OCCUPANT INTERACTION WITH VENTILATION SYSTEMS

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

PAPER S.4

EFFECT OF INSTRUCTIONS TO INHABITANTS ON THEIR BEHAVIOUR

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1. Introduction

1.1. General

Within the framework of the International Energy Agency (IEA) Annex VIII , "Inhabitants Behaviour with Regard to Ventilation" an investigation has been carried out on the use of windows in an apartment building in Schiedam. The measurements have been done by the TNO Division of Technology for Society. They started in November 1984 and stopped in May 1986.
Three inquiries and diaries have been set up in the two heating seasons and the summer period to get additional information from the dwellers.
In the 6th AIC conference [1] paper 20 dealt with the first heating season of this project.
As the project and analysis have to be finished in March 1987 the contents of this paper are only preliminary results.

1.2. Purpose

Determination of:
1. window behaviour, relation to climatic conditions
2. energyloss due to open windows
3. motives for opening windows
4. changes in behaviour by information and instruction to the inhabitant.

1.3. Building and meteo

The apartment building is situated in Schiedam which is at the west side of Rotterdam , some 20 kilometres from the coast of the North Sea in the Nether lands. The building is surrounded by similar apartment buildings except for the North to East side. The mean temperature in the heating season, which is approximately 200 days, is 5 degree Centigrade. The mean wind velocity is 5 m/s with a prevailing West direction except for the cold periods in winter (-15 to -5 degree C.) and also the hot periods in summer (above 20 degree C.) then the wind direction is East, coming from the land climate region of the continent of Europe. The building has 10 floors and 14 dwellings on one row per floor. In the middle of the building there is a staircase and elevators, these give access to the gallery, an open corridor hanging on the outside of the building just like

the balcony on the other side. The frontdoors of the dwellings , as seen from the wind and stack pressure point of view, are only linked to outside air and not to the thermal pressure in the staircase. Therefore the only difference between low and high floors is the difference in wind exposure and the thermal height of the natural ventilation ducts. However this last factor is largely eliminated by the frictionloss in the ducts. These ducts are meant to exhaust air from WC,bathroom and kitchen, but frequently they transport spoiled exhaust air from one dwelling, as supply air to another dwelling on a higer or lower floor. This is due to the fact that the ducts are vertically combined. The first 5 floors have 3 main ducts per vertical row of apartments, and the upper floors also have 3 main ducts. Every single duct, for example from the kitchen, goes up approximately 3 metres and then enters the main duct. These 3 metres have been thought to give a stack effect strong enough to deal with the wind pressure differences from floor to floor. But one can imagine that an open leeward window on one floor and a windward one on another can overrule 3 metres thermal pressure very easily. Since 1975 this system is no longer allowed in new buildings as it gives many complaints about the spread of odour. The mean duct flowrate is about 0,006 m3/s (20 m3/hour) per single duct, 0,017 m3/s (60 m3/hour) per dwelling.
A lot of these buildings in the Netherlands still exist and for reasons of easy access from the outside during the instrumentation this building was choosen.
80 of the 140 apartments have been instrumented. Every apartment has 16 windows and outside doors, 6 windows and a frontdoor on the gallery side and 8 windows and a balcony door on the balcony facade. Above every large casement window (area 0.9 m2) there is a smaller ventlight or pivoted flap window. The total number of windows and outside doors is 80 * 16 = 1280.

1.4. Amount of data

The measurements started on 29th November 1984 and stopped on 12 May 1986. This results in a total period of 529 days, however on 62 days due to several failures no data has been measured. There remain 467 days with all window positions with a 15 to 20 second time resolution.
On cold winterdays one or two front doors closed so badly that in the closed position the part with the sensor was still more than 15 mm away from the normal closed position, which caused in some way a false result. A few kitchen windows also suffered this phenomenon.

1.5. Instruction

In November 1986 before the second winter period all 80 inhabitants had a written example how to make proper use of the windows. About 20 inhabitants were selected by means of their measured window use and visited personally. In thesevisits we tried to give some information about the energyloss by a large window open for more than 8 hour a day, and also the risks of not opening windows. In all instructions and talks we tried to leave the choice to the inhabitant more by gentle hints than severe rules.
The written instruction had the following form:

Example for the use of windows and doors at normal weather in Spring/Autumn and Winter.

