3 hours against 2,3 hours per day (in half of the addresses all windows and fanlights were always closed when nobody was at home).

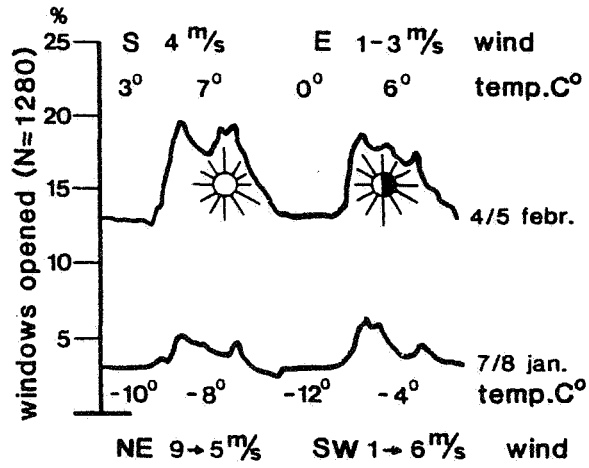
Per household the daily pattern in using the ventilation provisions and windows appears to be very consistent. In figure 2 this daily pattern is shown. At roughly the same climatical circumstances the variance in behaviour is low in the same households. "Deviating" behaviour has been found in the weekends.
Although seldom spontaneously mentioned by the occupants (it's taken for granted), a strong correlation has been found between the use of windows and outside climatical conditions like temperature, windspeed, wind direction and sunshine (1).
In this paper we restrict ourselves to the presentation of a figure which shows the percentages of windows opened in the flatbuilding in Schiedam during different circumstances. (figure 3).

Figure 2. Daily pattern of airing and ventilating



	weather night	day
temperature °C	8	9
windspeed m/s	7	8
winddirection	SW	SW/W
sun %		50

Figure 3. **Use of windows at different weathertypes**



Where occupants do smoke, the ventilation provisions in the living-room are used about twice as long as those where occupants do not smoke. On the basis of the information from the diaries, smokers to non-smokers ratio's are found of 1,9 in Schiedam, 2,0 in Oosterhout and 1,6 in Huizen. The results from the interviews in Almere (rad) even showed a ratio of 3,2, but in Zwolle (rad) no clear difference was found.

With respect to problems with condensation it appeared that its relation with the use of the ventilation provisions is subject to two interpretations: condensation owing to too short ventilation at too low temperatures inside; or the condensation problems themselves are solved by longer ventilation, but create derived problems like draught, too low temperatures, or more use of heating energy.

For instance in the living-rooms in Schiedam with problems of condensation the occupants ventilate on average 1,6 hours per day versus 2.4 hours in livingrooms with no condensation.

On the contrary in Oosterhout the living-rooms with problems of condensation were ventilated longer: 4.3 versus 3.3 hours per day. In the living-rooms with condensation a mean inside temperature was measured of 16°C, against 18°C in rooms without condensation. In bedrooms without condensation problems in Oosterhout the (double glazed) window was opened 7.2 hours per day on average with a mean inside temperature of 18°C. However, in the bedrooms with condensation problems, the window was opened 2.7 hours per day at a mean inside temperature of 14.4°C.

Preferred clothing behaviour is related to a preferred inside temperature. It is found that light clothed people prefer a 2°C higher temperature on average in the living-room than people with heavier clothes.

In the tables 7 and 8 relations are shown which are based on information obtained from the verbal interviews taken in Huizen, Zwolle and Schiedam. Per project a simple Pearson correlation has been calculated between the variables stated and the rate of ventilating (in hours) and airing (in hours times width of opening of a window) per day per dwelling.
If the correlation is marked with ** it is judged as significant (p value is ≦ 05), if marked with * a tendency of a relation is assumed (.05 <p ≦ .10).

Table 7. Correlation between variables and ventilation and airing of the livingroom and/or kitchen.

