

## PATTERNS IN VENTILATING AND AIRING BEHAVIOUR IN RELATIVELY WELL-INSULATED NEWLY-BUILT TERRACED HOUSES

JEF E.F. VAN DONGEN  
TNO Research Institute for Environmental Hygiene  
Delft, The Netherlands



### Abstract

This paper reports a case study dealing with the relation between ventilating and airing behaviour and the outside climate. Also the significance of other variables such as preferences with respect to the indoor climate are considered. An indication is found that wind speed correlates, but outside temperature (varying from  $-3^{\circ}\text{C}$  to  $+9^{\circ}\text{C}$ ) does not correlate with the length of time the windows in the bedrooms and bathrooms are opened. Rainfall and sunshine also seem to have some influence. The main reasons for airing is the opinion that the bedrooms are too warm and not fresh. On an average the windows of the bedrooms, if used for sleeping, were opened 6 hours a day. 70 % of the respondents opened these windows more than 2 hours a day. More field studies into condensation and moisture problems are recommended.

### Introduction

To gain an insight into the differences in energy use of different heating systems in newly-built terraced family house in The Netherlands, during the winter of 1983 two case studies (in the towns Oosterhout and Almere) into the daily behaviour and motives of the occupants with respect to airing and ventilation of their dwellings were carried out.

The execution of these two investigations was supported by the TNO Energy Research Project Office within the framework of the National Programme of Energy Research.

Selection and methodology. Especially the results obtained from the Oosterhout case will be presented here because the methodology used is most informative. Although the number of dwellings which are considered here is small ( $n=36$ ) some basic results appear to agree with the case study in Almere [1] and two other Dutch studies [2, 3]. In Oosterhout the information of the behaviour of the occupants was obtained by verbal face to face interviews, carried out in 57 households. In addition to these interviews the respondents were asked to fill in a logbook during 14 days. A total of 41 of these logbooks were completed; 36 of them were useful to this study.

The logbooks concern per hour information about people at home, the position of the room thermostat, the periods with open windows and open ventilating grilles in the different rooms, the use of radiator valves and the position of the doors inside the house. The information obtained has been related to the use of energy, the inside temperature, the orientation to the sun and, more in detail, to the weather conditions. In the period the logbooks were filled in (January 28 - February 10) the mean daily outside temperature varied from + 9°C till - 3°C in the daytime; there was stormy weather and there were periods without wind; the direction of the wind changed from west to north-east; there were some rainy days, cloudy days without rain, days of a variable weathertype and some sunny days.

### Characteristics of the dwellings and their occupants

The dwellings. All dwellings are identical (see ref. [4] for a description). The kitchen is separated from the living room. Three bedrooms and a bathroom, each with one window which can be opened, are at the first floor. For Dutch standards the dwellings are relatively well-insulated with a heat loss of the envelope of 150 W/K and an air infiltration of 150 m<sup>3</sup>/h in mean weather conditions (5 m/s,  $\Delta t=15$  K) when all windows and ventilating grilles are closed. The external walls consist of brick with insulation in the cavity, the windows are double-glazed and natural ventilation is used. Each house has its own gas burner furnace on the loft for heating and hot water. In the livingroom two radiators are installed, in each other room one. It is important to know that the pipes towards the livingroom run horizontally through the bedrooms. In most dwellings complaints are raised about "draught" in the livingroom near a bay window. The 36 dwellings can be divided into four orientation clusters. Nine dwellings were situated east-west (the entrance to the east), 11 north-south, 12 west-east and 4 south-north.

The occupants. The mean number of persons per household is 2,9. Eleven households consist of two persons. In 12 households children are younger than 5 years, in 5 households occupants are older than 50 years. On five addresses usually nobody is at home between 9 and 12 a.m. on working days.

## Results

### The consistency of the behaviour

In the first place it has to be said that over the period of 14 days the airing behaviour of the individual respondents appeared to be rather stable. With respect to the average use of the four windows at the first floor the standard deviation is less than 2 hours a day (24 h.) for 70% of the respondents and less than 1 hour for 30%. Another indication of the consistency in the housewives' daily routine is the finding that on the whole the results from the logbooks of 70% of the respondents in general confirm with the answers given in the interviews, carried out before the logbooks were completed. Where there was no consistency (especially this was the case for the windows orientated to the south) mostly the actual length of time windows were opened was underrated in the interviews.