Bedrooms

Day:	Night:
Large window open 20 minutes (at putting the bedclothes in order)	Ventlight half open.
Ventlight whole day ajar (1 cm)	

Livingroom

When one is in the room:	Night (or no one in the room):
Either: 2 persons -ventlight half.	Windows closed, except with
4 persons -ventlight full.	(more) smokers, then a ventlight
or: livingroom inner door open	open.
and some windows in bedrooms	
and kitchen open.	

Kitchen

During cooking:	After cooking:
Windows as one wishes	Either: ventlight 20 minutes open
	or: casement window 5 minutes open
	followed by an open ventlight

Shower

Inner door open for some hours on 10 cm after use of the shower.

Remark:
At strong wind and cold periods windows can be open for a shorter time and less wide.
At weak wind and warmer periods windows can be open for a longer time and more wide.

2. Results

2.1. Temperature

As stated earlier and by many others, temperature is the most predominant variable in window use. In the first paper [1] we found a linear relation between the number of all open windows together and the outside temperature both based on weekly means. Most wind and rain variance is lost by taking a weekly mean and therefore the correlation with temperature was very high (0.96). Now we looked more at daily mean values for the different windows and left the idea of linear temperature relations. In figure 1 all 467 daily mean values for the balcony door have been plotted against the outside temperature. As can be seen the door is not frequently used below 8 degree C. This door is used for ventilation in the livingroom and also allows inhabitants to keep in touch with outside. Above 10 degree C. a lot of doors are opened. Other windows just show the opposite behaviour with already an increase at very low temperature and stabilising (because there are no more windows practically available) at high temperature.
One could say that large windows tend more to the balconydoor and small ventlight more to the opposite behaviour.

2.2. 24 hour and temperature

The 24 hour course in window use cannot be seen apart from the temperature dependency. Therefore we produced a more 3-dimensional graph with vertically the percentage of open windows, horizontally to the righthand 0 to 24 hours of all days and into the backplane the outside temperature from -7.5 degree C. in the front to 22.5 degree C. in the back (figure 2). In figure 2 all 16 windows are plotted separately. The position and numbers of the windows are given in figure 3. It has to be noticed that these figures are the mean values for all 80 apartments, so if one group opens some windows during the morning and another group opens similar windows successively in the afternoon, there may be a constant number of open windows during the day and no changes seem to occur round 12:00 while reading the figures.
All windows show a more or less steady level which is temperature dependent but constant in time. On that constant level a daily pattern is added. This daily change is small relative to the constant level. This means that a lot of windows are set open or closed and left in that position for more than one day. This is the case for most ventlights , a bit less for larger windows

and not for the balcony door. Moreover the daily changes seem to be more or less constant as a function of temperature. This is true for the bedroom windows, and a bit less for the kitchen windows but not for the balcony door. The day peak for most windows occurs round 9:00 but 18:00 for the kitchen and 17:00 on hot days for the front door.
After having seen the results it is quite easy to give some explanation for these temperature and 24 hour patterns.
Kitchen windows need to be used also in cold weather at specific times of the day round 12:00 and 18:00 . In bedrooms windows can be opened after people got up and left open for hours without causing comfort problems because no one is in there. So also on cold days these windows can be used to air the room. Ventlights can be left open (ajar) without also causing draughts on cold days. Therefore there is little need for often changing positions of these windows .

2.3. Hierarchy

With hierarchy here we mean the rank of windows with respect to the number of hours a day they are open . Balcony side windows are opened more than gallery-side windows. The most frequently used windows are in the bedrooms. Ventlights are used more than casement windows. The front door is open for the shortest time followed by the casement window in the living room. Instead of opening the casement window people open the balcony door here.

2.4. Instruction

For some inhabitants the instruction would cause more use of windows, for others it meant less use of windows. We calculated the total effect of the instruction just by splitting up the window use as a function of temperature in a part before the instruction and a part after. For all 16 windows these graphs are given in figure 4. As can be seen there is a small total effect for some windows. For instance the kitchen casement window is used more often after the instruction, the windows in the livingroom show a more frequent use but in the bedrooms there is no clear decrease in large open windows. A lot of windows are opened more at low temperature and less at high temperature, so they give a more constant level less dependent on the temperature (this is not understood). When we look at these figures for all 80 apartments it can be said that no major energy saving can be expected from this instruction. But we must be careful as here we did not measure the difference between a wide open window and one set

