I M G - T N O
INSTITUUT VOOR MILIEUHYGIENE
EN GEZONDHEIDSTECHNIEK T N O
Publikatie no. 879
Postbus 214 2600 AE DELFT

PATTERNS IN HEATING AND VENTILATION BEHAVIOUR OF OCCUPANTS OF NEWLY-BUILT TERRACED HOUSES

by

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CIB - S 17 Heating and Climatisation 1983
Symposium "Heating Systems in Practice", Stockholm, Sweden,
7-9 September 1983

1. INTRODUCTION

1.1. Case study

Last winter, the daily behaviour with respect to heating, use of windows and ventilationmeasurements has been studied in newly built identical terraced houses in Oosterhout (Holland).

The houses are the same as analysed and discussed by mr Ham yesterday morning with respect to energy saving in practice resulting from the use of high efficiency boilers and from modification of the hot water system [figures 1, 2, 3].

The external walls consist of brick with insulation in the cavity, the windows are double-glazed and the ventilation is natural. Each house has its own gasburner furnace on the loft for heating and hot water.

A technical description of the house is available for those interested.

2.2. Methodology

We had extensive verbal interviews with 57 of the occupants to gain an insight into the energy-related household behaviour and motives. In addition to these interviews the respondents were asked to fill in a log-book during 14 days concerning per hour information about people at home, the position of the room thermostat, the periods with open windows and the opening of trickle ventilators in the different rooms, the use of radiator valves and the position of the doors inside the house [4].
Especially the results from these logbooks related to the weather conditions will be presented here, but also additional information was used from the verbal interviews.
A total of 41 log-books were completed. We were very lucky that the weather over the period they were filled in (January 28 - February 10, 1983) varied: the temperature varied from + 9°C till - 3°C in the daytime; there was stormy weather as well as periods with no wind; the direction of the wind changed from west to north east; there were a few rainy days, cloudy

days without rain, days of a variable weather type and a few sunny days.

1.3 Selection of data and restrictions

I restricted the analysis of the results I present here to 20 log-books, 17 of them in dwellings with conventional (not high-efficiency boilers). The first reason is a question of lack of time, a second reason is the fact that in the other dwellings the use of windows might be influenced by traffic noise from a highway. This appeared from the verbal interviews.

So, the behaviour of the people which have been analysed up to now and discussed here concern 20 dwellings, all situated in the same quarter: 9 with an east-west orientation (cluster 1) and 11 with a north-south orientation (cluster 2) [5].
The reason to distinguish these two clusters is the expectation that orientation may influence the window use and ventilation behaviour of the residents.
From demographic characteristics we can conclude that there are no big differences between the residents in the two clusters distinguished [6].
Of course, and I will stress this, the results of the analysis are tentative and concern a small case, so it is not possible to draw firm conclusions. Nevertheless, I dare to say, some regularities in behaviour are already discernible, even with the low number of respondents.
And it would be worthwhile to replicate the study on a higher scale.

2. RESULTS

Let me show some results.

2.1. The indoor climate objective and subjective

Firstly a few physical measurements and, from the verbal interviews, a registration of complaints [7].
Controlled,for presence at home the average temperature in the living-room seems slightly lower in the north-south dwellings. The number of respondents with complaints is higher there.
A general complaint as well in the north-south as in the east-west dwellings is draught, especially from the bay window in the livingroom (east and north orientated).
Not on the slide, but interesting to mention is the finding that the temperature in the bedrooms above the bay window is about the same as in the livingroom, when the radiator in this bedroom is not used and is only one or two degrees lower in the other bedrooms, also when the radiators are not used.
(The pipeworksystem to the livingroom runs through the bedrooms).

No wonder, residents wishing bedroom temperatures of about 15°C or just "fresh", open the bedroomwindows during a period of the day. Later we will see how they do that. If the radiator in the bathroom is used, which mostly is the case, the temperature is 1,5°C higher than in the livingroom.

2.2. Use of trickle ventilators

Knowing the average inside temperatures of the dwellings, how is the use of the trickle ventilators and the windows in the different rooms?

In figure [8] you can see the livingroom is mostly ventilated by the trickle ventilators, but even then only 1/3 of the respondents use them regulary, with a slight tendency to open them more when the sun shines, independent of the outside temperature and orientation of the dwelling.
About 1/4 of the respondents never use them.
A reason why the percentages of ventilators opened regulary are relatively low is the fact of draught from the bay window already mentioned, which, according to the respondents, ensures enough ventilation.
In the east-west cluster the inside door to the hall is more opened (25% of the time) than in the north-south cluster (10%).

The use of the trickle ventilators in the bedrooms and the bathroom is shown in figure [9].

In the bedroom, the trickle ventilators are more opened than in the living room, although the mean percentage not used is about the same. Continuously opened, which in 20% is the case in the living rooms, are they in the parents bedroom and in the bathroom in half of the cases. If variably used the use seems to correlate not directly with the weather, but more with the use of the windows.

2.3. Use of windows

How is the use of the windows in the bedrooms, if I confine myself to the bedrooms where one is sleeping [10] ?
We found nearly without exception (in those cases babies were sleeping there) that the windows were used, and on the average in most cases were opened widely.
Still, there is an indication that in the east-west orientated dwelling the windows are opened more widely than in the other cluster.
A reason for this difference can be the low numberof respondents, but on the other hand we found that where the windows were opened less widely (the north-south dwellings) they were opened longer in time (32% of the total time against 20%). Maybe this behaviour is connected with the heat from inside the houses I mentioned before. This is especially the case in the bedroom on the north façade. From the verbal interview it appeared that about 50% of the parents say to sleep usually with opened windows.

2.4. Weather influences

On figure [4] you can see the lay out of the log-book form. Now I want to show you some results after joining the lines each individual respondent draws. I shall restrict myself to the parents bedrooms respectively orientated to the west and to the south [11, 12].

The joined lines give the period of the day the windows are opened.

The lines are related to specific weather conditions.

Although based on a very small group of respondents it can be seen that on the whole on the west façade the windows are slightly less opened than on the south façade and shorter when there is stormy weather from the west. Also freezing weather with NE wind seems to influence the use of the windows on the west façade more than on the south façade.
February 4 was a typical airing day.
Comparable mornings, however, with and without rain, result in different uses of the windows.

2.5. Use of radiators

It appeared that in the bedrooms the radiators are not often used [13]. Remember the relatively high temperatures I mentioned before, especially in the room on the north façade. If radiators are used, it mostly concerns rooms where babies sleep. The radiator in the bathroom is used more, however, which can also be concluded from the number of hours a day it is burning. The relatively high humidity in this room plays a part here.
The thesis often heard, that so much energy is spoiled by using radiators while the windows are opened appeared to be not correct. The percentages of time this is the case are low.