### The preferred and the actual indoor climate

The mean indoor temperature preferred for the livingroom is 19.5 °C. With respect to the bedrooms only four respondents preferred a temperature  $\geq 17$  °C. Remarkable is, that 40% of the respondents could not give an answer here in grades or only spoke in terms of fresh, cool or even temperature outside.

The mean temperature measured (over 24 hours !) is 17,5 °C in the livingroom, 17 °C in the bedrooms and 18 °C in the bathroom. In the daytime these temperatures are about 2 °C higher. From the logbooks it appeared that on average the thermostat installed in the livingroom, was switched on a temperature higher than 15 °C during 12 hours a day (no differences are found between the clusters). In the bedroom the radiator was used 11% of the time, while the thermostat was higher than 15 °C (so 1,3 hours a day) and in the bathroom 53% of this time period. In the bedrooms the radiators are warm only 10 minutes a day, while the windows are opened, in the bathroom this is the case for about 20 minutes. Remember: the piping to the livingroom runs through the bedrooms and the bedroom floors are not insulated well. Conclusion: it is not the occupants' behaviour which is irrational with respect to the energy use, but home characteristics are.

### The use of the windows and the ventilating grilles

Knowing the preferred and the measured temperature and the use of the radiators, it is interesting to know how windows and ventilating grilles are used to realise a preferred indoor climate.

In the bedrooms. Table 1 shows, per orientation and in total, the distribution of the length of time the windows of the bedrooms (if used for sleeping) were opened during the logbook period.

Table 1. Distribution of the length of time the bedroom windows were opened (in percentages and absolute numbers ( ))

Hours opened	% of 24h opened	Orientation				Total (n=70)
		West (n=24)	South (n=15)	East (n=19)	North (n=12)	
< 0.5	< 2	0 (0)	0 (0)	0 (0)	25 (3)	4 (3)
0.5-1	2 - 4	13 (3)	13 (2)	11 (2)	0 (0)	10 (7)
1-2	4 - 8	20 (5)	27 (4)	21 (4)	0 (0)	19 (13)
2-4	8 - 17	33 (8)	27 (4)	21 (4)	33 (4)	29 (20)
4-8	17 - 33	13 (3)	7 (1)	26 (5)	25 (3)	17 (12)
> 8	> 33	20 (5)	27 (4)	21 (4)	17 (2)	21 (15)
mean time opened/24h		21 % = 5h	35 % = 8.5h	24 % = 5.8h	21 % = 5h	25 % = 6h

Nearly all these windows are used for airing, although ventilating grilles are present too. 67% of the respondents opened the windows more than two hours a day, with a peak in the morning between 9 - 12a.m. In the west-east cluster the use of windows orientated to the east is negatively influenced by traffic noise in six dwellings. In the north-south clusters the windows orientated to the south appear to be opened longer, but from the face to face interviews we know that they

are more set ajar; in 67% of the dwellings against 12% in the dwellings of the other clusters.

A calculation of the air supply per hour through the windows results in an air supply of 10 m<sup>3</sup>/h when the windows are set ajar, of about 100 m<sup>3</sup>/h at moderately opened, 200 m<sup>3</sup>/h at rather wide opened and 300 m<sup>3</sup>/h at wide opened windows when the wind speed is 3 m/s. With a wind speed of 9 m/s the air supply is 40-100 m<sup>3</sup>/h higher [5]. Together with the information from the face to face interviews (from which appeared that of the windows in the 70 bedrooms used for sleeping 21% was set ajar, 26% was opened moderately wide, 33% rather wide and 20% widely) this means that in at least 45% of these bedrooms air supply is more than 300 m<sup>3</sup>. The Dutch ventilation standard is based on 25 m<sup>3</sup>/h per person.

From the logbooks it appeared that on the average the window of the parents bedroom is opened 1,7 times longer than a window in each of the other (childrens) rooms: 33% of the day (= 8 hours) against 19% (4,5 hours). In the logbook period 25% of the "parents" slept with an open window. Only 3 of the 38 children (= 8%) do so.