ajar. As changes in hours open are so small the total effect, saving or loss, will be dependent on how wide windows have been opened.
We have also looked preliminarily at the behaviour of individual inhabitants. This is shown in figure 5 which needs an explanation. On the left side above each other the 16 windows of one apartment are plotted against 24 hours of the day. Per window two "bar"graphs are produced one full= before and one dashed = after instruction indicating that a window has been open or not. The "bars" are vertically and 10 minutes wide but only the envelope has been plotted. Here four similar days (same meteo) are selected before the instruction and four comparable days after . If a window has been open on a time interval on all four days the little "bar"graph for that window fills the assigned rectangle. If it is filled for 3/4 it means that on three of the four days the window has been open on that moment out of the 24 hours, and so on.
So in this part the moments and number of days a window has been open can be seen.
On the righthand side the total duration of open window in hours per day is labelled and also indicated with a horizontal bar. This is also done before and after the instruction. This part gives a faster indication whether a window has been opened more or less hours per day.
On the bottom the total number of "hours open window" is summed for the 16 windows, again before and after the instruction.
Up till now only a small number of these plots has been produced. It appeared that there are inhabitants that follow the window behaviour example incredibly well. But others did not change at all or opened more windows after the instruction. It is impossible to investigate the changes in behaviour by comparing these kinds of graphs for all 80 apartments on a variety of meteorological conditions. The way in which we planned to do this is to make a model of the behaviour for every apartment and window before and after the instruction and then compare either the difference in the "model before" and the actual measured "behaviour after" or the difference between the "model before" and the "model after". This can be done by means of hours per day difference as a function of time, temperature and so on.

3. Conclusion

A large amount of data has been gathered, from which a lot of information can be obtained, but only about this (special) apartment building and the Dutch climate. There is a good view on the number of open windows as a function of

the 24 hours of the day and as a function of outside temperature.
The instruction has been followed by some inhabitants,others did not change their behaviour (modeltechniques have to give the final answers).
The hierarchy shows a preference for the use of balconyside bedroom windows.

4. Literature

[1] Phaff, J.C. J.E.F. van Dongen, W.F. de Gids. Inhabitants' behaviour with regard to ventilation; The use of windows. First heating season. Proceedings, 6th AIC conference, paper 20, September 1985.