2.6. Use of the thermostat

On the next graph [14] it can be seen how each respondent uses his thermostat if switched on higher than 15°C. You can see that each respondent has his own pattern. Some respondents (cases 5, 11, 13, 16) never or seldom change the state of the thermostat in spite of the differences in outside temperatures given by the lines drawn. Other respondents have a less constant behavioural pattern with respect to this.

Restricting ourselves to the graph of the north-south orientated dwellings you can see that the outside temperature does not seem to influence the state of the thermostat [15]. Marking points seem more to be weekend days or sunny days. But, again I have to conclude this on the basis of small numbers and tentative analyses.
More work has to be done.

2.7. Use of energy

At last, some information about the relation found between the mean temperature (over 24 hours) in the living room and the consumption of heating gas, with respect to those dwelling where measurements were done and controlled for presence influencing the use of the thermostat [16].
Clearly two cases, respondent A (case 5) and respondent B (case 6) fall out of the pattern.
Looking for differences in behaviour I found the following, which is shown in [17].
The mean temperature in case A's livingroom is lower than in B's living-room. A ventilates continuously in the livingroom by the trickle ventilator. A reason mentioned was cigarettesmoke and their smell. A also ventilates longer by the windows in the bedroom and bathroom: the result is that at the same gas consumption, the indoor temperature is about 2°C lower.

To conclude

This contribution has to be considered as a kind of interim report. A lot of information has not yet been analyzed and it is too early to make firm conclusions. Still, I want to make one: the method we chose to take verbal interviews followed by the use of logbooks appeared to function very well and the information we have got seems reliable.