In bedrooms where there were problems with condensation on the windows (n=19) the mean temperature was relatively low (14,4 °C) and the mean time these windows are opened is found to be 2,7 hours; this while the use of the ventilating grilles did not differ from the total means: always opened 30%, variably opened 40% and never opened 30%.

In the bathroom. The window in the bathroom is opened about 2 hours a day, while the ventilating grille is always opened in 50% and never opened in 25% of the dwellings. Problems with condensation occur in ten bathrooms, proportionally more often orientated to the north.

In the livingroom. The only window in the livingroom which can be opened is not used often. On an average in the logbook period this window was opened longer than one hour a day in 3 of the 36 dwellings. In 19 dwellings the window was never opened. (In the Almere case in 40% of the dwellings a window was open > 1 hour, but there the kitchen was situated in a corner of the livingroom). The ventilating grilles on both sides of the livingroom are always closed in about 20% of the dwellings, in about 35% at least one was open. In total on the west and on the east facade the grill is open about 3,5 hours a day, on the south facade about 1,5 hours a day and on the north facade about 5 hours. Problems with condensation on the window (also rising at a relatively low mean temperature of 16 °C/24 h) form a reason why in this case the ventilating time is longer than on the other facades. On an average the inside door to the hall is opened about 5,5 hours a day, but in the north-south cluster, where the grill on the north facade is opened more, this door is opened less: 2,5 hours. A factor which seems to influence negatively the ventilating of the livingroom is the draught from the bay windows already mentioned.

#### Factors influencing airing and ventilating

Besides a number of factors connected with characteristics of the dwelling (kitchen apart from the livingroom, draught in the livingroom, the piping of the central heating through the bedrooms and a bedroom floor with a low thermal insulation) and condensation at relatively low inside temperatures, other factors related to airing and ventilating have been analysed.

Weather conditions. The length of time windows on the first floor were opened, as a mean over the four windows concerned, was investigated in relation to the mean outside temperature (over 24 h) (Figure 1) and in relation to the wind speed (Figure 2). There appears to be no correlation between the outside temperature and the length of time windows are open. Although it is only an indication because of the limited number of cases, there seems to be a correlation between the length of time and the wind speed. Rainfall and sunshine seem to have some influence too. Roughly it can be said that, leaving out the direction of the wind, at low wind speeds (5 m/s) each of the four windows was opened one hour longer (or one window four hours longer) than in situations with a high wind speed.

Because of the above mentioned traffic noise in a part of the west-east orientated dwellings, a good assessment of the relation between wind direction and window use was not possible, but there probably will be one. An indication of it is that if the hinging of the windows is unfavourable to the wind direction these windows are opened shorter about one hour a day.

With respect to the grilles in the livingroom a slight indication is found that when the weather is dry and the wind speed is low the grilles are opened longer when the outside temperature is higher: about 3,5 hour at  $-3^{\circ}\text{C}$  and about 4,5 hour at  $+2^{\circ}\text{C}$ . With respect to other weather factors no regularities were found.

Other factors. It is found that the windows in bedrooms not used for sleeping are opened two hours on an average, so three times shorter than in the parents bedrooms. Although statistically not significant there is a slight indication that where young children ( $< 5$  years) sleep the bedroom windows are opened shorter. Smokers appear to ventilate the livingroom twice as long as non-smokers: 4,8 hours a day against 2,4 hours. In the livingroom the ventilating grilles tend to be more closed on Sundays. Attitudes to energy use do not influence the airing behaviour. Maybe surprisingly no relations were found between the use of energy and the mean length the windows and ventilation grilles are opened. The use of heating gas only correlates with the temperature of the livingroom ( $r = .83$ ) and the length of time the thermostat is higher than  $15^{\circ}\text{C}$  ( $r = .39$ ). Those who are used to wear jerseys (in 65% of the dwellings this is the case) consumed 225 m<sup>3</sup> natural gas per month, those who like to be dressed lightly 300 m<sup>3</sup>.