	Huizen (n=31)		Zwolle (n=104)		Schiedam (liv) (n=70)		Schiedam (kitchen) (n=70)	
	low vent.	air	vent.	air	vent.	air	vent.	air
low energy consumption			**			*		
low number dwellers		**						
low age respondent	-*			**	*		-*	
low absence	*		-**					-*
low thermostat evening	**			-*	/	/	/	/
low thermostat 24 hours			-*				-*	
few hours therm. low at absence	*				/	/	/	/
few hours inside door liv.room open			-*		/	/	/	/
low temp. livingroom prefered	**						-**	
low temp. livingroom measured				-**				
low temp. bedrooms prefered								-**
low satisfaction indoor climate	**							
low minutes of shower-bath								
low freq. of use of washing-mach.		**					**	
many problems with:								
heating ground floor								
heating bedroom floor					/	/	/	/
cooking smells								
sigarette smoke			-*		*	-*		
fresh air						-*	*	
condensation								-*
draught	/	/						-**
cold radiation	/	/				-**		
cooling	/	/	/	/		-**		
low ventilating livingroom		-**		*				
low airing livingroom	-**		*					
low ventilating bedrooms			**	*	**		**	
low airing bedrooms		*	**	**	**			**

** p ≦ .05

* .05 < p ≦ .10

/ = not analysed

Table 8. Correlation between variables and ventilation and airing of the bedrooms.

	Huizen (n=31)		Zwolle (n=104)		Schiedam (n=70)	
low	vent.	air	vent.	air	vent.	air
low heating energy consumption						
low numer dwellers			-**			-*
low age respondent						**
low absence						-**
low thermostat evening		-*			/	/
low thermostat 24 hours		-*				
few hours therm.low at absence			**	**	/	/
few hours inside door liv.room open			-**	*	/	/
low temp. livingroom prefered	-*			-*		
low temp. livingroom measured			-**			
low temp. bedrooms prefered			-**	-**		
low satisfaction indoor climate			-**			
low minutes of shower-bath		**	-*	**	*	
low freq. of use of washing-mach.	*			*	**	
many problems with:						
heating ground floor		-*				
heating bedroom floor		**			/	/
cooking smells		*				
sigarette smoke						*
fresh air						
condensation			-*			
draught	/	/				
cold radiation	/	/				
cooling	/	/	/	/		
low ventilating livingroom			**	**	**	**
low airing livingroom		*	*	**		
low ventilating bedrooms		-*		**		**
low airing bedrooms	-*		**		**	

** $p \leq .05$

* $.05 < p \leq .10$

/ = not analysed

The above mentioned findings are confirmed by the statistical information presented in the tables 7 and 8, although not in all three distinguished locations. In addition it can be stated that if people tend to ventilate or air their living-room at a high level, they also tend to do the same in the bedrooms. Moreover, the frequency of use of a shower-bath or a washing machine appears to influence the use of windows.

The consumption of energy to heat is primarily related by the mean state of the thermostat in the living-room. In turn the thermostat is sensitive to air flows from outside coming through the ventilation provisions.

Surprising may be the finding that the way the bedrooms are aired or ventilated does not influence the energy consumption. (This was also found in the project Oosterhout). The reason may be the fact that the bedrooms are usually heated only shortly or never. (In Schiedam and Huizen a correlation of .37 and .40 respectively was found between the number of radiators which are used and the consumption of energy to heat. In Zwolle this relation is leaking).

Validity and reliability

To assess the validity of the information from the respondents the results from the diaries (in (half) hours per day) has been compared with the results from the technical measurements (magnets on the window-frames) during the diary period.
Figure 4 shows the facades of an apartment in the flat-building in Schiedam and gives the codification of the windows.
It appeared that the correlation between those measurements was very high: If the windows or fanlight were opened more than one hour per day on average, in winter 1985 a correlation on individual level (per apartment) was found of .90 per window or fanlight on average and .73 if these were opened less than one hour per day. In summer 1985 the rates of correlation were .95 and .53, in winter 1986 .80 and .57 respectively.
Although not as high as above mentioned correlations, the information from the verbal interviews (taken before the diary period of winter 1985) concerning previous subjectively experienced "cold" and "not so cold" winter periods, fairly agree with the findings from the diaries too, assuming that the period in which the diaries were filled in (3°C during day time) as been defined as cold. In table 9 the mean times are given during which window opening occurred in winter 1985 according to the interviews, diaries and technical measurements taken in identical households (n=52).