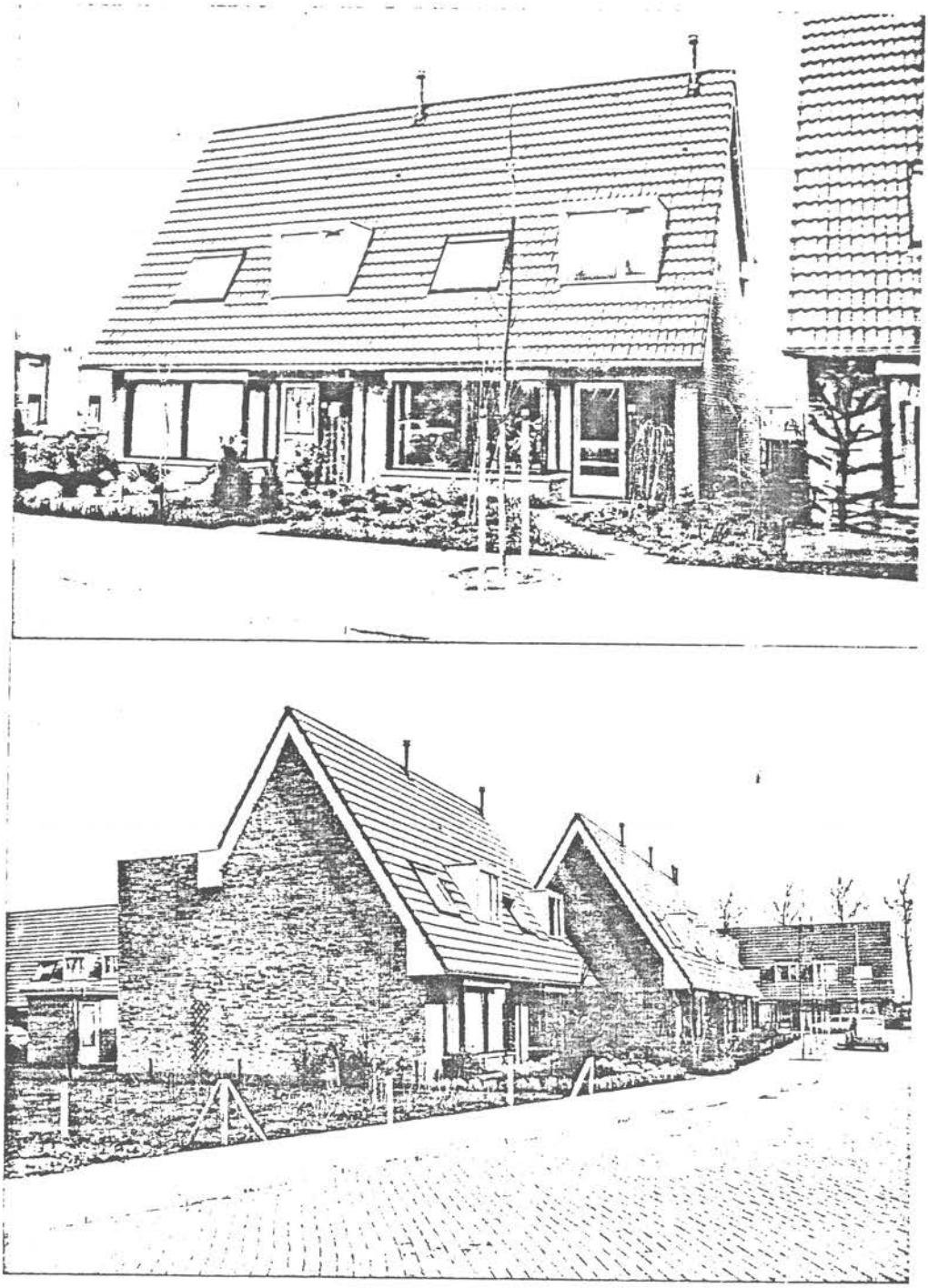


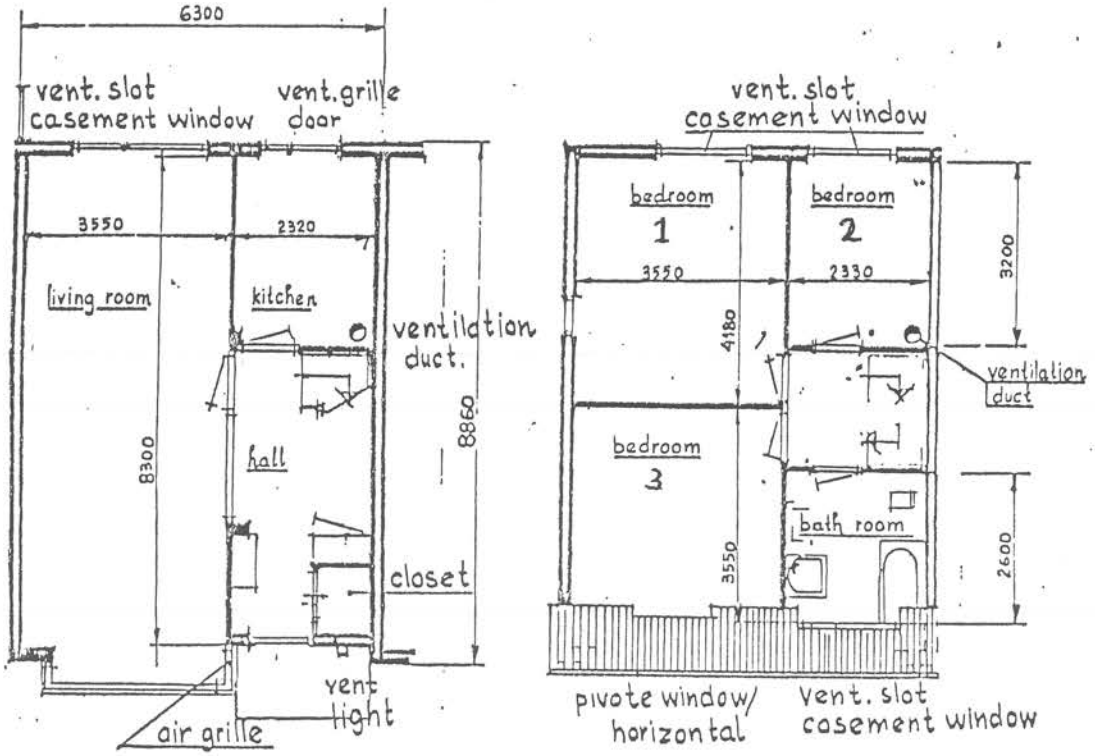
Fig. 1 THE DWELLING CONCERNED

VENTILATION

System : Natural ventilation optimal fan in kitchen on ventilation duct

Control : All provisions open/closed manual casement windows controlable manual

Place air provisions :

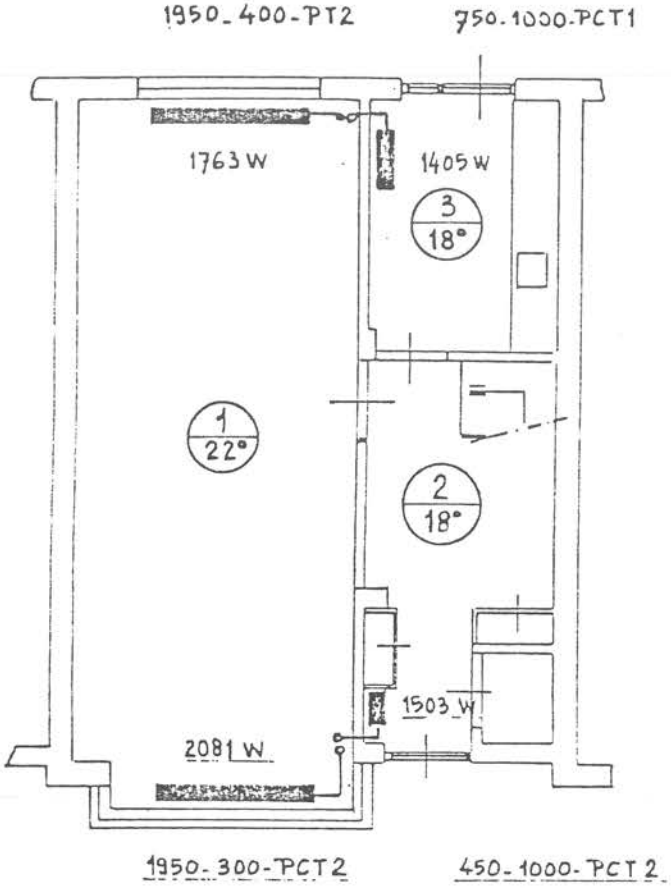


GROUND FLOOR.

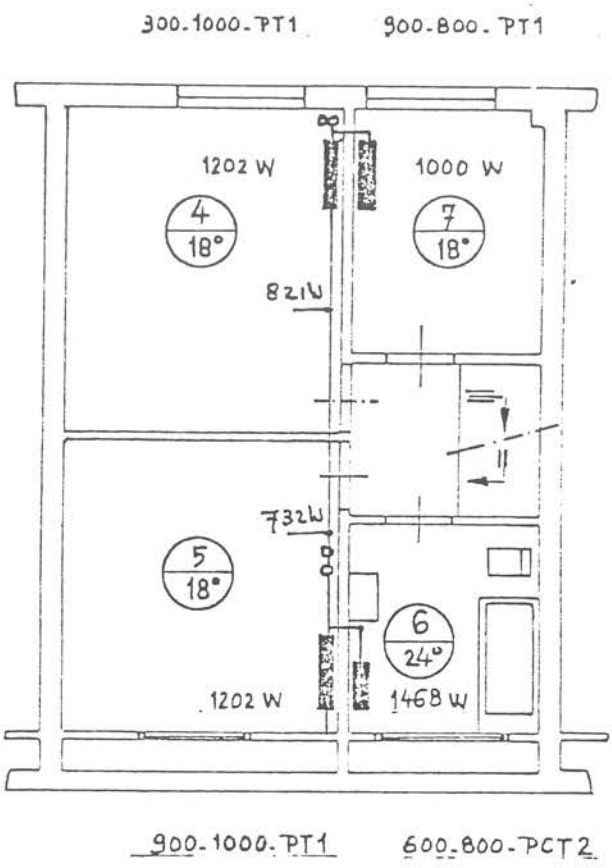
FIRST FLOOR

vent light on the LOFT

FIG. 2 AIR PROVISIONS



GROUND FLOOR



FIRST FLOOR

watertemp. 90°/70°C

FIG. 3 CAPACITY RADIATORS
NORMAL INSTALLATION

FIG 4, LOG-BOOK

Adres: Sluytershof 1 Betreft de datum: 4-2-1983

Situaties	Verdeling van de dag in uurperioden ochtend / (na)middag / avond/nacht 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 22 23 1 6
Niemand aanwezig	
Stand van huiskamer-thermostaat	10 16 16 15 15 15 15 15 16 16 16 16 16 16 17 17 10 10
Ventilatierooster open in:	6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 22 23 1 6
huiskamer voorkant:	
huiskamer achterkant	
keuken	
grote slaapkamer	
slaapkamer voorkant	
kleine slaapkamer (boven keuken)	
badkamer	
Raam/deur naar buiten open in:	6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 22 23 1 6
huiskamer	
keuken (deur)	
grote slaapkamer	
slaapkamer voorkant	
kleine slaapkamer (boven keuken)	
badkamer	
zolder	
Radiator open in:	6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 22 23 1 6
huiskamer voorkant	
huiskamer achterkant	
keuken	
benedengang	
grote slaapkamer	
slaapkamer voorkant	
kleine slaapkamer (boven keuken)	
badkamer	
Deuren binnenshuis open in:	6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 22 23 1 6
huiskamer	
keuken	
grote slaapkamer	
slaapkamer voorkant	
kleine slaapkamer (boven keuken)	
badkamer	