### Conclusions

Comparing the above mentioned quantitative results with basic results from other Dutch studies, a conclusion is that by using logbooks very detailed and reliable information about the daily behaviour can be obtained. At an individual level this behaviour appears to be consistent and also at group level it seems to be well predictable. But what we found may be a reflection of a typical Dutch housing and weather situation and cultural pattern. The question rises whether the Dutch airing and ventilating behaviour is comparable with the behaviour in other countries.

Another conclusion is that the energy-saving behaviour may lead to moisture and condensation problems when the mean inside temperatures and the air supply in well-insulated dwellings are relatively low. In other words: the occupants need an answer to the question how to balance minimal heating and ventilating. More field studies into dealing of this problem in practice are recommended.

### References

- [1] Dongen, J.E.F. van, Research into the behaviour of occupants of dwellings with an air-heating and ventilating system. Report D 79, IMG-TNO, Delft, 1984 (in Dutch).
- [2] Beek, F.M. van, Hurkmans, P.A.J.J. and Smit, J.F. Experience and use of windows in dwellings. Nationale Woningraad, Almere, 1981 (in Dutch).
- [3] Jong, P.P.G. de, and C.P.M. Sadée. Insulation testcase Vlaardingen. Bouwfonds Nederlandse Gemeenten. Hoevelaken, 1982 (in Dutch).
- [4] I.E.A., Annex III.-Evaluation of energy conservation measures for heating of residential buildings. Project description. IMG-TNO, Delft, 1980
- [5] Phaff, J.C. e.a. Ventilation of buildings research into the effect of the opening of one window on the indoor climate of a room. Report C 448, IMG-TNO, Delft 1980 (in Dutch).

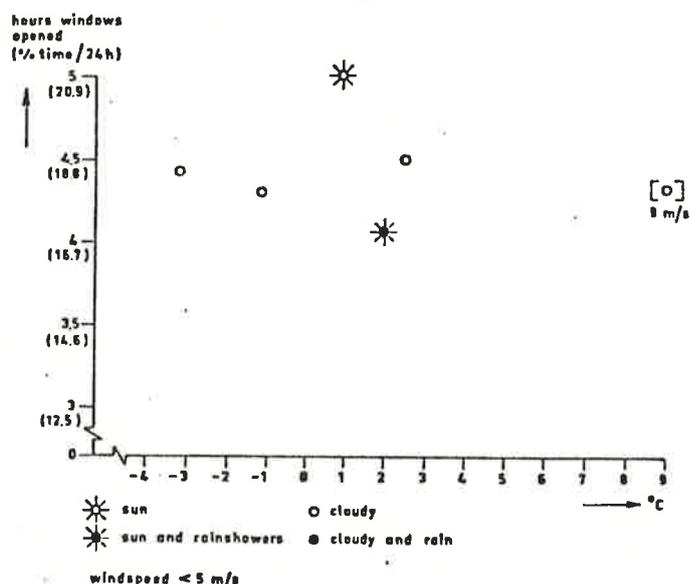


Figure 1. Mean outside temperature and the use of the windows

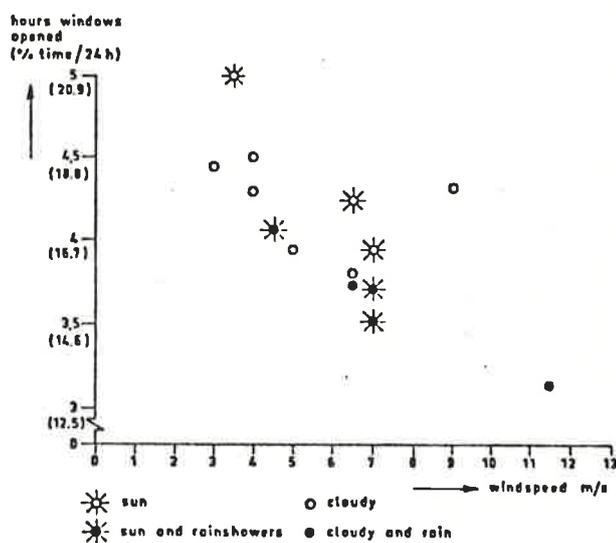


Figure 2. Mean windspeed and the use of the windows