Figure 4. Façades and codification of windows and fanlights in Schiedam

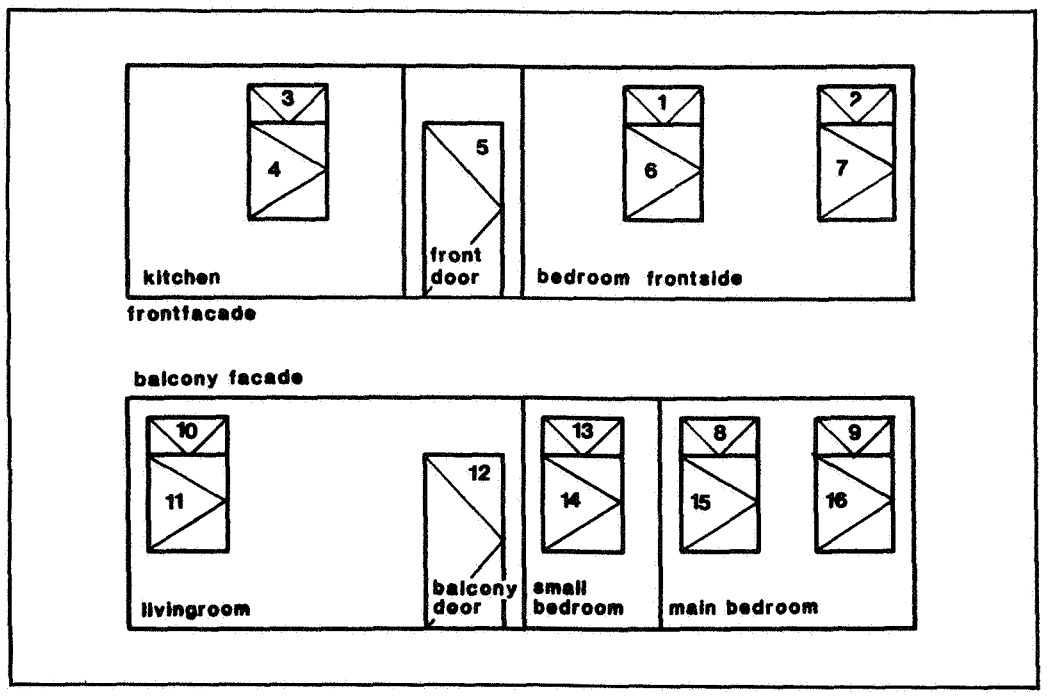


Table 9. Comparison between results from interviews, diaries and technical measurements

Codification (see figure 4)		Mean hours opened per day: interviews less cold	interviews cold	diaries	measurements
livingroom	10	3,9	1,5	1,1	1,5
	11	0,3	0,1	0,4	0,6
	12	2,4	0,9	0,7	0,8
small bedroom	13	11,6	4,4	5,1	5,5
	14	3,0	1,3	1,8	2,8
main bedroom	8	15,4	9,5	9,0	8,6
	9	4,2	1,9	3,6	3,4
	15	1,6	3,0	6,1	6,2
	16	5,6	1,3	1,6	1,6
bedroom front-side	1	5,9	2,6	4,3	4,5
	2	7,2	3,4	1,8	1,6
	6	0,6	0,3	0,9	0,6
	7	2,0	0,9	0,6	0,5
kitchen	3	5,7	3,4	3,0	3,1
	4	1,5	0,8	0,3	0,4
Total mean		4,7	2,4	2,7	2,8

In the 18 apartments where the occupants only participated in the interviews, they tended to be less at home or it concerned households with small children. However, no significant difference was found in the use of windows and fanlights between those who participated in the interviews (n=70) and those still participating during more than one year and three diary periods (n=38).

In theory a changed behaviour could also be caused by the magnets installed on the windows-frames and by the participation of the occupants at interviewing and diary keeping. However, apart from the already mentioned high validity of the results, a comparison shows no surprizing differences in behaviour with the results of diaries which are filled in by a reference group (occupants of apartments of another (identical) flatbuilding) during the same period in winter 1986 (see table 11). The main difference is the use of airing and ventilation provisions in the living-room, but this can be explained by the prevailing wind direction during the diary period (the livingroom of the main group was orientated to the east, those of the control group to the west).

Change in behaviour

One of the purposes of the investigation in Schiedam was to give information and instruction to the occupants how to ventilate and air sufficiently at minimal use of heating energy. The base of this information campaign was formed by the results of the interviews and the technical measurements of winter 1985.

Integrating behavioural aspects like smoking and the experience of aspects of indoor air climate, it was found that in about 10% of the apartments the ventilation tended to be too low, in another 10% clearly too high and in about 45% very unbalanced: too high in the bedrooms and too low in the living room or kitchen.
The information was given written and consisted in short of the following advice (table 10).