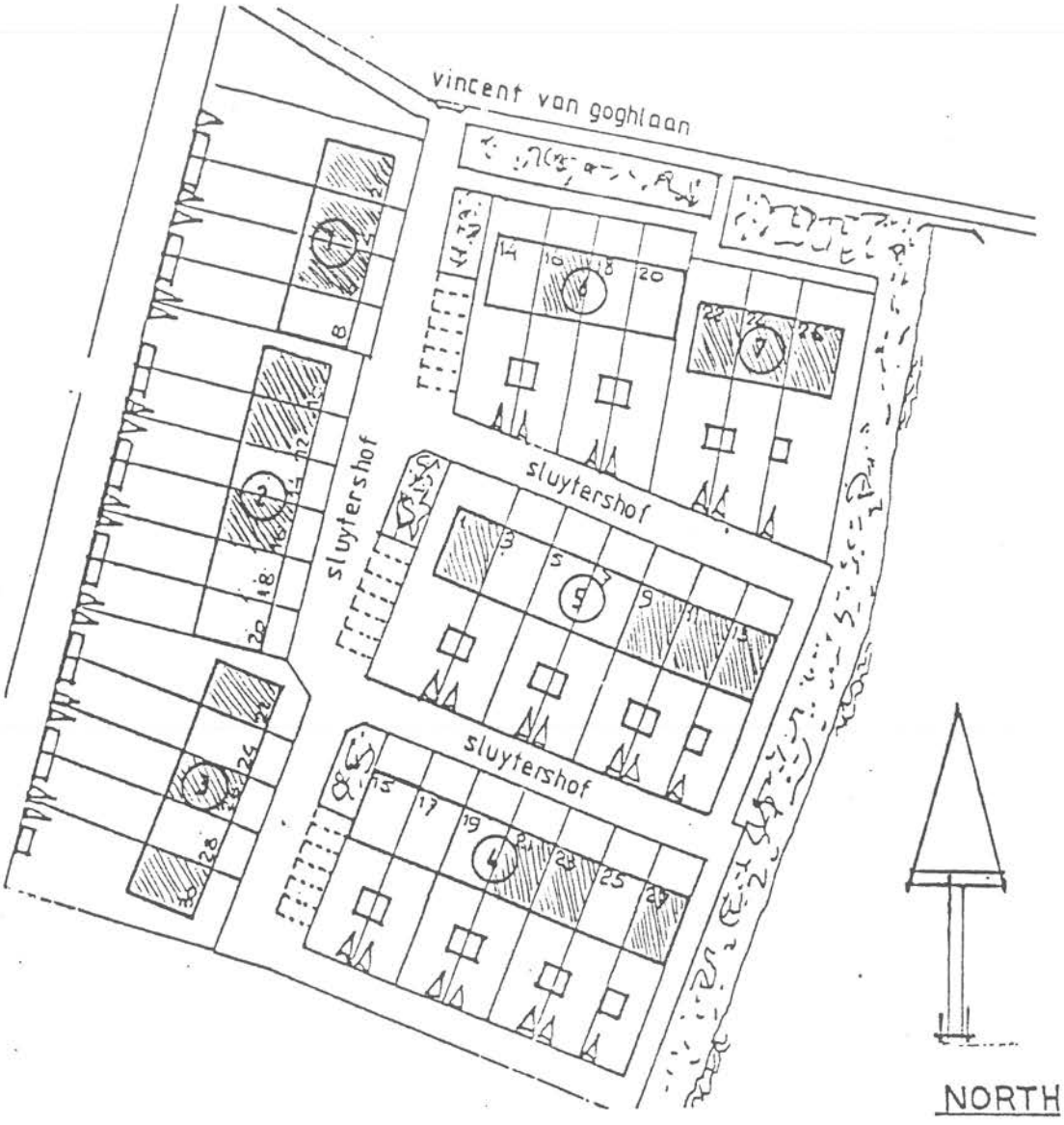


FIG.5 MAP PART OF DWELLINGS OOSTERHOUT.

	EAST/WEST	NORTH/SOUTH	TOTAL
NUMBER OF DWELLINGS	9	11	20
PERSONS PER HOUSEHOLD			
2	2	4	6
3	4	6	10
4	3	0	3
5	0	1	1
< 2 YEAR	4	3	7
> 50 YEAR	2	6	8

NUMBERS OF DWELLINGS IN WHICH:	E/W	N/S
- OFTEN NOBODY HOME	4 (1)	4 (3)
- BEFORE 10 A.M. NOBODY HOME (AVERAGE PER DAY)	0.8	1.9

FIG. 6, DEMOGRAPHIC DATA

	EAST/WEST N = 9	NORTH/SOUTH N = 11
AVERAGE USE OF HEATING GAS IN M^3 (17/1 - 14/2)	260 (300 - 245)	245 (300 - 215)
AVERAGE TEMPERATURE IN °C		
IN LIVINGROOM/24 H	18.6	17.8
MEASURED TEMPERATURE	20.2	19.9
PREFERRED TEMPERATURE	19.3	19.2
COMPLAINTS ABOUT:		
TOO COLD	1	3
CONDENSATION	1	4
DRAUGHT	5	8

FIG. 7, OBJECTIVE AND SUBJECTIVE MEASUREMENTS

FIG. 8, USE OF TRICKLE VENTILATORS AND WINDOW IN LIVING ROOM

	ORIENTATION	NOT OPENED % (N)	SELDOM OPENED % (N)	OPENED REGULARY % (N)	WEATHER CONDITIONS		MEAN ROOM TEMPERATURE 24/H
					OPENED LESS	OPENED MORE	
N = 9	W VENT.	22 (2)	45 (4)	33 (3)	WIND > 10 M/S OR RAIN OR FREEZING (NO SUN)	SUNSHINE 0 - 9 °C	18,6 °C
	WINDOW	44 (4)	44 (4)	12 (1)			
N = 9	E VENT.	22 (2)	56 (5)	22 (2)			
N = 11	S VENT.	28 (3)	36 (4)	36 (4)			17,8 °C
	WINDOW	73 (8)	9 (1)	18 (2)			
N = 11	N VENT.	27 (3)	36 (4)	36 (4)			