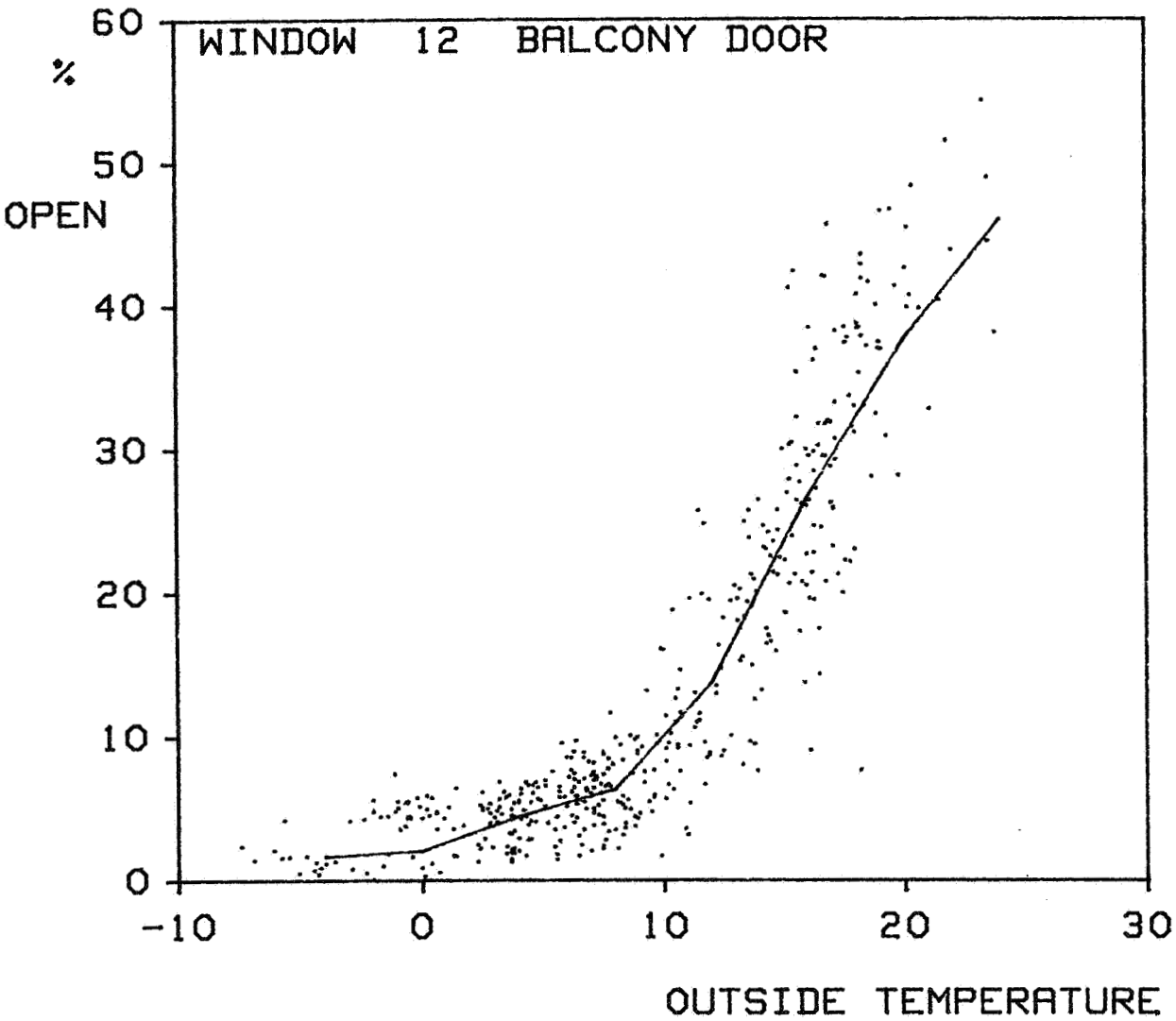

FIGURE 1: Use of the balcony door as a function of the outside temperature. Every dot is a daily mean value.