Table 10 Ventilation and airing advice

Bedrooms:	
daytime	: casement window 20 minutes fanlight 1 cm wide continuously
nighttime	: fanlight half opened continuously
Livingroom:	
If 2 persons present	: fanlight half opened
If 4 persons present	: fanlight opened totally or inside door opened, together with fanlight and windows opened in bedrooms or kitchen.
at night	: after smooking a fanlight open
Kitchen:	
at cooking	: casement window or fanlight open
after cooking	: casement window 5 minutes fanlight few hours open

The written information was also sent by post to the inhabitants of other identical flatbuildings, but these inhabitants were not drawn into the investigations, except from a small number of them (n=27) used as a reference group.
On this basis of the diaries filled in in the same households (n=38), table 11 shows the difference in the total time the windows and fanlights were opened per day during the diary periods of winter 1985 and winter 1986. Also the time is given during which respondents in the reference group used their windows and fanlights in the same period in winter 1986.

Nearly all windows and fanlights were less opened in the winter period of 1986. Especially this is the case in the main bedroom, where both the casement windows and the fanlights were kept open half as long as in the winter period of 1985. With respect to the provisions in the living room it was found that especially those who prefer to wear light clothes ventilated or aired less: 3.3 hours per day in total in 1985 to 1.6 hours in 1986. The kitchen was ventilated or aired shorter by the lightly clothed respondents (3.1 hours in 1985 to 1.6 hours in 1986), but heavily clothed respondents ventilated or aired the kitchen longer on the contrary: 4.7 hours in 1985 to 5.5 hours in 1986.

Although the above mentioned results suggest an effect of the information campaign, this effect is highly influenced by climatical conditions: During the diary period of 1986 it was approximately 5°C colder on average, which will "automatically" lead to about 0.8 hours per day less use of provisions (1). Therefore it can be concluded that in total the information campaign only led to 0.6 hours per day less use of windows or fanlights per apartment.

Table 11 Comparison between 1985 and 1986.

Codification (see figure 4)		Mean hours opened per day: main group 1985	main group 1986	reference group 1986
livingroom	10	1,1	0,7	1,9
	11	0,5	0,3	0,2
	12	0,7	0,4	0,7
small bedroom	13	6,5	1,9	3,6
	14	2,3	0,7	1,1
main bedroom	8	10,0	4,8	2,5
	9	3,6	1,9	3,1
	15	5,5	2,0	2,4
	16	1,6	0,4	2,2
bedroom front-side	1	4,7	3,3	4,8
	2	2,3	2,1	1,7
	6	0,4	0,6	0,3
	7	0,9	0,7	0,4
kitchen	3	3,8	4,3	3,9
	4	0,4	0,2	0,4
total mean hours		3,0 h	1,6 h	1,9 h
% windows opened		12,5 %	6,7 %	7,9 %

Conclusion

A large number of data are obtained to get insight into the behaviour and motives of occupants of dwellings with respect to ventilation and airing nowadays. Although only a part of these data are presented in this paper and more detailed information has not been analysed yet, it can be assumed that the results give a reasonably good representation of the "state of the ventilation art" in newly built dwellings in the Netherlands.
The methods used, especially the combined application of verbal interviews, diaries and technical measurements, were successful.
On the basis of the available information more precise calculations can be made about air quality and air flows in dwellings.
It appeared that an air exchange which seems to be sufficient in a pure physical sense, does not exclude per definition problems of indoor air quality in practice.
Four types of factors can be distinguished which determine the experiences and the behaviour of the occcupants with respect to airing and ventilation:

- factors which cannot be influenced like personal characteristics of the occupants;
- factors which hardly or ought not to be influenced like the indoor climate preferred by the occupants and the indoor air quality they experience;
- factors which may be influenced, like specific routines in the daily household behaviour;
- and factors which can be changed in behalf of the occupants: characterictics of the dwellings and the applied heating systems and ventilation provisions.

Especially the last mentioned factors deserve the highest attention, in view of the reported deficiences in controling the indoor air quality and climate.
The results of the studies showed that most problems are not caused by "deviant" or "irrational" patterns of behaviour of the occupants. Therefore technological solutions ought to be adapted to these patterns not visa verse, as happens in more than one case, however well intended (reduction of costs, energy saving) that may be.

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