ORIENTATION	NOT OPENED %(N)	OPENED VARIABLY %(N)	OPENED CONTINUOUSLY %(N)	WEATHER CONDITIONS		MEAN ROOM TEMPERATURE 24/H
				OPENED LESS	OPENED MORE	
W (N=9) LARGE (PARENTS)	33(3)	12(1)	55(5)	SUNNY OR AFTER SUNNY DAY OR WINDY	SUNNY OR RAINY OR WINDY	17,2°C
W (N=9) SMALL	33(3)	45(4)	22(2)			--
S (N=11) LARGE (PARENTS)	18(2)	27(3)	55(6)			17,3°C
S (N=11) SMALL	18(2)	37(4)	45(5)			--
E (N=9)	22(2)	56(5)	22(2)			18,2°C
N (N=11)	9(1)	36(4)	55(6)			18,2°C
TOTAL 60	22(13)	35(21)	43(26)			
IN BATHROOM						
E (N=9)	11(1)	33(3)	56(5)	WINDY	SUNNY OR WINDY	19,5°C
N (N=11)	18(2)	27(3)	55(6)			19,3°C
TOTAL 20	15(3)	30(6)	55(11)			

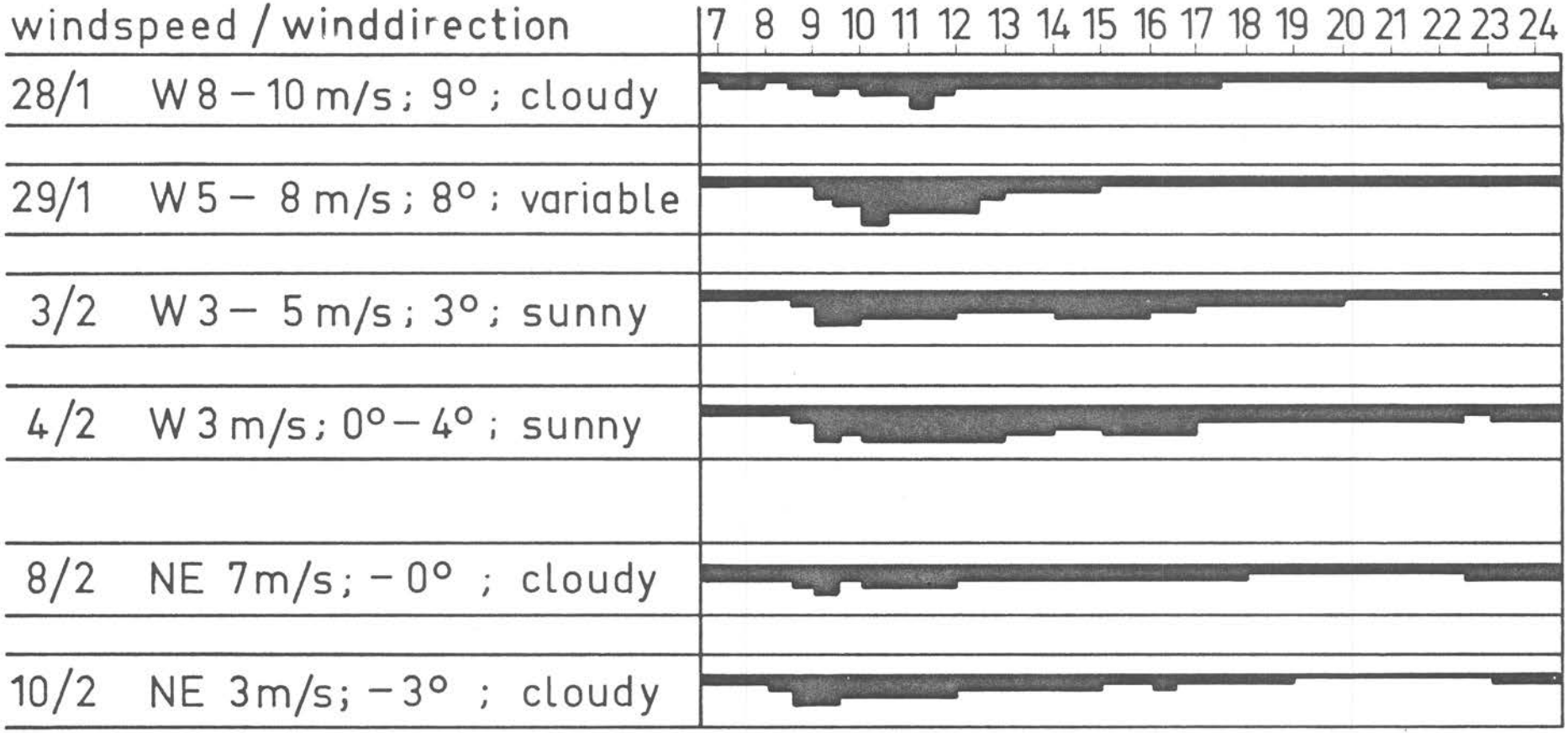
FIG. 9, USE OF TRICKLE VENTILATORS IN BEDROOMS AND THE BATHROOM

FIG. 10, USE OF WINDOWS IN BEDROOM, WHERE ONE IS SLEEPING

ORIENTATION		N	NOT OPENED %(N)	SET AJAR %(N)	MODERATELY WIDE %(N)	WIDE %(N)	WINDOW USUALLY OPEN WHEN SLEEPING %(N)
W	LARGE (PARENTS)	9	0(0)	0(0)	22(2)	78(7)	44(4)
W	SMALL	6	0(0)	17(1)	0(0)	83(5)	0(0)
S	LARGE (PARENTS)	9	0(0)	45(4)	22(2)	33(3)	56(5)
S	SMALL	5	20(1)	60(3)	0(0)	20(1)	20(1)
E		4	0(0)	0(0)	25(1)	75(3)	0(0)
N		5	20(1)	40(2)	0(0)	40(2)	40(2)
TOTAL		38	5(2)	26(10)	13(5)	56(21)	32(12)