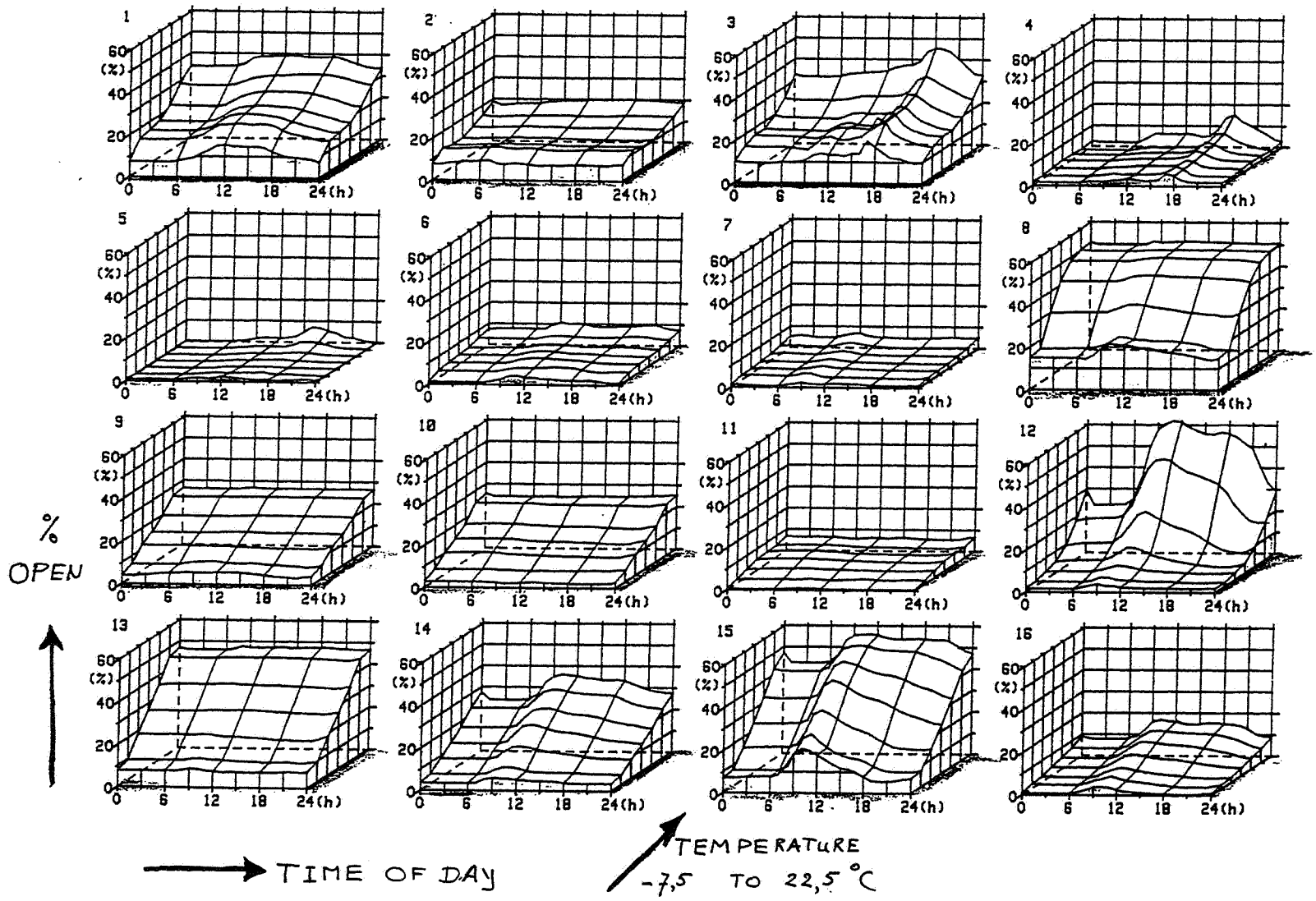

FIGURE 2: Use of the 16 windows as a function of temperature and 24 hours of the day.