FIG. II

Windows opened in the parents bedroom orientated to the west as a function of :



rainy, compared with not rainy weekend morning

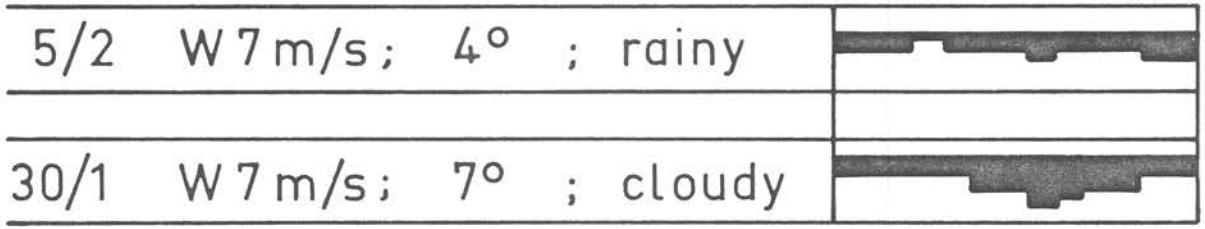
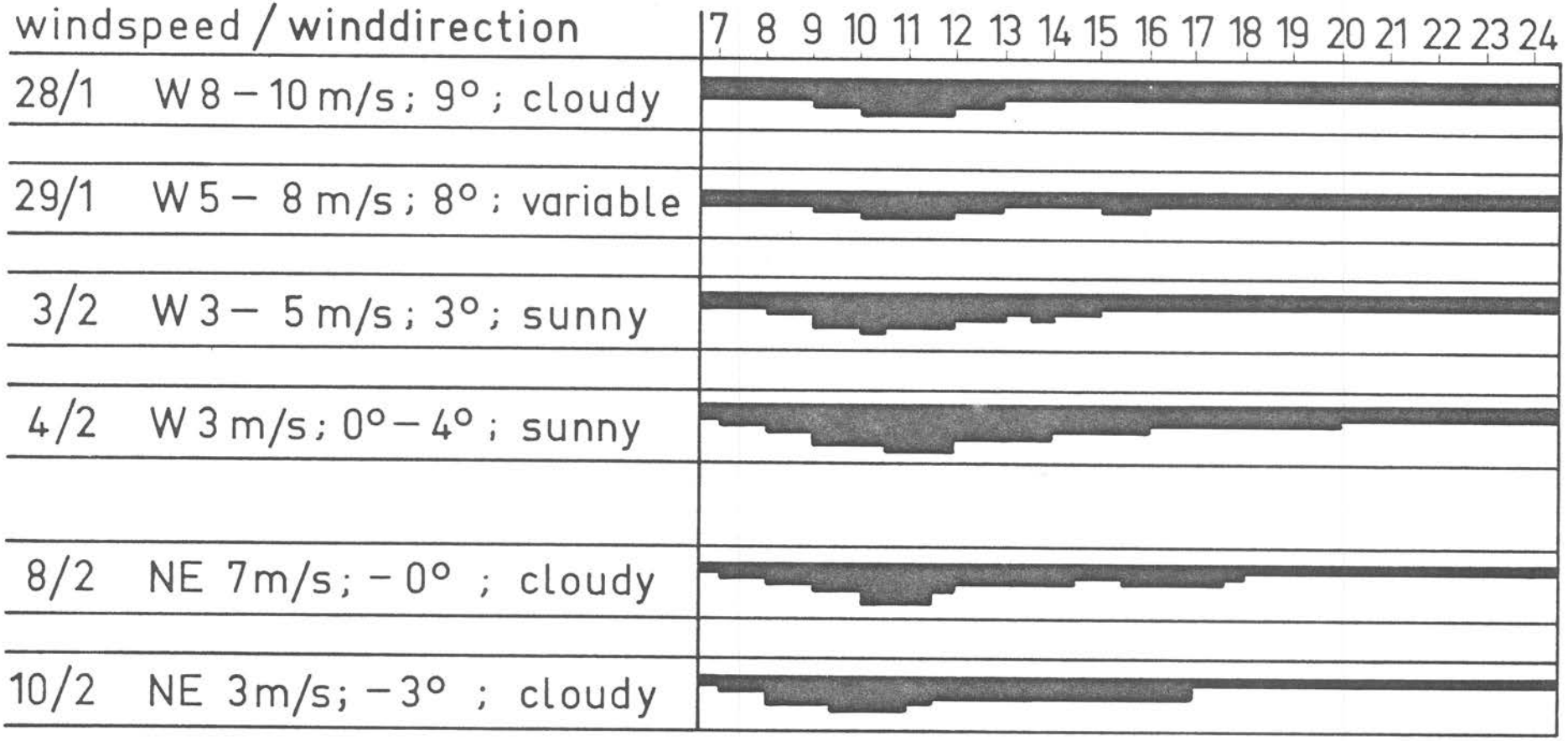


FIG. 12

Windows opened in the parents bedroom orientated to the south as a function of:



rainy, compared with not rainy weekend morning

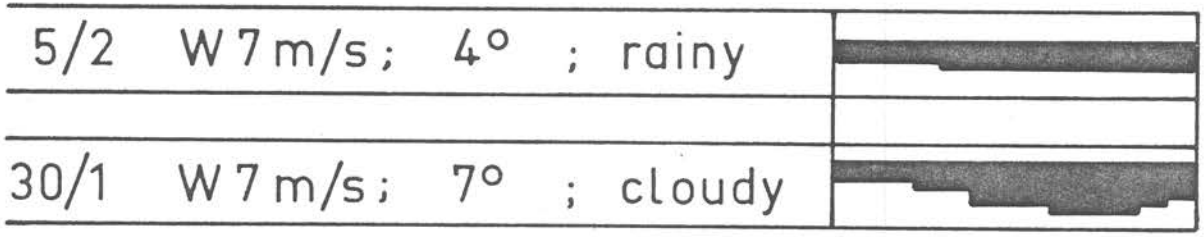


FIG. 13, USE OF RADIATORS

		N	NOT OR SELDOM USED %(N)	USED REGULARLY %(N)	USED CONTINUOUSLY %(N)	MEAN TIME RADIATORS USED (HOURS/DAY)	TIME WINDOW OPENED, RADIATORS USED %
IN BEDROOMS:							
W	LARGE (PARENTS)	9	78(7)	11(1)	11(1)	0.9	23
	SMALL	6	67(4)	17(1)	17(1)	1.6	10
S	LARGE (PARENTS)	9	89(8)	11(1)	0(0)	0.4	2
	SMALL	5	40(2)	40(2)	20(1)	3.3	0
E		4	25(1)	50(2)	25(1)	2.9	11
N		5	100(5)	0(0)	0(0)	0.0	0
TOTAL		38	71(27)	18(7)	11(4)	1.3	7.7
IN BATHROOM:		N					
E		9	44(4)	22(2)	33(3)	4.7	5
N		11	27(3)	27(3)	46(5)	6.8	5
TOTAL		20	35(7)	25(5)	40(8)	5.8	5

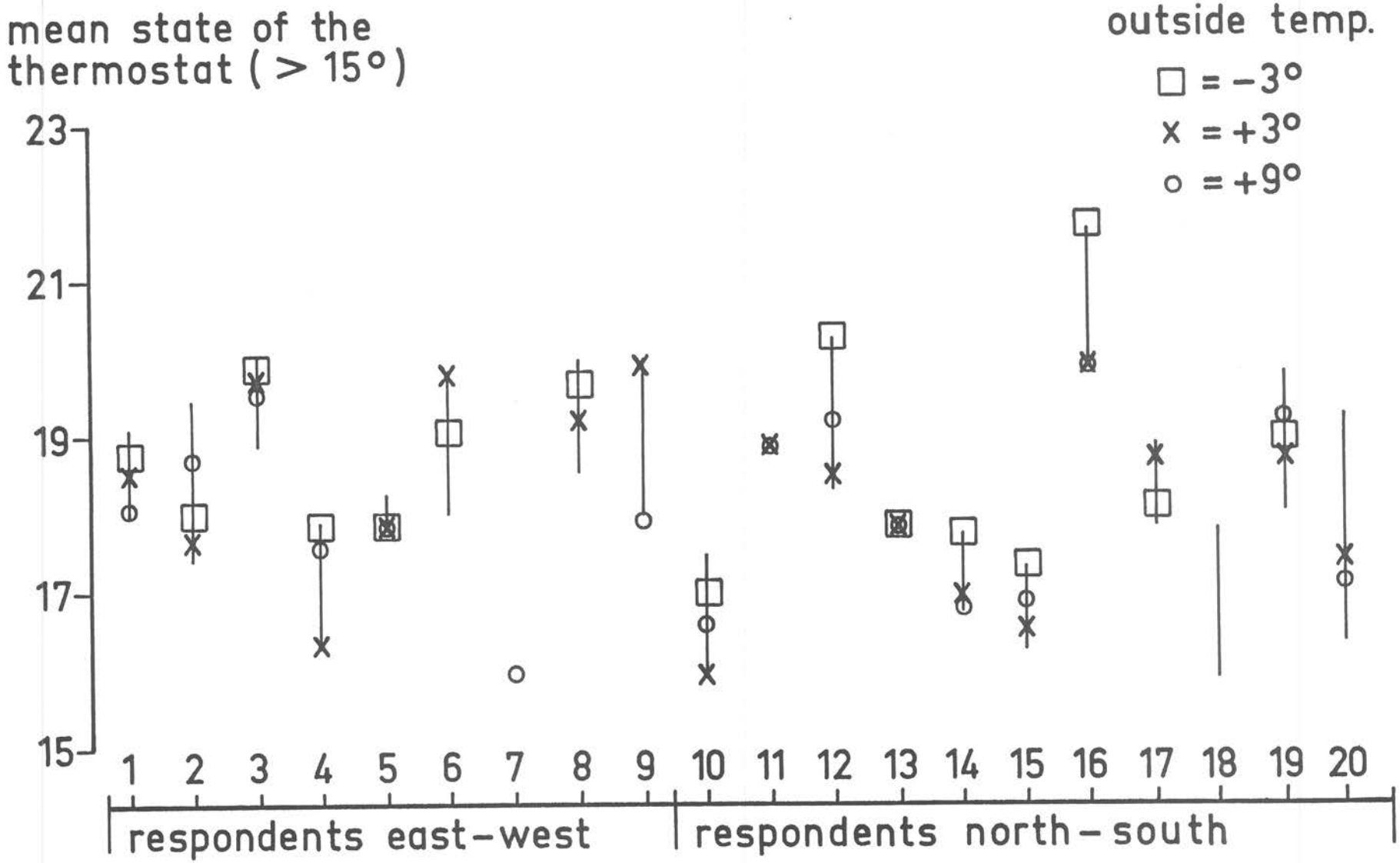
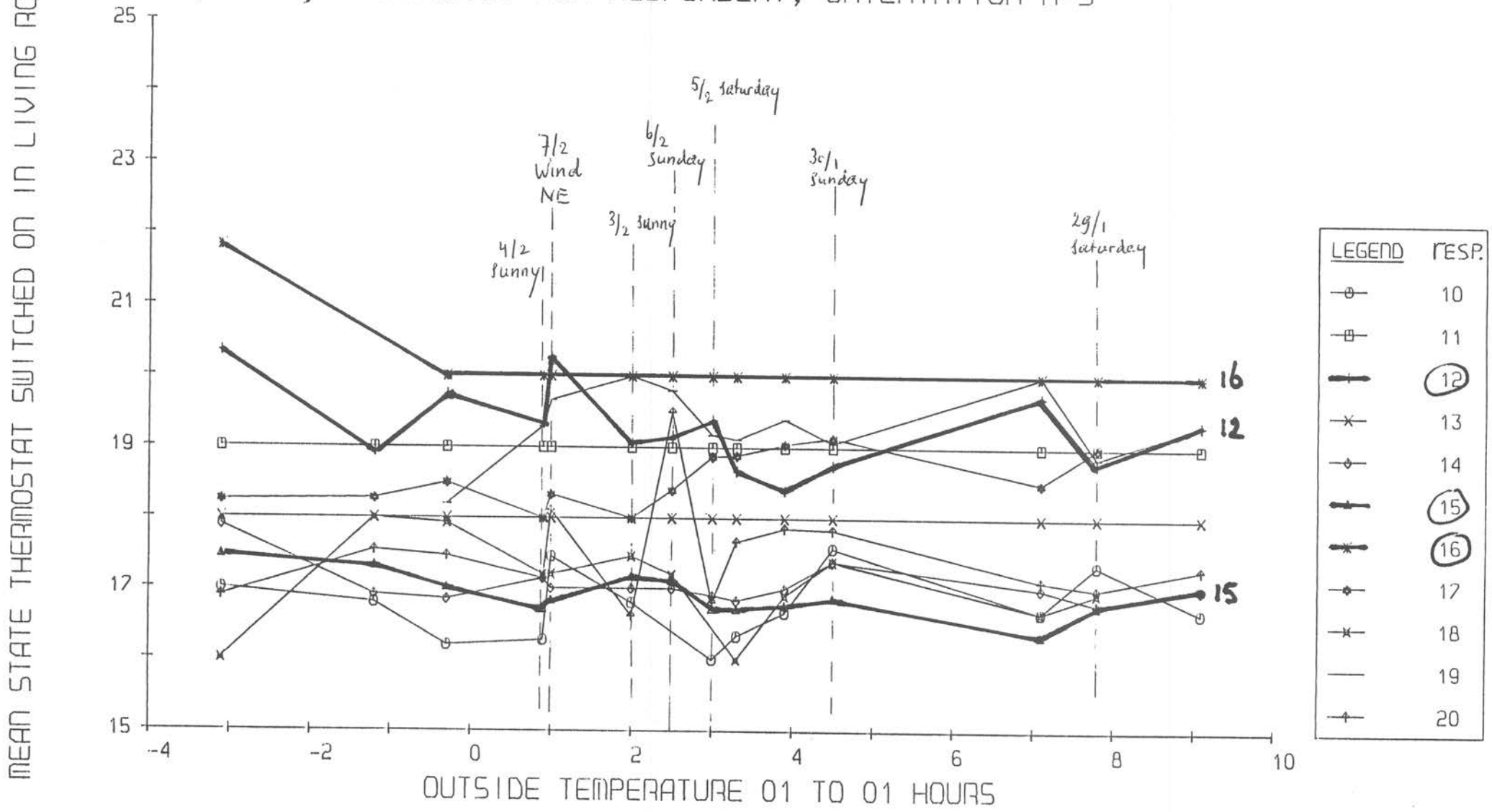