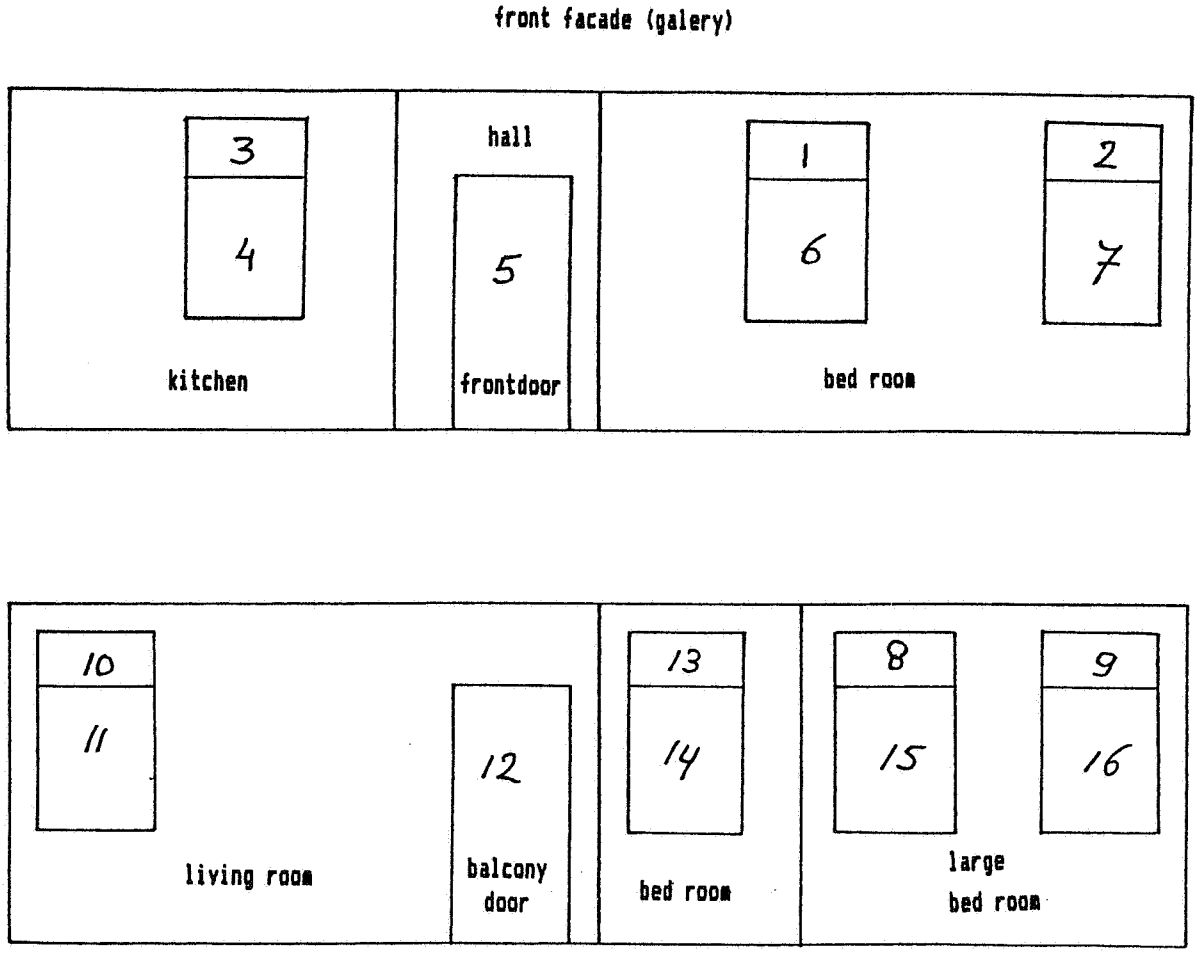

FIGURE 3: Numbers of the windows on the front (gallery) and rear facade (balcony).

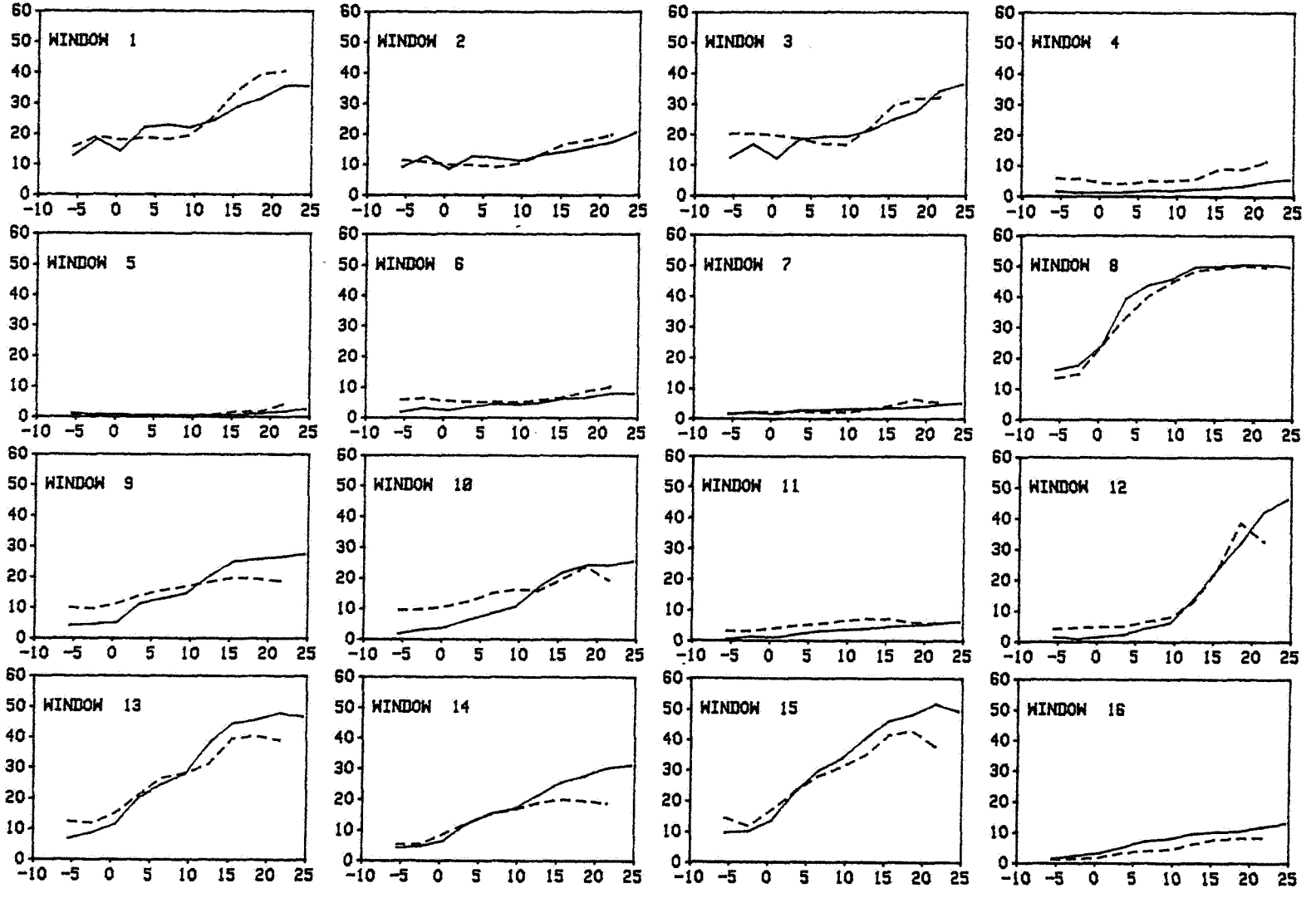

FIGURE 4: 16 windows before and after the instruction as a function of temperature.