Fig.14 Individual variation in using the thermostat

FIG. 15, THERMOSTAT PER RESPONDENT, ORIENTATION N-S



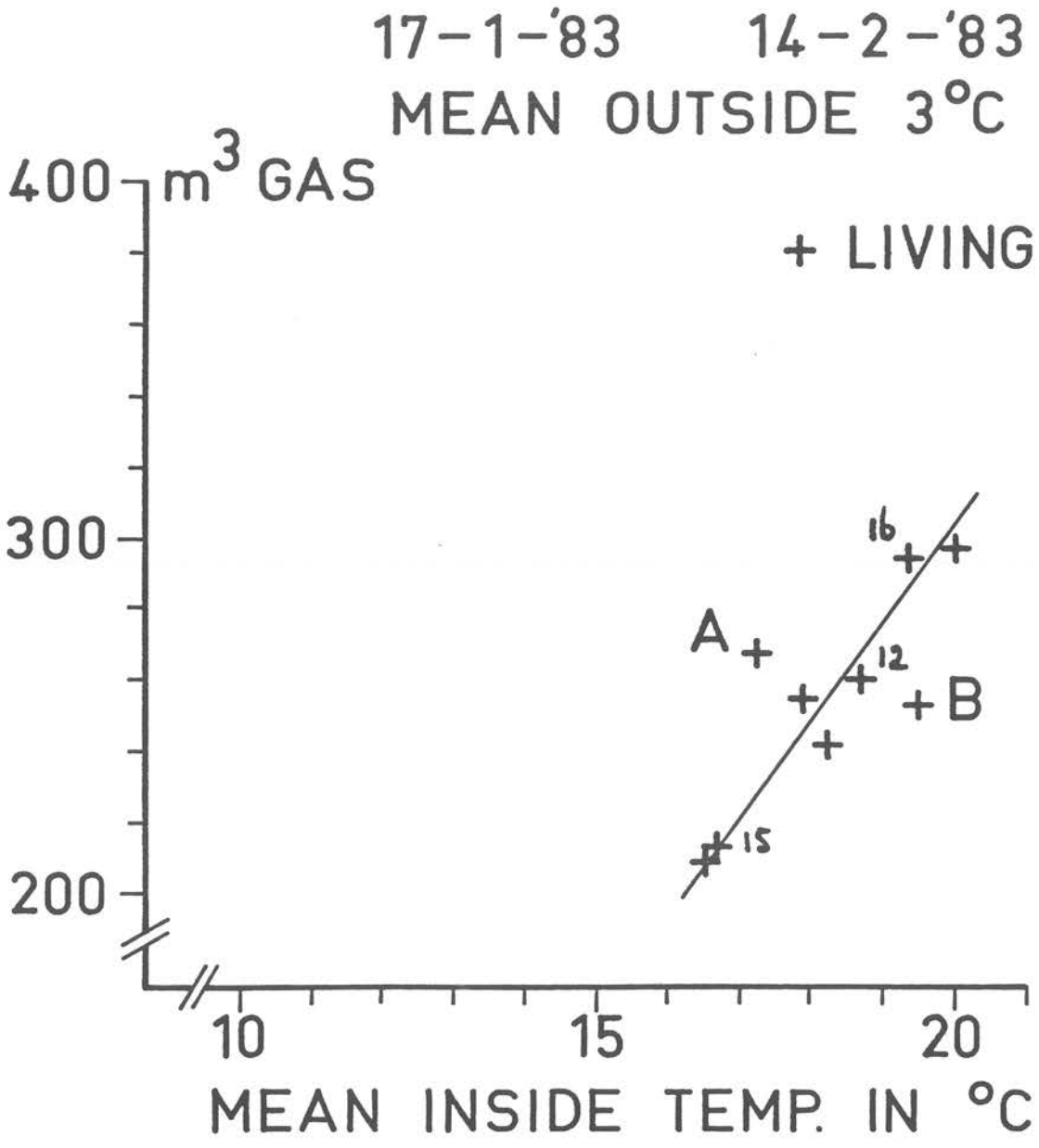


Fig. 16 Consumption of gas and inside temperature

		RESPONDENT A (= SMOKER)	RESPONDENT B (= NON-SMOKER)
USE OF TRICKLE VENTILATORS	LIVING ROOM	CONTINUOUSLY	NO
	BEDROOM	NO	NO
USE OF WINDOWS PER DAY	BEDROOM	8 HOURS, WIDE	2 HOURS, WIDE
	BATHROOM	3 HOURS, WIDE	1 HOUR, ?
RADIATOR USED	BEDROOM	NO	NO
	BATHROOM	CONTINUOUSLY	CONTINUOUSLY
MEAN TEMP. OVER 24 HOURS	LIVING ROOM	17.3 (20)	19.5 (20)
	BEDROOM	17.6	19.8
	BATHROOM	20.2	21.4
THERMOSTAT	LIVING ROOM	HOURS/DAY 18° 7.8	HOURS/DAY 18° 6 19° 2 20° 1.8
HEATING GAS USE		269 M^3	253 M^3

FIG. 17, DIFFERENCE IN BEHAVIOUR
(BOTH RESPONDENTS LIVING IN EAST - WEST DWELLING)