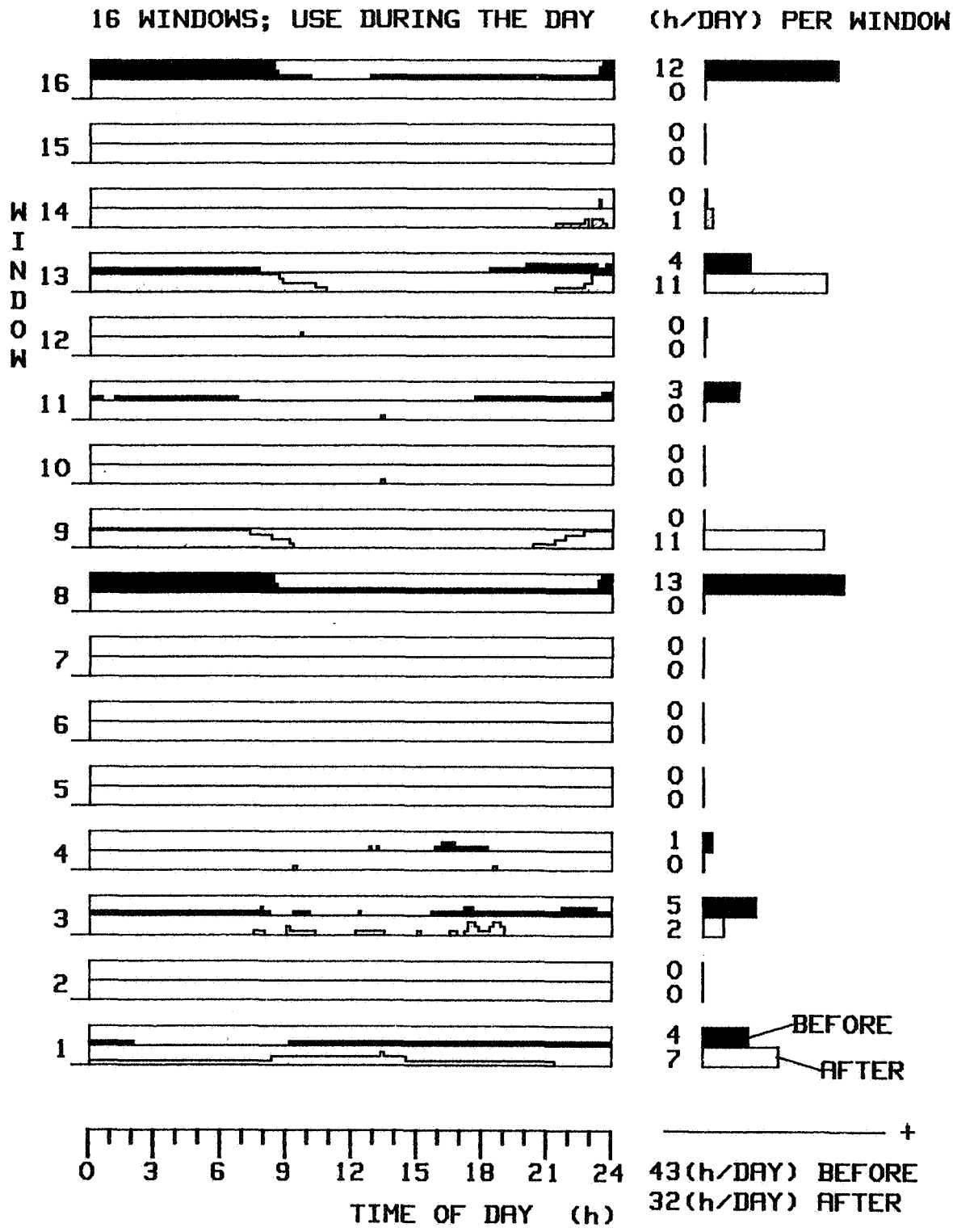

FIGURE 5: Comparison of the use of windows on four comparable days before and four days after the instruction. Only for one apartment.